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AN ANALYSIS OF THE RELATIONSHIPS BETWEEN SELECTED MANUFACTURING STRATEGIES, PRODUCTION COMPETENCE, AND COMPETITIVE PRIORITY COMPETENCE

By

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ABSTRACT

AN ANALYSIS OF THE RELATIONSHIPS BETWEEN SELECTED MANUFACTURING STRATEGIES, PRODUCTION COMPETENCE, AND COMPETITIVE PRIORITY COMPETENCE

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The theory of manufacturing strategy states that firms with manufacturing resources aligned with business strategy objectives will outperform firms without properly aligned resources. The production competence construct was created to obtain a measure of the support provided to the business strategy by manufacturing[1]. Upon improving the construct, a positive relationship between production competence and firm performance was identified[2].

As the global economy grows and becomes more competitive, many firms are redirecting their attention to the manufacturing function to provide a competitive advantage. Simultaneously, many new and old manufacturing strategies are available to firms. With limited resources, firms must decide which strategies to implement.

This research is directed at the identification of the manufacturing strategies, programs, and techniques (SPTs) firms use to support the business strategy (i.e., become "competent"). To identify the SPTs, a survey was mailed to the manufacturing managers of the firms in Vickery, et al.[3], all of which compete in the furniture industry. The survey collected data on the extent of use of several different manufacturing SPTs and was combined with firm-

level data from Vickery, et al. Regression analysis was used to measure the relationship between production competence and the use of SPTs.

The 16 SPTs related to production competence include both structural and infrastructural factors. Most notable was the large number of employee-related and sourcing-related SPTs.

When regarding the list of SPTs related to production competence, one becomes aware of the fact that these SPTs provide little guidance to firms competing along *specific* competitive dimensions. The competitive priorities of cost, delivery, flexibility, and quality were used to create new competence constructs (e.g., cost competence) directed at measuring the support provided to particular strategic initiatives. Again, the list of SPTs related to the each of the constructs contained several structural and infrastructural elements.

Finally, the SPTs were grouped together to form bundles of SPTs that the literature suggests can be used to support the individual competitive priorities. Several of the SPT groupings were related to production competence and competence within the competitive priorities.

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[1]Cleveland, Gary, Roger G. Schroeder and John C. Anderson (1989), "A Theory of Production Competence," Decision Sciences, 20 (4), 655-668.

[2]Vickery, Shawnee K., Droge, Cornelia and Robert E. Markland (1993), "Production Competence and Business Strategy: Do They Affect Business Performance?", Decision Sciences, 24 (2), 435-455.

[3]ibid.

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I. INTRODUCTION

Competitiveness is "the degree to which a nation can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously expanding the real incomes of its citizens" (Cohen and Zysman, 1987, p. 279). In the late 1940s, United States firms were extremely competitive, dominating the manufacturing world and supplying nearly half of world Gross National Product (Giffi, Roth and Seal, 1990). Gradually, that position eroded until 1971 when, for the first time in this century, the balance of trade for the United States became negative. After a brief recovery and a positive balance in the mid-1970s, the trade balance has been negative since 1982 and increases in magnitude every year (Hill, 1994). Meanwhile, the United States' share of the global market is down to 19.2% (Giffi, Roth and Seal, 1990).

A major factor in the United States' increasing trade deficit and reduction in world share is the increased number of global competitors. The number of competitors in an industry is an important factor in determining the competitiveness of the industry (Porter, 1980). The emergence of Japan, other Pacific Rim countries, and Europe has greatly increased in the number of global competitors. As the number of global competitors has grown, so has the level of competitiveness.

Since the 1950s, American firms have not responded to increased global competition very well, resulting in a negative trade balance and decreased world share. Using measures such as the trade deficit, growth in profit margins and real wages, price elasticities of imports, and productivity growth, Cohen and Zysman (1987) demonstrate the delicate position of the United States economy. For each measure, the performance of the United States—relative to international competitors—is decreasing over time. Currently, the trade balance is negative and increasing in magnitude, profit margins and real wages are declining, and productivity growth is lagging. The authors note that while the possibility of explaining away the economic impact of any one measure exists, taken as a group, they send a powerful message regarding the competitiveness of the United States.

According to the United States government, the growth rate of productivity is an important indicator of economic vitality and is responsible for the long term prosperity and wealth of nations (Freedman, 1989; Porter, 1990). Due to the long period in which the growth rate of productivity in the United States has languished, Bernstein (1991) purports the present generation might be the first in this country that will be economically worse off than their parents.

In their recent study of productivity in the United States, the MIT Commission on Productivity (Dertouzos, Lester, Solow and the MIT Commission on Industrial Productivity, 1989) report that for the period 1979-1986, the United States had the second highest growth rate among industrialized nations. They note, however, that four items generated much of the increase in productivity for this period—closing inefficient plants, permanently laying off workers, miscalculations in the growth rate by the Department of Commerce, and that this time-frame included a post-recessionary period, which historically have been periods of growth. These items, while explaining the rise in productivity growth for the period, perhaps obscure the dismal level of productivity growth in the U.S. due to improvements in products, processes, and people.

Since 1986, the growth rate of productivity in the United States is again one of the lowest among industrialized nations, never rising above 3% (United States Department of Labor, Bureau of Labor Statistics, 1991). Over the last 30 years, the growth rate of productivity in the United States is the lowest among industrialized nations at 2.9% (See Figure 1.1).

The MIT Commission analyzed the competitiveness of United States firms in eight industries: automobile, chemical, commercial aircraft, consumer electronics, machine tool, semiconductor, steel, and textile. They observed that overseas competitors had surpassed American firms, controlling the production of large percentages of—if not entire—product groups (e.g., VCRs and televisions) and industries (e.g., consumer electronics and machine tools). The MIT Commission also indicated that American industry "indeed shows worrisome signs of weakness. In many important sectors of the economy, United States firms are losing ground to their competitors abroad" (Dertouzos, et al., 1989, p. 8).

Along with declining productivity, the United States suffers from inadequate quality, insufficient capital spending, and sluggish technological innovation (Hayes, Wheelwright, and Clark, 1988). Hayes, et al. attribute many of the problems to "... human behavior—especially American managers' attitudes, capabilities, strategies—particularly in the areas of manufacturing and technological development" (1988, p. 11).

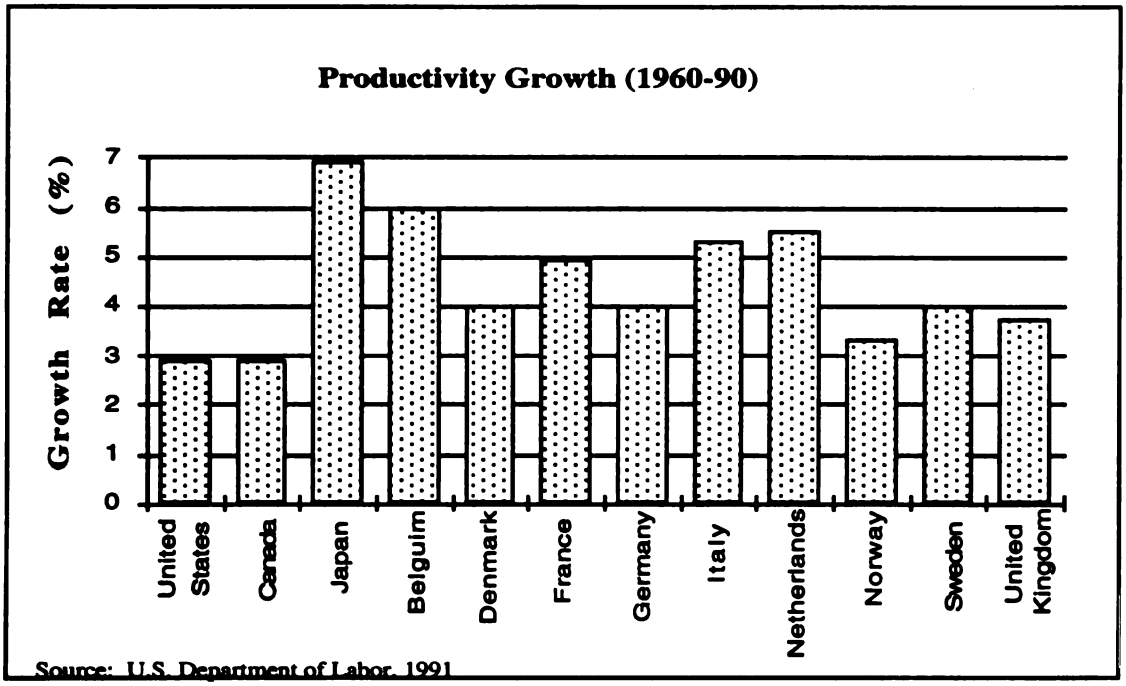


Figure 1.1: Productivity Growth of Industrial Nations

The MIT commission observes that manufacturing is responsible for many of the competitiveness problems of the United States:

> "Much of the evidence we have gathered points to the manufacturing sector as the area where the American advantage in cost and quality have been most severely eroded" (Dertouzos, et al., 1989, p. 31).

Clearly, there is significant evidence of a competitiveness problem in America and several analysts are indicating that the manufacturing sector is a prime source of the problem.

Decline of American Competitiveness

Skinner (1985) offers an explanation for the decline of American competitiveness: due to various distractions, U.S. firms lost sight of the importance of manufacturing. During the 1950s and 1960s, the emphasis of American companies and their top management shifted away from manufacturing. He writes that their new emphasis "was on growth in sales and market share," and that "top management seemed to be dominated and influenced more by executives who were especially competent in marketing and finance..." (Skinner, 1985, p. 4). Because of the shift in emphasis in American firms, manufacturing executives felt separated and possibly excluded from the core of the business. Conflicting business requirements and outdated management methods also contributed to manufacturing problems. Finally, Skinner notes that external competitive pressures and rapidly increasing technology have exacerbated the existing problems of U.S. manufacturers.

The MIT Commission (Dertouzos, et al., 1989) indicates that the competitiveness decline is the result of a set of factors. First, the scope and extent of use of outdated strategies such as large-lot production has limited the responsiveness of American firms. Second, the short planning horizons of financial institutions and managers has reduced the ability of firms to achieve long-term competitive changes. Finally, the Commission mentions a fundamental lack of knowledge and training in human resources and issues concerning cooperation, such as inter-functional communication and labor-management relations.

Hill (1990) observes that, in the early part of this century, world demand outstripped capacity. This imbalance, coupled with post-WWII growth, provided importance and prestige to the manufacturing function. In the mid-1960s, however, the relationship between world capacity and world demand shifted (capacity becoming greater than demand), making it more difficult to sell product in existing markets. This begat the rise of the marketing function as a base of power in corporations. Following this was the energy crisis and the recession in the early 1970s, heralding the importance of the legal, finance and accounting functions.

Meanwhile, corporate policies of the 1960s and 1970s diverted profits away from capital investment and caused management to become focused on the short-term. This, coupled with the popularity of portfolio management theory, which suggests firms diversify their businesses, caused top management interest in the actual manufacture of goods to wane. Also, as Crawford-Mason and Dobyns (1991) observe, the Vietnam War and other social problems of the 1960s diverted the attention of society away from issues such as quality and productivity.

Besides the declining corporate importance of the manufacturing function, Hill (1990) suggests that the competitiveness problem is related to other factors such as society's and management's failure to recognize the size of the competitive challenge, stockholder and management obsession with short-term performance, and top management's manufacturing inexperience. These observations corroborate the arguments of Skinner and the MIT Commission, and highlight top management's shift in emphasis away from production to marketing and finance.

In the late 1970s, the effects of previous manufacturing "isolationism" became apparent as domestic firms started to feel pressure from international competitors, especially the Japanese (Giffi, Roth and Seal, 1990). Domestic firms responded to the new economic threat, not by becoming more competitive, but instead by managing international exchange rates. This action allowed domestic firms to keep *prices* of American goods competitive, thus maintaining international market share. Domestic firms did not, however, move to make the goods themselves more competitive. Later, taking advantage of lower wage rates in foreign countries, many companies built factories overseas. Outsourcing production further depleted the base of manufacturing skills and knowledge of American firms (Prahalad and Hamel, 1990). Porter (1990) notes that both of these actions—managing exchange rates and outsourcing production—will have negative effects on firms and countries that respond to international competition in this manner.

One result of sending production overseas was the inadvertent creation of new competitors (Giffi, Roth and Seal, 1990). By providing training and access to United States technology and equipment, foreign countries were able to learn U.S. methods of production and enter the global marketplace. This policy has had the long term effect of increasing the competitive pressures experienced by American companies, both in the Unites States and abroad, by increasing the number of competitors (Meredith, 1992).

Increasing Standards

In countless industries, global competition has made long-term viability much more difficult. In the past, tradeoffs between competitive dimensions such as quality and cost, or features and delivery speed were thought to exist (Skinner, 1969). Firms attempting to be competitive along multiple dimensions were either introducing too much complexity or were "stuck-in-the-middle", not doing anything well (Porter, 1980). Today, in response to competitive pressures, firms are simultaneously focusing on multiple competitive dimensions in product and service offerings (Blackburn, 1990; Ferdows and DeMeyer, 1990; Chrisman, Hofer, and Boulton, 1988). Introducing products or services that compete along multiple dimensions makes the traditional offerings of existing firms less appealing and makes it more difficult for new competitors to enter industries.

For example, American auto producers are making tremendous strides in quality and productivity with quality records of some U.S. auto producers nearly equal to recent Japanese figures (Zellner, 1990). At the same time, however, leading Japanese manufacturers are pushing out the limits of quality, redefining quality by stretching the definition beyond defects per unit to include subtle human perceptions (e.g., all control buttons require identical amounts of force to activate) (Woodruff, Miller, Armstrong, and Peterson, 1990; Walton, 1986). Domestic auto producers must move beyond the already difficult task of reducing defects; they must simultaneously build cars that consumers desire. Rates of improvement in quality must be faster for domestic producers than they are for Japanese car makers, otherwise, they will never catch up. Standards of excellence are not static—they increase and move higher as competition increases.

Global competitors in many industries have achieved improvements in cost and quality through the concept of continuous improvement or Kaizen (Imai, 1986; Brocka and Brocka, 1992; Treece, 1993). Continuous improvement is constant and embraces incremental product and process improvements made by all members of an organization. Japanese firms have been practicing Kaizen for several decades, making Kaizen an integral part of Japanese management style. Since Kaizen is ingrained into Japanese business practice, one should not expect its emphasis to diminish. Therefore, U.S. firms can expect the cost and quality levels of their Japanese competitors to continually improve. Increases in the number of competitors in an industry and the concept of continuous improvement or Kaizen are combining to constantly elevate global standards of excellence.

Influenced by American computer producers and Japanese automobile and consumer electronics manufacturers, global customers are becoming accustomed to receiving high quality merchandise at a fair price in a reasonable time period. As customers come to expect more from product and service offerings, the competitive standards in those industries will experience upward pressure. It is irrefutable that characteristics and skills such as high quality production, the speed with which a firm can change production from one product or model to another, quickly responding to customer needs, and rapidly developing new products are also becoming more critical (Stalk and Hout, 1990; Blackburn, 1990; Wheelwright and Clark, 1992).

To close the gaps between themselves and their rivals, U.S. firms must work extremely hard at choosing the appropriate means and implementation methods (i.e., strategies) to achieve their competitive goals. Meeting such demands presents new and challenging problems for U.S. firms, especially for the manufacturing functions within these firms. Rapidly changing customer and market expectations and increased competitiveness of global manufacturers exacerbate the need for change in manufacturing. To guide and direct the change process, many companies are focusing on manufacturing strategy to develop and implement competitive manufacturing and business responses.

Manufacturing Strategy

Alfred Chandler defines strategy as "the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals" (1962, p. 13). Strategies can occur at three levels in an organization: Corporate, Business, and Functional (Hofer and Schendel, 1978; Ansoff, 1965; Andrews, 1971). Corporate strategy defines which industries the firm should operate in. Business strategy dictates the manner in which a firm will compete within a given industry. Finally, functional-level strategies are often determined by the business strategy and are designed to support the business strategy.

Hill and Jones (1989) note that a major objective of functional strategy is to develop and exploit a distinctive competence within the firm. Often, when companies possess a distinctive skill, ability or technology, the business strategy is formulated around this distinctive competence (Porter, 1980; Hitt and Ireland, 1985; Snow and Hrebiniak, 1980, Prahalad and Hamel, 1990). Business strategy researchers have identified a strong relationship between the presence of a distinctive competence and improved business performance (Snow and Hrebiniak, 1980; Hitt and Ireland, 1985). Such research highlights the critical relationship between business strategy and functional strategy.

Porter (1980) presents the idea that companies compete using three generic strategies (Cost Leadership, Differentiation, and Niche), and that firms should only operate under one of these strategies at a time (Dess and Davis, 1984). Firms that simultaneously try to do more than one are "stuck-in-the-middle" and, therefore, are unsuccessful at any of the strategies. While Porter suggests that firms either differentiate (e.g., by product performance, or features, or service, or quality, etc.) or become the low cost producer, it became apparent in the 1970s and 1980s that international competitors were succeeding in markets by simultaneously competing on factors such as cost, quality and time (Stalk and Hout, 1990). Additional research into business strategy has revealed that firms can compete on several dimensions simultaneously—results that contradict Porter's model (Chrisman, Hofer, and Boulton, 1988; Ferdows and De Meyer, 1990; Roth and Miller, 1990).

Ferdows and De Meyer (1990) suggest that, to achieve simultaneous capabilities, a sequence of skill and capability acquisition exists. This sequence starts with improvements in quality, which allow a firm to add the capability of dependability. After mastering quality and dependability, a firm can develop speed capability. Finally, once these skills have been developed, a firm can work at increasing its cost efficiency. One key result of the authors' early findings is that the manufacturing function can expect to play a critical role in providing the ability for companies to concurrently compete on several dimensions. For years, foreign competitors—namely the Japanese—based their business strategies on manufacturing capabilities and, as a result, have driven customers to expect more value from their purchases (Giffi, Roth, and Seal, 1990). According to the results of Ferdows and DeMeyer, as global and domestic markets demand products of higher quality, at lower prices, and with shorter delivery cycles, U.S. firms will likely turn to the manufacturing function for a source of competitive advantage.

Broadly stated, manufacturing strategy is the pattern of manufacturing decisions that will provide the support necessary for products to win orders in the marketplace (Hayes and Wheelwright, 1979a; Hill, 1994; Giffi, Roth and Seal, 1990). Skinner (1969, 1974, 1992a), one of the earliest writers on manufacturing strategy, notes that manufacturing should be utilized as a source of competitive advantage for a firm, not merely as a cost center. He argues that corporate leaders misunderstand the function, and therefore, delegate much of strategic manufacturing decision-making. Skinner proposes that manufacturing have a voice in formulating corporate and business strategy. In doing so, manufacturing managers would have the visibility to make manufacturing decisions that are in alignment with the strategic direction of the firm. To make those decisions, Skinner states that manufacturing managers must have knowledge of what they must do well to support the business strategy. Further developing the premise of manufacturing as a source competitive advantage, Hayes and Wheelwright (1979b, 1984) discuss the notion of aligning manufacturing resources to assist a firm in gaining competitive advantage. To focus resources on the manufacturing task, they suggest that the concept of "competitive priorities"—the dimensions along which firms choose to compete in the marketplace—be used. Competitive priorities link manufacturing objectives to the business strategy and other functional areas by clearly establishing how a firm will compete in the market. Four priorities have emerged as major categories: cost, quality, flexibility, and delivery/time (Krajewski and Ritzman, 1990; Roth, De Meyer, and Amano, 1989).

Another phase of development in manufacturing strategy has occurred in which researchers have attempted to identify the specific manufacturing practices and programs that allow firms to achieve competitive objectives such as cost, quality, time and flexibility (De Meyer and Ferdows, 1990; Roth, DeMeyer and Amano, 1989; De Meyer and Ferdows, 1987). This research suggests that several programs and strategies separately contribute to improvements in cost, quality, flexibility and delivery.

Manufacturing strategy continues to be a rapidly growing area for researchers, and an area of increasing concern for practitioners (Voss, 1992a; Maruchek, Pannesi and Anderson, 1990; Anderson, Schroeder, and Cleveland, 1991). Recently, research in the field has matured to the degree that separate streams for the content and process of manufacturing strategy have developed (Adam and Swamidass, 1989; Ward, Leong and Snyder, 1990).

As strategists look to the manufacturing function as a source of competitive advantage, the *process* of formulating manufacturing strategy and the *content* of the strategy decisions must be determined (Ward, Leong, and Snyder, 1990). The process decision refers to methods of gathering and incorporating manufacturing and firm information into strategy formulation. The content of manufacturing strategy refers to the *outcomes* of the decision areas that are of long term importance to the function and to the competitive dimensions upon which a firm chooses to compete. Outcomes can also be the programs and practices (i.e., manufacturing strategies) implemented to achieve the objectives of the business strategy or decision areas, including such items as just-in-time, statistical process control, and inventory reduction techniques.

Choosing appropriate manufacturing strategies is a critical step towards regaining competitiveness and meeting ever-increasing customer requirements. As stated earlier, several authors have linked the decline of American competitiveness to the manufacturing function. To ensure that improvements will result, the manufacturing strategies implemented by companies should be aligned with the goals and objectives of the business strategy. The wide range of manufacturing strategies and programs available increases the complexity of these critical decisions.

One of the basic tenets of manufacturing strategy is that manufacturing decisions and resource allocations should be in alignment with business strategy. Firms with manufacturing resources properly supporting business objectives should outperform those firms whose manufacturing function is not in alignment with the business strategy. Until recently, the necessary models to adequately test and validate this tenet had not been constructed. To this end, the notion of "production competence"—manufacturing resources properly aligned with the business strategy—was developed.

Production Competence: What Is It?

Production competence concerns the ability of the manufacturing function to support product-market initiatives. Hayes and Wheelwright (1979a, 1979b) first discuss the concept of competence in manufacturing in the context of their familiar product-process matrix. They first observe that, just like products, processes have life cycles. As product volumes change as the product moves through its cycle, processes must also change. The product-process matrix suggests that for a given product life cycle stage, an appropriate production process (or stage) exists.

Hayes and Wheelwright designate an appropriate match of products and processes as "being on the diagonal" and suggest that this match is a requirement for firms desiring to be competitive. They call the area or "patch" around the intersection of the product and process structures "competence"—the ability of the production process to support the characteristics of the products or product line. In the product-process matrix, competence is something a firm either has (being on the diagonal) or does not have (being off the diagonal).

Building on the product-process matrix, Cleveland, Schroeder and Anderson (CSA) (1989) propose a theory of production competence (PC) that attempts to explain what Skinner called the "elusive set of cause-and-effect factors which determine the linkage between strategy and production operations" (1969, p. 139). The link between the business strategy and the manufacturing function is what Cleveland, Schroeder and Anderson call production competence. They define competence as "the preparedness, skill, or capability that enables manufacturers to prosecute a product-market specific business strategy" (Cleveland, et al., 1989, p. 655). One important way in which the CSA definition of competence differs from that of Hayes and Wheelwright is that the CSA model characterizes competence as a continuous variable, rather than a fixed attribute. In this context, a *degree* of competence exists, rather than the dichotomous characterization of the Hayes and Wheelwright model.

In the CSA model, production competence is a "measure of the combined effects of a manufacturer's strengths and weaknesses in certain key performance areas" (Cleveland, et al., 1989, p. 657). The CSA method incorporates both the objectives of a firm's business strategy—which determine the key performance areas—and the strengths and weaknesses of the firm's present production process. Together, these two items determine the competence score.

To verify that the theory of production competence was tenable, the CSA model was tested on a small sample of manufacturers (Cleveland, et al., 1989). Results suggest the existence of strong linkages between competence and firm performance.

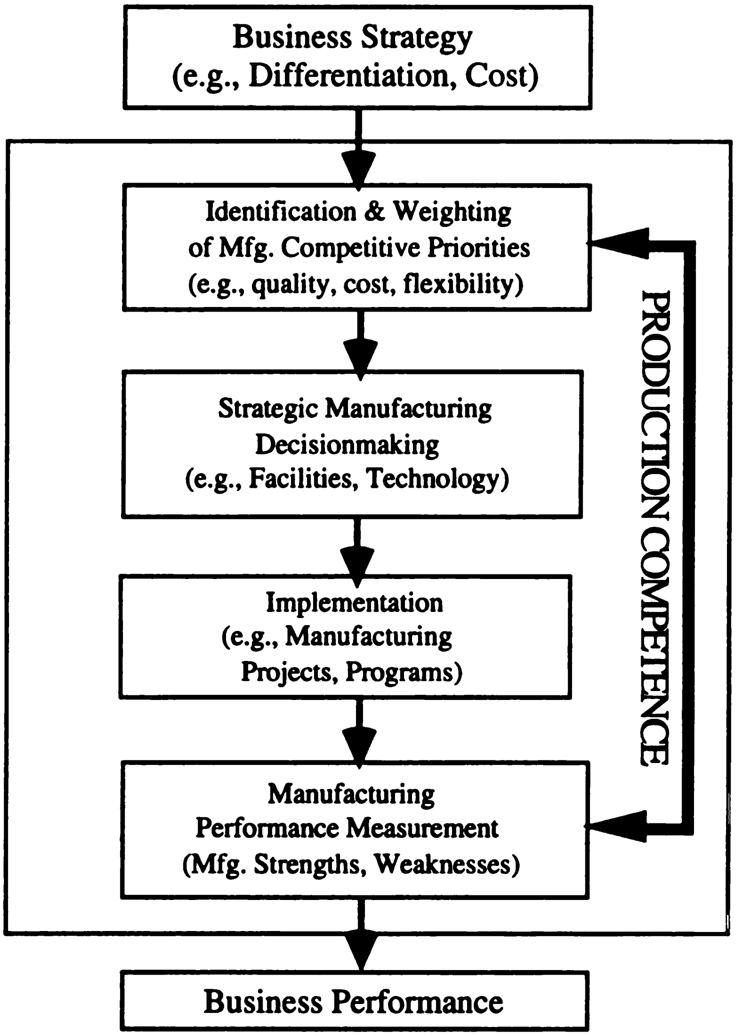
While the CSA model is a new and interesting method for analyzing the contribution of production activities, there are some problems with the methodology of the CSA study. For example, the authors test the model on a very small sample (n=6) and use regression analysis to investigate the nature of the relationship between production competence and performance. When using such small sample sizes, results must be viewed cautiously. Also, Vickery (1991) observes that the variables used to operationalize the business performance and production competence constructs are closely related. On occasion, both constructs include the same variables. This overlap of variables creates an artificially large correlation between firm performance and production competence, perhaps overstating the true relationship.

Vickery (1991) addresses these problems and presents an improved theoretical framework for understanding the production competence (PC) construct (see Figure 1.2). The Vickery model views the PC construct in the context of a process model of manufacturing strategy, one that translates the objectives of the business strategy into manufacturing competitive priorities. Vickery states that production competence is best understood within this framework and that production competence can be determined for a firm regardless of the strategic process utilized.

The Vickery model draws on the work of Schroeder and Lahr (1990), who combine strategy formulation methodology from the organizational literature with accepted ideas of manufacturing strategy to form a process model of manufacturing strategy. In Vickery's model, competitive priorities provide the linkage between business strategy and manufacturing decision-making. Vickery argues that production competence is a function of the importance of various competitive priorities to the firm and the strength or weakness of the support provided to these priorities by manufacturing. The strength of support provided (i.e., manufacturing performance) is a function of the selection and implementation of various manufacturing strategies. Production competence, therefore, is a function of manufacturing strategy selection and implementation.

In the model proposed by Vickery (1991), manufacturing performance is determined by two elements—the strategic manufacturing decisions made (i.e., facilities, technology, quality management, etc.) and the projects and programs implemented. Schroeder and Lahr (1990) indicate that manufacturing programs link together strategies and tactics, and that the programs themselves are also tactical in nature. It is clear from Vickery's model that the selection of manufacturing strategies, combined with the implementation of the strategies through tactical programs and techniques, determine whether performance targets are met, and, therefore, the level of competence that a firm achieves. Vickery concludes that the production competence construct can be a used to investigate the link between manufacturing strategy and business performance.

Vickery, Droge, and Markland (1993) extend the earlier Vickery model and develop an improved measure of production competence. The model is extended to include a business strategy construct for the purpose of investigating whether being competent in manufacturing is enough to produce superior business



Source: Adapted from Vickery (1991)

Figure 1.2: A Process Model of Production Competence

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performance. The measure of production competence was improved to include an enlarged number of competitive priorities and an allowance was made for the proportion of each competitive priority for which manufacturing is responsible. Results from this research suggest a positive and significant relationship between production competence and firm performance. This work validates the earlier research of Cleveland, et al. (1989) and Vickery (1991) and encourages additional research on production competence.

Research Purpose

Several authors and government statistics have identified striking weaknesses in American competitiveness and manufacturing (Giffi, Roth and Seal, 1990; Hayes, Wheelwright, and Clark, 1988; Dertouzos, Lester, Solow and the MIT Commission on Industrial Productivity, 1989; Cohen and Zysman, 1987). The authors and reports suggest that poor quality, high production costs and lagging productivity growth have reduced the competitiveness of American firms in global markets. Today, increased global competition has refocused the attention of top management, and manufacturing is again being looked upon as a potential source of competitive advantage for companies.

The task of generating advantage from within manufacturing is extremely complex. To assist firms in becoming more competitive, myriad strategies, programs and tools have been introduced (e.g., JIT, TQM, group technology, MRPII). Given the multiplicity of programs and methods available, companies face the challenging task of determining which programs and methods to implement in view of the firm's strategic objectives. For example, if a company has chosen to compete on product quality and delivery speed, which manufacturing strategies and/or programs will enable it to excel in these areas?

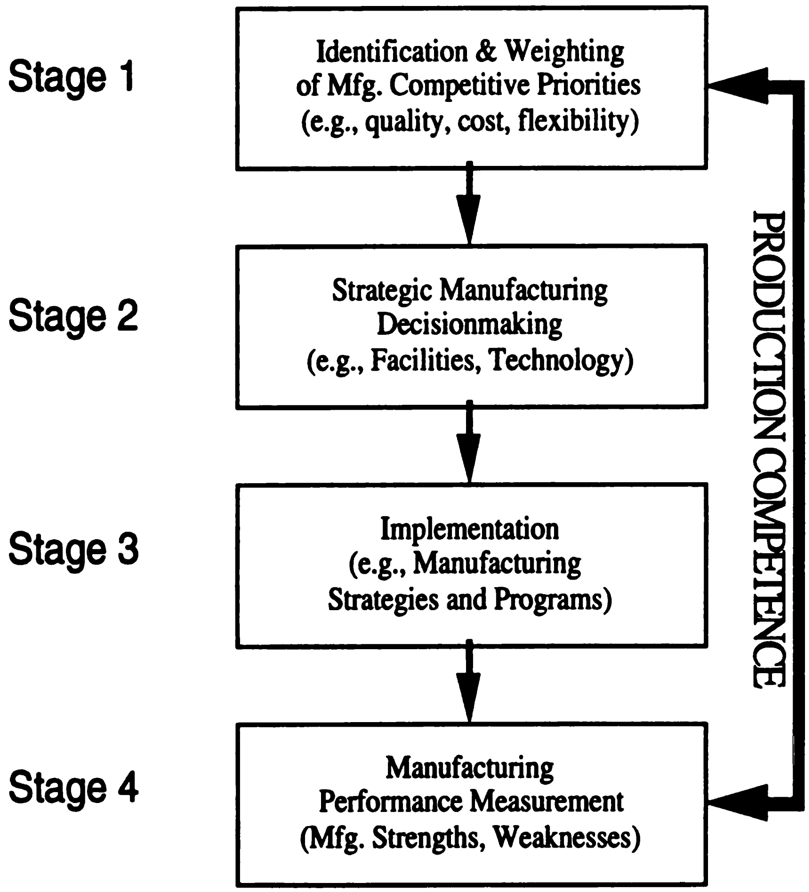
Recently, researchers have introduced the production competence construct to determine whether the programs and methods selected and implemented by the manufacturing function are, in fact, supporting business strategy objectives. Vickery (1991) improved an earlier model presented by Cleveland, et al. (1989) and discussed the construct of production competence in the context of a process model of manufacturing strategy. Vickery, Droge, and Markland (1993), after further developing the measurement of the construct, tested their model and discovered a significant positive relationship between production competence and firm performance.

The theoretical framework introduced by Vickery indicates that production competence is a function of the competitive priorities important to a firm and the ability of the manufacturing function to properly select and implement manufacturing strategies and programs that support the competitive priorities (See Figure 1.2).

The purpose of this research is to identify the manufacturing strategies, programs and techniques that best support manufacturing strategic objectives or competitive priorities. Relating this research objective to Figure 1.3, the purpose is to identify the strategies and programs implemented in Stage 3 to support manufacturing competitive priorities identified in Stage 1. The manufacturing competitive priorities—determined by the business strategy objectives—guide the strategic manufacturing decision-making process portrayed in Stage 2. The manufacturing strategies and programs implemented are the outcomes of this decision-making. Stage 4 represents the measurement of manufacturing performance. Finally, production competence is a measure of the support provided to the manufacturing strategic objectives. In this context, production competence provides a measure to evaluate the effectiveness of the support provided by various manufacturing strategies and programs implemented in Stage 3.

In the manufacturing strategy literature, four main competitive dimensions have been identified: quality, delivery response, cost, and flexibility (Skinner, 1985; Roth, De Meyer, and Amano, 1989). Within a given competitive dimension, researchers have identified a set of manufacturing techniques and action programs related to improved performance (Hayes and Wheelwright, 1984; Sharma, 1987; Roth, 1987; Roth, De Meyer and Amano, 1989; Ferdows and DeMeyer, 1990). As managers ready their firms for changes in strategic posture and competition along multiple competitive dimensions, they need to know which manufacturing techniques and strategies are <u>most</u> effective in supporting specific manufacturing competitive priorities, and hence, the business strategy itself.

The Global Manufacturing Futures Project has perhaps produced the largest body of research into the use of manufacturing techniques. This research team has generated a list of 39 techniques—called "action programs"—which are presented to respondent firms for evaluation and projection of use (Ferdows and DeMeyer, 1990). In various papers, the team has linked the use of particular action programs to competitive priorities. Other



Source: Adapted from Vickery (1991)

Figure 1.3: A Closer View of the Production Competence Construct

researchers are also studying the choices of manufacturing techniques that firms are making (Oakland and Sohal, 1987; Roth, 1987; Schmenner, 1988b; Tunalv, 1992). A major benefit of this stream of work is that it begins to focus attention on the particular activities necessary to both achieve manufacturing objectives and make improvements within specific areas of manufacturing.

A key concept missing from this research stream, however, is the appropriateness of the strategies and techniques that firms implement. Skinner (1992a) notes the deficiencies in the manufacturing strategy field, observing that adoption of "off the shelf" technologies and strategies is not making firms more competitive. He writes that manufacturing strategy will continue to miss its potential until the field "can provide more links between tasks, objectives and specific manufacturing policies" (Skinner, 1992a, p. 22). He has also identified "research and conceptual development of concrete, explicit bridges between task and structural decisions" as *the* primary need in the field (1992a, p. 25).

Knowing that the role of any functional strategy is to support the overall business strategy, the most appropriate choices of manufacturing techniques and programs are those that are most effective in supporting the goals of the business. Firms implementing the most effective strategies and techniques will have the most "competent" manufacturing functions. Given the findings of Vickery, et al. (1993), these firms should also realize improved performance. Previous studies have investigated the use of manufacturing strategies and programs without measuring their effect on overall performance or performance in critical areas.

Results of this research will indicate the manufacturing strategies and programs that are most effective in supporting manufacturing and business objectives. Using data gathered from an earlier study (Vickery, Droge, and Markland, 1993) and this project, the overall competence and performance of a firm's manufacturing function can be determined. Thereby, those manufacturing strategies and programs enabling firms to be competent in production—and thus, good performers—will be identified.

In the same manner that performance and competence scores can be determined and calculated for the entire manufacturing function, competence scores can be computed for each major competitive priority (i.e., cost, quality, delivery response, and flexibility). Thus, constructs can be created that attempt to measure manufacturing's ability to support specific business objectives in the areas of cost, quality, delivery, and flexibility.

The new constructs will be called *cost competence*, *quality competence*, *delivery response competence*, and *flexibility competence*. This research will identify the manufacturing strategies and programs that, in addition to overall production competence, are associated with competence and performance for the major competitive priorities. These results will directly respond to the research need identified by Skinner (1992a).

Research Questions

Vickery, Droge, and Markland (1993) observe a link between firm performance and production competence. This project will extend their results and investigate the relationship between the use of manufacturing strategies and programs, and production competence. As such, the following research question will be examined:

1. What is the relationship between the use of manufacturing strategies and programs, and production competence?

Vickery, Droge and Markland (1993) determine production competence for a firm in part by identifying the importance, performance, and manufacturing responsibility (expressed as a percentage) of 31 competitive priorities. The competitive priorities in that study are a combination of manufacturing, design, and marketing dimensions.

Using previous research and the four established manufacturing competitive priorities (cost, quality, delivery, and flexibility) as a guide, the competitive priorities appearing in the Vickery et al. (1993) study that relate to manufacturing can be placed into one of the four major categories. Each of the four priority groups will then be comprised of a collection of "sub-priorities". Since each established priority would encompass several sub-priorities, the same method used to determine the overall production competence score (summing the product of strategic importance • firm performance • percent manufacturing responsibility across 31 priorities) can be applied to the four competitive priority groups. This results in the calculation of a competence score for each of the four priorities.

Using the method described above, a cost competence score, a quality competence score, a delivery competence score, and a flexibility competence score will be calculated for each firm. This will expand the production competence construct, allowing for analysis of the relationship of manufacturing strategies and programs with specific business objectives and competitive priorities. This analysis responds to the need identified by Skinner (1992a) to develop specific linkages between tasks and strategic decisions. The research questions this extension raises are:

> 2a. What is the relationship between the use of manufacturing strategies and programs, and cost competence?
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> 2b. What is the relationship between the use of manufacturing strategies and programs, and delivery competence?
>
> 2c. What is the relationship between the use of manufacturing strategies and programs, and flexibility competence?
>
> 2d. What is the relationship between the use of manufacturing strategies and programs, and quality competence?

While some research has been conducted regarding the relationship between action plans and competitive priorities, this research does not, for the most part, account for firm performance in the relationships (Roth, De Meyer, and Amano, 1989). In addition to the major competence constructs described above, the notion of categorizing the 31 priorities relating to manufacturing into four groups can be applied to performance.

Each firm in the study has subjectively rated their own performance on each of the 31 priorities. Using the same groups as identified above, *performance* scores for cost, quality, delivery-response and flexibility can be determined for each firm. A benefit of analyzing the relationship between the use of manufacturing strategies and performance is that a more direct assessment of the effect of individual strategies and programs might be observed. This raises the following research questions:

> 3a. What is the relationship between the use of manufacturing strategies and programs, and subjective cost performance?
>
> 3b. What is the relationship between the use of manufacturing strategies and programs, and subjective delivery performance?
>
> 3c. What is the relationship between the use of manufacturing strategies and programs, and subjective flexibility performance?
>
> 3d. What is the relationship between the use of manufacturing strategies and programs, and subjective quality performance?

Much of the research in the strategy/policy area relates the use of strategies to overall firm performance. In this study, the use of manufacturing strategies, programs, and techniques and their relationship to overall firm performance would be of interest. This raises the following research question:

> 4. What is the relationship between the use of manufacturing strategies and programs, and overall firm performance?

Finally, much of the practitioner and academic literature contains suggestions for the manufacturing strategies and techniques that may support a particular competitive priority. By combining several of the strategies that relate to specific priorities, new constructs can be created and the bundle of strategies can be tested as one group. These bundles can be related to all of the competence and performance constructs discussed above. As such, the following research questions can be raised:

> 5. What is the relationship between the use of groups of manufacturing strategies, programs, and techniques and competence?
>
> 6. What is the relationship between the use of groups of manufacturing strategies, programs, and techniques and performance?

Scope Of Research

The furniture industry is one that is experiencing many changes. Once an industry characterized by small shops producing furniture by hand, it is now an industry striving to implement competitive business and manufacturing techniques. This is a period of transition for many furniture makers who seek to implement the newest technology and practices into businesses that, in the past, have relied on very traditional methods. The furniture environment offers an opportunity to examine manufacturing practices and changes among a diverse group of firms. There are participants at both ends of the technology spectrum, from programmable technology to hand saws.

The objective of this research is <u>not</u> to chronicle the differences between technology adopters and more traditional enterprises in the furniture industry, but to see if, in fact, the new manufacturing strategies, programs and technologies are doing what they are purported to do—that is, to improve the competitiveness of the firm.

The study will be limited to participants in the furniture industry, with annual sales of the target firms ranging from ten million to hundreds of millions of dollars. The study will include only the CEOs and managers in the manufacturing function of the firms. Questionnaires will ask about the use of manufacturing strategies and programs currently in use in their company. In addition, measures relating to cost, quality, flexibility, and delivery performance of participating firms will be included. Finally, the participants will be asked about the level of interaction between the managers in the manufacturing function and those working in both marketing and product design.

Contributions Of Research

The ability of American firms to be competitive in a global market has diminished over the past 45 years. Economic data and government statistics indicate that the U.S. economy has several weaknesses and many researchers have identified the manufacturing sector as a primary source of the nation's troubles. More positively, these researchers are turning to the manufacturing sector to increase the competitiveness of the nation and its firms.

In response to the complexities and difficulties in manufacturing, a multitude of manufacturing programs has become available during the past 20 years. Operating with finite resources and limited time horizons, American firms are faced with important decisions regarding which manufacturing strategies and programs are best for their companies. Adding to the difficulties is the fact that investments in manufacturing are often very expensive and, therefore, difficult to reverse (Hill, 1994). This research will help to identify the manufacturing strategies and programs firms should adopt to achieve their goals and objectives.

Production competence is a measure of the support provided to business objectives by manufacturing. Business goals and objectives are communicated to manufacturing through competitive priorities. It is manufacturing's role to provide support to these priority areas. Vickery, Droge, and Markland (1993) identified a significant positive relationship between production competence and firm performance. In their model of production competence, manufacturing performance is a function of the appropriateness and effectiveness of the manufacturing strategies and programs selected and implemented by a firm. If positive firm performance and increased competitiveness are related, and competence is related to performance, it then follows that the selection of appropriate manufacturing strategies and programs is directly related to competitiveness. In other words, to increase their competitiveness in a world of finite resources, U.S. firms must select and implement manufacturing strategies and programs that are in alignment with the firm's strategic business objectives.

This study will identify the manufacturing strategies and programs firms are using to achieve production competence and, therefore, become more competitive. Given the multitude of manufacturing programs and techniques introduced and the competitiveness of the domestic and global markets, companies need information regarding the effectiveness of these programs in providing support for their business goals. Data about particular programs will provide information to alleviate some of the uncertainties involved in making critical manufacturing decisions. The results of this study will provide that crucial information.

Research Limitations

Several factors limit the results of this study. First, it is restricted to firms in the furniture industry, which reduces the external validity, or generalizability, of the results (Kerlinger, 1986). That the furniture industry is one experiencing rapid change may mitigate the impact of this limitation. The rapid pace of change provides an opportunity to gauge the success of the programs among the early adopters.

Another factor that limits the study is that it does not account for the resources or methods/processes firms use to formulate and implement the strategies and programs. Manufacturing strategy is a relatively young field and is in need of additional research into the formulation process.

Organization Of Dissertation

The organization of the remainder of the dissertation follows. Chapter 2 contains the literature review which includes a discussion of empirical-based research and theory development in operations management, an examination of research pertaining to the development of manufacturing strategy and the use of manufacturing techniques, and an in-depth review of the production competence construct. Chapter 3 is the methodology chapter and includes discussion of model development, manufacturing strategies and programs, hypotheses, method of testing, and data collection issues. Chapter 4 contains the results and preliminary analyses of the tests. Chapter 5 discusses further implications of the results, contributions of the research, limitations, and suggestions for further research on the topic.

II. LITERATURE REVIEW AND THEORY DEVELOPMENT

This section will discuss the need for more empirical-based research and theory development in operations management (OM), and describe more fully the development of theories. In addition, this section will address theory development in terms of the production competence construct. Finally, research regarding the use of particular manufacturing techniques and programs and their relationship to competitive priorities is discussed.

Empiricism In Operations Management

Until the late 1950s, manufacturing played a significant role in developing the United States' stature as a world economic power. During the 1960s and 1970s, however, as global capacity outstripped demand, top management began to regard the finance and marketing functions as strategic and critical, reducing manufacturing's role to a secondary, reactive one (Skinner, 1978; Hill, 1990).

Similarly, academics in operations management (OM) felt as though researchers in organizational behavior, finance, and marketing received more respect than they did (Miller and Graham, 1981).

Another problem facing academics in operations management was that the practitioner community considered much of the research in manufacturing and operations management to be of dubious value (Miller and Graham, 1981; Fryer, 1981; Meredith, Raturi, Amoako-Gyampah, and Kaplan, 1989). Practitioners lamented that the problems studied by academics were unrealistic and that, even if the problems were realistic, the solutions were incomprehensible. In 1980, the bulk of the research in OM was grounded in optimization and other operations research and management science (OR/MS) techniques, solidifying the perception that academic solutions were not applicable to practitioner problems (Miller and Graham, 1981; Chase and Prentis, 1987; Wood, 1989).

To address the gap between what practitioners felt were the real problems and those being researched by academicians, several turn-of-the decade articles appeared (Miller and Graham, 1981; Chase, 1980; Buffa 1980; Hax, 1981). The articles called for a move away from traditional OR/MS research to research that was more useful to practitioners. The authors hoped this move would raise the consciousness of the entire research community to the field of OM, thus increasing its stature within the academic community. Recognizing that operations management is an applied field, the authors suggested a more applied or empirical approach to OM research.

In commentaries to Miller and Graham, Buffa (1980) and Groff and Clark (1981) recognized that conducting empirical research requires a completely new set of research tools, very different from those developed for OR/MS research. Buffa hypothesized that a movement to empirical research would be slow as the current OM teachers, researchers, tenure committee members, and journal editors had all been trained in the traditional ways. Furthermore, training research methods for the doctoral students of the period continued to be in techniques of the OR/MS school.

To investigate if research in OM had indeed acted on the agenda presented by Miller and Graham (1981), Amoako-Gyampah and Meredith (1989) conducted a review of articles published in OM-related journals during the mid-80s. Classifying articles according to research area and methodology, their results indicated that, for the most part, research in OM had continued along the same course, just as Buffa had surmised it might. Empirical research comprised just 15% of the research appearing in their study, with the majority of research falling under the headings of "model formulation" (mathematical, algorithmic, heuristic, statistical and graphical) and "laboratory simulation".

Also addressing the issue of a lack of progress in closing the industry-academia gap, Meredith, Raturi, Amoako-Gyampah, and Kaplan (1989) proposed that the current research paradigm used by OM researchers was inadequate. They said the paradigm "is typically prescriptive, deterministic, non-contextual, and exhibits a preponderance of 'rational' constructs" (Meredith, et al., 1989, p. 301). They noted that a lack of knowledge of alternative research paradigms may contribute to this narrow view. Building on the work of Emory (1985), they developed a research cycle and a 2-axes generic framework for characterizing research methods. The first axis of the framework concerned whether the research process was rational or existential (i.e., deductive or inductive). The second axis described the proximity of the model or problem to reality (artificial or natural).

Applying this framework to operations management, Meredith, et al. classified research in three OM journals (*Management Science, Decision Sciences* and the *Journal of Operations Management*) from

1977 and 1987 according to methodology used. They wrote "the inescapable conclusion is that our research in operations is still overwhelmingly artificial in nature, though breaking the methodological tie with the field of management science has allowed us to begin moving toward more existential (primarily interpretive) paradigms and to move away from the more rationalistic, 'scientific' paradigms" (Meredith, et al., 1989, p. 317).

The call for more empirical research in operations management still exists today, just as it did in the early 1980s (Swamidass, 1991; Meredith, et al., 1989; Anderson, Cleveland, and Schroeder, 1989). This time, however, it appears that the call will receive due attention as articles that detail empirical research techniques (Flynn, Sakakibara, Schroeder, Bates and Flynn, 1990; Wood, 1989), present new paradigms for OM research (Meredith, et al., 1989), and discuss theory development (Swamidass, 1991) are beginning to appear in OM-related research journals. The *Journal of Operations Management* continues to announce its receptiveness to empirical and field-based research. These developments appear to be positive steps toward overcoming many of the barriers to empirical research in operations management identified by Buffa (1980).

Researchers can reduce the gap that exists between academics and practitioners by concentrating on problems that practitioners perceive to be important. Using the notion of material requirements planning (MRP) and production activity control (PAC) as examples, Chase and Prentis observe: "The practitioner literature has frequently led the way in identifying significant topics for OM research and in providing new terminology to label particular aspects of the field" (1987, p. 361). They further state "that OM, perhaps more than any other field of business draws its research thrusts from the real world" (Chase and Prentis, 1987, pp. 361-362).

Currently, the "real world" consists of increasing global competition and diminishing competitiveness of U.S. firms, forcing many companies to reevaluate their businesses. Facing difficult and complex problems, businesses and manufacturing managers are seeking solutions that they can understand and implement. This presents a unique opportunity for researchers in the field of OM to simultaneously close the gap between themselves and practitioners and to make significant contributions to business research.

This research project will attempt to accomplish both tasks. It will identify manufacturing strategies and techniques being used by firms in the furniture industry to improve financial performance and become more competitive. Results of the research should be of value to practitioners and researchers alike.

Manufacturing Strategy

Skinner (1969) was among the first to recognize that manufacturing can be a competitive weapon for a firm. Skinner observed that, in most American companies, the interrelationships between manufacturing policy decisions and business strategy alternatives were being ignored. Skinner's notion of the interrelationships was "that a company's competitive strategy at a given time places particular demands on its manufacturing function, and, conversely, that the company's manufacturing posture and operations should be specifically designed to fulfill the task demanded by strategic plans" (1969, pp. 138-139). Skinner called the set of activities required of manufacturing to support the strategic plans the "manufacturing task".

Skinner noted that, without knowledge of the overall strategic direction of a firm, manufacturing will be unaware of the business implications of policy decisions made *within* the function. Therefore, manufacturing will be unable to proactively and effectively contribute to the pursuit of strategic competitive objectives (i.e., the manufacturing task). Skinner also noted that, long dominated by specialists and experts, the manufacturing function was considered too technical and was, therefore, avoided by top management. As a result, manufacturing policy decisions were delegated to manufacturing executives. Usually, these executives did not participate in formulating strategic policy for the business. Consequently, manufacturing policy decisions were made in isolation from the rest of the organization and, therefore, did not contribute to strategic business objectives as strongly as they might have. This is part of what Skinner meant by using manufacturing as a competitive weapon—allowing manufacturing executives entree to the strategic debate so they can make strategic decisions that align with business strategy objectives.

Manufacturing strategy is rapidly gaining in popularity as witnessed by the dramatic increase in books and papers published on the subject (Wheelwright and Hayes, 1985; Swamidass, 1986; Gunn, 1987; Suzaki, 1987; Ettlie, Burstein and Feigenbaum, 1990; Hill, 1994; Swamidass and Newell, 1987; Voss, 1992a; Gunn, 1992). Several models have been presented describing the purpose and process of manufacturing strategy (Skinner, 1969; Wild, 1980; Hayes and Wheelwright, 1984; Fine and Hax, 1985; Cleveland, Anderson, and Schroeder, 1989; Gunn, 1987; Schroeder and Lahr, 1990; Roth and Miller, 1990; Vickery, 1991; Anderson, Schroeder, and Cleveland, 1991; Voss, 1992b). Since it is still a young discipline, many of the models contain philosophical differences. Still other differences can be attributed to misunderstandings arising from mixed uses of terminology. This terminology problem also existed in the strategy/policy field.

To facilitate the development of business strategy/policy research, researchers classified previous work into two categories—content and process. Fahey and Christiansen wrote that content research refers to "research which examines the content of decisions regarding the goals, scope, and/or competitive strategies of corporations" (1986, p. 168). Process research refers to the actions involved in the formulation and implementation of strategy (Huff and Reger, 1987). Recently, OM researchers employed this dichotomy and classified manufacturing strategy literature into content and process categories (Schroeder, Anderson, and Cleveland, 1986; Adam and Swamidass, 1989; Ward, Leong, and Snyder, 1990).

In the context of manufacturing strategy, content usually refers to two categories: 1) the strategic decision areas of manufacturing and the programs implemented in those areas, and 2) competitive priorities. Building on the work of Skinner, Hayes and Wheelwright (1984) identify eight strategic decision categories and place them into two groups: structural and infrastructural. Structural categories include capacity, facilities, technology, and vertical integration.

Infrastructural categories include workforce, quality, production planning/materials control, and organization (Hayes and Wheelwright, 1984; Anderson, Cleveland, and Schroeder, 1989). The second content category—competitive priorities—are the ways in which firms choose to compete in markets and include low cost, conformance quality, design quality, delivery speed, delivery dependability, product development speed, volume flexibility, and product flexibility (Krajewski and Ritzman, 1993; Wood, Ritzman and Sharma, 1990).

Work in the process area has progressed at a slower pace. Skinner's (1969) breakthrough work presented one of the earliest manufacturing strategy process models. Skinner's model was later refined by Hayes and Wheelwright (1978, 1984). Fine and Hax (1985) adapted a corporate strategy model to manufacturing strategy development. Sharma (1987) developed a comprehensive model linking manufacturing to corporate strategy, business strategy, other functional areas and external forces. Schroeder and Lahr (1990) merged traditional policy models from strategy research with concepts from manufacturing strategy to create a process model for use by practitioners. Gunn (1987) presented a four-pillar approach to developing a manufacturing strategy.

Throughout the development of various manufacturing strategy process models, a fairly common set of stages has emerged. Additionally, the elements or stages of *process* models often overlap with *content* areas of manufacturing strategy. Generally, manufacturing strategy process models start with the formulation of corporate or business strategy. Competitive priorities, or the competitive dimensions along which firms choose to compete, communicate the strategic business objectives to manufacturing. After the identification and communication of competitive priorities, manufacturing organizations must decide how to allocate resources to successfully support competitive business objectives.

In several models of manufacturing strategy, the manufacturing decisions regarding manufacturing resources or strategic variables are called "strategic manufacturing decisions". It is at this point in process models that the overlap to content variables occurs. The strategic decisions made in process models concern content issues and variables. For example, to ensure adequate capacity exists to produce a new product, additional capacity may be required. Capacity is one of the major content variables. Process models and research are concerned with *how* the decision was made, while content research is concerned with the *outcome* of the decision process.

Following the strategic decisions, the next general stage in manufacturing strategy process models is the identification and implementation of specific strategies and programs to execute the strategic decisions and achieve business objectives. Again, there is some overlap with content issues as the strategies and programs to be implemented can be classified as content variables (Fahey and Christensen, 1987). In the final stage of process models, the performance of the strategies and programs is evaluated and the performance results are fed back to earlier stages or decision making points in the model.

Similar to the Hayes and Wheelwright designation, the strategic variables in Sharma's (1987) manufacturing strategy process model were broadly defined as those dealing with (1) structural decisions, concerning the design of operations systems (i.e., location, facilities, layout, etc.), and (2) infrastructural decisions, or those concerned with the shorter-term management of operations (i.e., aggregate planning, scheduling, inventory control, etc.). In research by Sharma and others, content and process variables are discussed *simultaneously* (see Fine and Hax, 1985; Schroeder, Anderson, and Cleveland, 1986; Roth and Miller, 1989). Adam and Swamidass (1989) noted that manufacturing strategy researchers often combine process and content ideas and suggested that development in the field would be aided by establishing two distinct streams.

Recently, Adam and Swamidass (1989) and Anderson, Cleveland and Schroeder (1989) separately review manufacturing strategy and synthesize progress in the field, together highlighting three common areas in need of research. The first area of opportunity concerns the link between manufacturing strategy and firm performance. Anderson et al. write: "The underlying, and often presumed argument that exists within the literature that links operations strategy and operations decisions with corporate strategy is that proper strategic positioning or aligning of operations capabilities can significantly impact competitive strength and business performance of an organization" (1989, p. 134). Several others share this position, including Stobaugh and Telesio (1983), Wheelwright (1984), and Fine and Hax (1985). Anderson et al. observe that this premise, while powerful, has only recently been empirically tested. Adam and Swamidass (1989) also identify the

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relationship between operations strategy and business performance as a "missing theme".

The second area of manufacturing strategy requiring additional work is in the area of content issues. Anderson et al. report that "The literature pays very little attention to the actual content of operations strategy" (1989, p. 151). Again, Adam and Swamidass identify content issues as a "missing theme".

The third issue common to both reviews is a call for an increase in the amount of empirical research performed in both process and content areas. Anderson et al. write: "The literature is largely expository in nature—it contains very few empirical studies" (1989, p. 152). Adam and Swamidass corroborate: "The shortcoming of content research is that it lacks empirical investigations of relationship among its variables" (1989, p. 185).

The three missing themes of research in manufacturing strategy—its effect on business performance, increased coverage of content issues, and more empirical research—are each addressed in the study proposed here, as is the separation of process and content issues. This study is the second stage of a research project investigating production competence. The first stage (Vickery, Droge, and Markland, 1993) identified a link between production competence and performance that will be augmented by this project.

The results of the study by Vickery et al. indicated that firms with higher production competence scores outperformed firms with lower scores. The authors also accounted for two other variables in the study: (1) the main effect of the business strategy on performance, and (2) the interaction of business strategy and production competence on performance. Results of this analysis revealed that, for this study, the main effect of business strategy type was not related to performance. However, the interaction between business strategy and production competence did have an effect, particularly when the strategy adopted was one of Differentiation. This result broadens the spectrum of manufacturing involvement and support of business strategy from a traditional low cost focus to one that must support a variety of strategic objectives and corroborates what Skinner has been saying all along.

This project, an extension of Vickery et al. (1993), is an empirical study directed at the identification of the specific strategies and programs implement by firms and their relationship to production competence. As such, the content issues related to the firm's manufacturing strategies will be captured. Data regarding overall firm performance gathered by Vickery et al. and new performance data obtained in this study will be used to relate the use of manufacturing strategies to overall performance and performance within competitive priorities. Thus, this study is a direct response to the manufacturing strategy research needs identified by Anderson et al. (1989) and Adam and Swamidass (1989) and an extension of current research in manufacturing strategy.

Production Competence

While the notion that a properly aligned operations strategy can improve business performance is consistent and prevalent in the literature, Anderson, Cleveland and Schroeder (1989) observed that it has never been empirically tested. To investigate the relationship between operations strategy and performance, Cleveland, Schroeder, and Anderson (CSA) (1989) propose a model of manufacturing strategy that includes the construct of "production competence".

According to Cleveland et al., the production competence construct explains the "long-suggested link between production processes and business strategy" (1989, p. 667). This addresses what Skinner (1969) called the "missing link". The CSA model defines production competence as "the preparedness, skill, or capability that enables manufacturers to prosecute a product-market specific business strategy" (Cleveland, Schroeder, and Anderson, 1989, p. 655). The production competence construct describes the degree of support supplied to the business strategy by manufacturing.

Earlier, Hayes and Wheelwright (1979) had proposed a narrower definition of production competence saying that competence was the result of proper alignment between the life cycle stages of the product and the production process. In their model, competence was a characteristic a firm either possessed or did not possess. In contrast, the CSA model suggests that production competence can be expressed as a continuous variable, rather than the dichotomous characterization of Hayes and Wheelwright.

Production competence, in the CSA model, is a "measure of the combined effects of a manufacturer's strengths and weaknesses in certain key performance areas" (Cleveland, Schroeder, and Anderson, 1989, p. 657). The calculation of the production competence score involves several steps. First, the authors identify nine performance areas from the literature considered to be critical to the success or failure of the business plan: adaptive manufacturing, cost-effectiveness of labor, delivery performance, logistics, production economies of scale, process technology, quality performance, throughput and lead time, and vertical integration. Second, the business strategy of the firm is captured by ranking the nine critical manufacturing performance areas in descending order of importance to the business strategy of a particular firm (1 = most important, 9 = least important). The importance rankings of each performance area are then inverted so that a larger value is associated with increased importance (9 = most important, 1 = least important). Next, using the type of production process (job shop, batch, connected line flow, or continuous flow) adopted by the firm as a guide, the nine performance areas are evaluated as being a strength, neutral, or a weakness. Based on the evaluation, a rating is assigned (strength = +1, neutral = 0, weakness = -1) to each performance area. To improve the fit of the CSA model and compensate for the narrow performance scale, the authors incorporated a logarithmic transformation of the inverted rankings.

The final step is to calculate the production competence score, which is accomplished by multiplying the assigned strength/neutral/weakness rating (+1, 0, -1) by the log-transformed inverted ranking for each of the nine performance areas. This product is summed across all nine performance areas to determine the total production competence score.

The theory represented by the CSA model is that firms with competent manufacturing functions—one that provides strong, aligned support to a business strategy—will outperform firms with less competent manufacturing functions. To test this theory, both a competence score and a measure of firm performance are needed. The calculation of the production competence score is described above.

In the CSA model, firm performance was measured by rating, relative to competitors, performance on the dimensions of cost, quality, dependability, flexibility, market share, share growth rate, and return on assets. Each dimension was rated on a 5-point Likert scale (5 = best in industry, 1 = worst in industry) and the firm performance score was simply the sum of the Likert scores.

Cleveland et al. (1989) tested this model on a sample of six firms to investigate if a relationship between manufacturing strategy and business performance existed. For each of the six firms, a production competence score and the index of firm performance were determined. A simple regression was run and the coefficient of determination registered very strongly (r^2=.97), indicating an extremely strong relationship between production competence and firm performance. This result suggests validity for the theory of manufacturing strategy, which claims that firms with properly aligned manufacturing functions will achieve superior performance than firms whose functions are not properly aligned.

Vickery (1991) addressed this study and the circumstances that contributed to create such an extraordinary coefficient of determination. Vickery recognized that several of the components of the firm performance index overlapped considerably with components of the production competence score. It was also observed that the performance measure itself contained a degree of redundancy. For example, in the CSA calculations, performance areas such as cost and flexibility are closely related to the balance sheet data and market share. Each of these issues—overlap and redundancy—contributed to the inflated coefficient of determination.

Vickery (1991) also pointed out potential problems in the theoretical treatment of production competence given by Cleveland et al. (1989). First, it was observed that manufacturing strategic decision outputs (e.g., facilities, technology, policies, etc.) could not adequately be captured and operationalized by the four-category production process definition. Second, Vickery observed that the CSA model failed to relate production competence to the formulation and implementation of manufacturing strategy.

To overcome perceived deficiencies in the CSA model, Vickery presented a conceptual framework "based on the premise that manufacturing strategy is developed in the context of and concomitantly with a firm's business strategy..." (1991, p. 639) (see Figure 1.2). This model accounts for strategic manufacturing decision-making and portrays production competence as a "snapshot" of manufacturing's performance with respect to identified competitive priorities. The Vickery model draws on the work of Schroeder and Lahr (1990) and is similar to basic strategic planning models one observes in organization strategy literature.

In the model proposed by Vickery, business strategic objectives are communicated to manufacturing through the identification and weighting of competitive priorities (e.g., quality, cost, delivery, and flexibility). To achieve success in the competitive dimensions, decisions concerning strategic manufacturing areas (i.e., facilities, technology, quality management, etc.) are made. Next, manufacturing strategies and programs are implemented to support the strategic decisions. Finally, manufacturing performance on the competitive dimensions is measured. Production competence is a function of the level of manufacturing support provided to competitive priorities.

Vickery, Droge, and Markland (1993) empirically investigated the relationship between production competence and business performance. Adapting the earlier Vickery model, they defined production competence as: "The degree to which manufacturing performance supports the firm's business strategy" (Vickery, Droge, and Markland, 1993, p. 436). The authors developed an improved method for calculating production competence scores that included three factors: (1) a comprehensive assessment of what is important to a firm's strategic profile, (2) manufacturing's responsibility for the areas identified in the strategic profile, expressed as a percentage, and (3) firm performance measures.

After an exhaustive review of the operations, marketing, innovation, organization theory, and strategy/policy literature, 31 competitive priorities were identified as "competitive abilities a firm was seeking to acquire, sustain, or improve on, with a goal of differentiating itself relative to competitors and/or lowering costs" (Vickery, et al., 1993, p. 437). The competitive priorities are listed in Table 2.1.

Respondents were asked to rate, for each of the 31 priorities, the strategic importance of each priority on a seven-point Likert scale (1 = least important, 7 = most important), the percentage of

Table 2.1: 31 Competitive Priorities (from Vickery, et al., 1993)

Product Flexibility (Customization)	The ability to handle difficult, nonstandard orders, to meet special customer specifications and to produce products characterized by numerous features, options, sizes and/or colors.
Volume Flexibility	The ability to rapidly adjust capacity so as to accelerate or decelerate production in response to changes in customer demand.
Process Flexibility	The ability to produce low quantities of product cost efficiently so that product mix changes are easily accommodated.
Low Production Cost	The ability to minimize the total cost of production (inclusive of labor, materials, and operating costs) through efficient operations, process technology and/or scale economies.
New Product Introduction	The ability to rapidly introduce large numbers of product improvements/variations or completely new products.
Delivery Speed	The ability to reduce the time between order taking and customer delivery to as close to zero as possible.
Delivery Dependability	The ability to exactly meet quoted or anticipated delivery dates and quantities.
Production Lead Time	The ability to reduce the time it takes to manufacture products.
Product Reliability	The ability to maximize the time to product failure or malfunction.
Product Durability	The ability to maximize the time to product replacement.
Quality (Conformance to Specifications)	The ability to manufacture a product whose operating characteristics meet established performance standards.
Design Quality (Design Innovation)	The ability to provide a product with capabilities, features, styling, and/or operating characteristics that are either superior to those of competing products or unavailable with competing products.
Product Development Cycle Time	The ability to minimize the time it takes to develop new products.
Product Technological Innovation	The ability to engage in new product development involving major advances in product technology.
Product Improvement/ Refinement	The ability to further develop and refine existing products.
New Product Development	The ability to develop new products for existing markets.
Original Product Development	The ability to develop original (i.e., "new-to-the-world") products that create entirely new markets.

Table 2.1 (cont'd).

Brand Image	The ability to create a positive or favorable image in the customer's mind when he/she hears the product's brand name.
Competitive Pricing	The ability to offer a lower product price than direct competitors.
Low Price	The ability to offer one of the lowest or the lowest available product price.
Advertising and Promotion	The ability to create effective advertising and/or promotional campaigns.
Target Market(s) Identification and Selection	The ability to identify promising target markets and select the best ones for consideration.
Responsiveness to Target Market(s)	The ability to respond to the needs and wants of the firm's target market(s).
Pre-Sale Customer Service	The ability to service the customer during the purchase decision process (i.e. before the customer buys the product).
Post-Sale Customer Service	The ability to service the customer after the sale of the product to ensure continuing customer satisfaction.
Broad Product Line	The ability to provide a comprehensive set of related items within a given product line offering.
Widespread Distribution Coverage	The ability to effectively provide widespread and/or intensive distribution coverage.
Low Cost Distribution	The ability to minimize the total cost of distribution.
Selective Distribution Coverage	The ability to effectively target selective or exclusive distribution outlets.
Personal Selling Proficiency	The ability to successfully move products through personal selling activities.
Company Reputation	The ability to create a positive or favorable image in the customer's mind when he/she hears the company's name.

responsibility accorded to manufacturing, and their firm's performance relative to their competitors, again on a seven-point scale (1 = poor, 7 = excellent). Eventually, this scale was transformed (-3 = poor, +3 = excellent) to give credit for superior performance and subtract credit for inferior performance. The production competence score for each firm was calculated by summing the product of [importance • performance • % manufacturing responsibility] across the 31 priorities.

The study consisted of 65 firms in the furniture industry. The CEO of each firm received and answered the questionnaire. As discussed previously, the results indicated a significant positive relationship between production competence and firm performance. This work validated the earlier research of Cleveland, et. al. (1989) and Vickery (1991), and encourages additional research into the competence construct.

The authors also investigated the impact of the business strategy on performance, as well as its interaction with competence. For a Differentiation strategy, the interaction of between strategy and production competence was also significantly related to performance, indicating a need for manufacturing support beyond cost reduction.

Interestingly, this result corroborates and magnifies the research need previously identified by Skinner, in which he states that "research and conceptual development of concrete, explicit bridges between task and structural decisions" is *the* primary need in the field (1992, p. 25). Specifically, there are several ways that a firm can differentiate itself from competitors, including design, quality, brand image, technology, features, service, distribution, delivery speed, and others (Porter, 1980; Stalk and Hout, 1990). If the interaction of production competence and a Differentiation strategy can affect firm performance, then the importance of successfully executing the manufacturing task is dramatically increased.

The manufacturing task describes the competitive areas of the business strategy that manufacturing must support. Since there is a wide variety of business strategies (e.g., differentiation), there will be many variants of the manufacturing task. What is needed is guidance on the relationship between the manufacturing task, structural decision making, and manufacturing strategies, programs, and techniques. The study being proposed is an attempt to build a theory to describe these relationships.

Programs and Techniques

Schroeder and Lahr (1990) observe that manufacturing *programs* are developed to link strategies and tactics, and that programs themselves are developed to implement strategies. They point out the differences between the *objectives* of a firm, which refer to performance areas such as quality, service, etc. (manufacturing priorities) and the *strategies* developed by a firm, which refer to *how* to achieve the objectives. Strategy development can occur in topic areas such as make or buy, process technology, quality assurance, suppliers, just-in-time, service response, etc.

Implementation, as discussed by Schroeder and Lahr (1990), involves the application of manufacturing programs and techniques to assist in the achievement of business and manufacturing goals. It is at this juncture that content and process models of manufacturing strategy come together. The programs and techniques used to implement strategies (i.e., strategy content), embody the outcome of the process of formulating manufacturing strategies. For example, the choices made regarding the strategic variables of process models developed by Sharma (1987) and Vickery (1991) are evident in the strategies and programs implemented. It is clear from the Vickery (1991) model of production competence that the selection and implementation of manufacturing strategies and programs determine whether performance targets are met and, therefore, the level of competence that a firm can achieve.

As mentioned earlier, Skinner (1992a) has reported this—the identification of the strategies and techniques firms should implement to achieve specific business objectives—to be a critical need in OM research. In this area, the Manufacturing Futures Project (MFP) research and the Manufacturing Roundtable at Boston University have been instrumental. For each year since 1982, the team surveys companies in North America, Europe, and Japan and gathers data regarding the level of emphasis—both current and two years hence—placed by the firms on particular manufacturing techniques and programs (Roth and Miller, 1990). Over time, the Futures team has generated a list of 39 techniques, called "action programs", which they present to respondent firms for evaluation (Ferdows and DeMeyer, 1990).

Results of this research stream suggest that many of the 39 action programs contribute separately to improvements in cost, quality, flexibility and delivery (DeMeyer and Ferdows, 1990; Roth, DeMeyer and Amano, 1989; Ferdows and DeMeyer, 1987). Results of Roth (1987) and Ferdows and DeMeyer (1990) appear in Tables 2.2 and 2.3 respectively. Analysis of these two tables indicates that there is not much agreement regarding the competitive priority best served by each action plan. For example, Value Analysis is negatively related to quality and delivery response in Roth (1987) and positively related to quality, speed, and cost in Ferdows and De Meyer (1990).

Several other books and articles relating to the use of manufacturing programs and techniques have been written, both with and without reference to competitive priorities. Beyond the competitive priority framework, discussion and analyses of techniques have used linking mechanisms such as productivity (Schmenner, 1982; Harmon and Peterson, 1990), Just-in-Time (Gilbert, 1990; Chan, Samson and Sohal, 1990) and management barriers (Oakland and Sohal, 1987) to further study in the area. A list of authors and the competitive priority(ies) included in their articles is in Table 2.4.

The most recent efforts of the MFP team have centered around the relationship between action plans and competitive priorities. Applying principal components analysis (PCA) to a larger set of competitive priorities resulted in the emergence of four main priorities—flexibility, quality, delivery and cost efficiency (Roth, 1987; Roth, De Meyer and Amano, 1989). To determine usable sets of competitive techniques and programs, Roth (1987) applied PCA to the 39 action programs resulting in 11 categories. To maintain

Table 2.2: Competitive Priorities and Action Plans

Key action programs	Low Price	Flexibility: Product, Volume	Quality: Conformance, Performance	Delivery: Reliability, Speed
Broader Jobs	**	**		
Worker Planning		**		
Labor/Mgt. Relationships	**		--	
DL Motivation	**			**
Reorganization				
Safety Programs				
QC		**	**	
Automation		**		
Supervisor Training		**		
Maintenance				
Zero Defects		**	**	
Production & Inventory Control				
Reduce Lead Time		**		
Purchasing Mgt.		**		
Vendor Quality		**		
CAM		**		--
CAD		**	**	
Reduce Set-up		**		
Value Analysis		**	--	--
Group Technology		**	--	**
Reduce Workforce	**		--	
Expansion		**		
Reduce # of mfg. units		**		
Relocation				
New processes/Old products		--		
New processes/New Products		**	**	
Standardizing			--	
Strategic Planning		**	**	
Mfg. Info. Sys.		**		
Lateral info. sys.		**		
Reconditioning		**		
Robots			**	**
FMS		**	--	**
Closing plants	**		--	
Process SPC	**	**	**	
Product SPC		**	**	

NOTE: (**) indicates positive relationship; (--) indicates negative relationship (adapted from Roth, 1987)

Table 2.3: Relationships Between Action Plans and Priorities

ACTION PLAN	Qual.	Cost	Inv. Turn-over	Prod. Dev. Speed	On Time Deliv.	Deliv. Speed	Over-head Cost	Batch Sizes
Broader task range								
More worker planning resp.	**	00			**			
Changing labor/mgt. relations								
Worker training								
Mfg. reorganization						00		
Worker safety								
Quality circles	**							
Direct labor automation							**	
Mgt. training								
Supervisory training								
Preventive maintenance								
Zero defects	**		**	**	**			
PIC system								
Vendor lead time reduction								
JIT			**					**
Vendor quality	**			**				
CAM								
CAD								
Reduce setup times								**
Value analysis	**			**			**	
Group technology	**							
Reduce workforce size								
Capacity expansion			00				**	
Reduce size of mfg. units			00	00				
Plant relocation		00	00					
New processes/old products		**						
New processes/new products				**				
Narrowing product lines	**		00					
Defining a mfg. strategy							**	
Integrating mfg. info. sys.				**				
Lateral information systems			00			00		
Reconditioning plants	**							
Introducing robots								
FMS	**							
Closing plants								**
SPC of process	**	**						
Mfg. lead time reduction								**
New prod. intro. capability				**				
SQC of products								

**: Indicates Action Plan being emphasized by best performers
00: Indicates Action Plan being emphasized by worst performers

Source: (Ferdows and De Meyer, 1990)

Table 2.4: List of Authors and Competitive Priority Focus

AUTHOR(S), DATE	Qual.	Flex.	Deliv.	Cost	Other
Schonberger, 1982	X	X			
Harmon & Peterson, 1987	X	X	X	X	Productivity
Abegglen & Stalk, 1985		X			
Shingo, 1987	X	X		X	
Oakland & Sohal, 1987	X		X		Service
White & Flores, 1987	X			X	Productivity
De Toni, Caputo & Vinelli, 1988				X	
Gilbert, 1990	X	X	X	X	JIT
Chan, et al., 1990	X	X		X	JIT
Voss & Robinson, 1987					JIT
Im & Lee, 1989	X		X	X	JIT
Stalk, 1988			X		
Stalk & Hout, 1990			X		
Schlie & Goldhar, 1989				X	
Schmenner, 1988				X	
Hopp, Spearman & Woodruff, 1990				X	
Bower & Hout, 1988			X	X	
Ruch, 1990				X	
Blackburn, 1990a, 1990b, 1990c				X	
Robbins, 1989				X	
Gerwin, 1987		X			
Gerwin & Tarondeau, 1989		X			
DeMeyer, Nakane, Miller & Ferdows, 1989	X	X	X	X	Futures
Slack, 1990		X			
Roth & Miller, 1990	X	X	X	X	Futures
Horte, Lindberg & Tunalv, 1987	X				
Miller, Amano, De Meyer, Ferdows, Nakane & Roth, 1989	X	X	X	X	Futures
Roth, De Meyer & Amano, 1989	X	X	X	X	Futures
De Meyer & Ferdows, 1987, 1990	X	X	X	X	Futures
Ward, Miller & Vollmann, 1988					Futures
Ferdows & De Meyer, 1988, 1990					Futures
Saraph, Benson & Schroeder, 1989	X				
Modarress & Ansari, 1989	X				
Garvin, 1983, 1984a, 1984b	X				
Derrick, Desai & O'Brien, 1989	X				
MAPI, 1991	X				
Ross & Georgoff, 1991	X				
GAO, 1991	X				

consistency with previous work in manufacturing strategy, Hayes and Wheelwright's (1978) traditional ideas of structural and infrastructural variables served as a guide to describe and make sense of the 11 new "components of manufacturing strategy".

Continuing to apply techniques from other disciplines, Roth and Miller (1990) used cluster analysis to segregate high and low performing firms in the 1988 Futures database. High manufacturing performers were termed "superstars" and low performers "weaklings", with the group in between called "middlemen". In this study, the authors were working the constructs of managerial ability and success, as well as overall firm performance, into the model. High overall performing firms were called "winners" and low performers "losers". They discovered that, for the most part, superstars were more likely to be winners and weaklings more likely to be losers. However, there were several cases of weaklings/winners and superstars/losers, indicating that it might be better for firms to be good managers, rather than strong manufacturers.

Principal components analysis of the action programs was also conducted in the Roth and Miller (1990) study with 28 of the 39 programs combining to form seven dimensions of strategy—materials flow/JIT, advanced process technology, capacity upgrade, restructuring, resources improvements, quality programs and information systems. These dimensions were similar to the 11 identified earlier by Roth (1987).

The relationship between action programs and competitive priorities was also studied by Roth, De Meyer and Amano (1989).

After using principal components analysis to identify the four major competitive priorities (flexibility, quality, delivery and cost efficiency), these priorities were regressed onto the 39 action programs to evaluate the relationships between priorities and action plans.

An emerging discovery of the work by the MFP team indicates that firms may be attacking several competitive priorities simultaneously. Ferdows and De Meyer (1990) investigated the possibility of simultaneous improvements in competitive priority areas, showing some support. They also presented a theory stating that there is a sequence of capability acquisition that begins with quality and ends with cost reduction. This result of simultaneously competing on different priorities is contrary to the trade-off model first proposed by Skinner (1969), in which he stated that manufacturing must focus on a limited set of tasks.

Summarizing the MFP research, the 39 action programs identified form a good starting base for developing a list of important manufacturing techniques. Data analysis techniques new to OM, such as principal components analysis and cluster analysis, were applied with good success. Further evidence of the existence of a limited set of competitive priorities was discovered. Finally, some statistical evidence regarding the presence of simultaneous improvements in priorities was identified.

What Is Good Theory?

Swamidass (1991) asserts that OM researchers are quite adroit at using deductive research methods and have made many worthwhile contributions in doing so. Realizing, however, that OM research must become more empirically oriented, Swamidass states the need to base new research ideas in "empirical theory". Pointing out that the field of OM has some empirical theory of its own (even though we may not know it), he uses the example of waiting line theory (which we do know about) to highlight the steps in evaluating what a good theory is and how one is developed. As an example, Swamidass uses the frameworks developed by Whetten (1989) and Bacharach (1989) to develop the waiting line theory.

Whetten (1989) describes the elements of what a "complete theory" should have. He uses a familiar framework—questions of what, how, and why—to describe a complete theory. The <u>what</u> question asks: "Which factors (variables, constructs, concepts) logically should be considered as part of the explanation of the social or individual phenomena of interest" (Whetten, 1989, p. 490). A complete theory should explain a given phenomenon with a great level of *comprehensiveness*, while simultaneously being as *parsimonious* as possible. The <u>how</u> question seeks to understand how the factors included in the theory are related. Whetten reminds us that these relationships are the "arrows that connect the boxes," which introduce causality into the theory. Taken together, the what and *how* questions describe or define the domain or subject matter of the theory and are combined to "produce the typical model, from which testable propositions can be derived" (Whetten, 1989, p. 491).

The *why* question seeks to identify "the underlying psychological, economic, or social dynamics that justify the selection of factors and the proposed causal relationships" (Whetten, 1989, p.

491). This justification constitutes the assumptions of the theory. These three factors combine to form the essential elements of good theory—description and explanation.

Bacharach describes theory as "a statement of relations among concepts within a set of boundary assumptions and constraints" (1989, p. 496). He gives the following definitions of terms:

> THEORY: A statement of relationships between units *observed* or *approximated* in the empirical world.
>
> OBSERVED units mean *variables*, which are operationalized empirically by measurement.
>
> APPROXIMATED units mean *constructs*, which by their nature cannot be directly observed.

Kerlinger (1986) defines a *variable* as a symbol to which numerals or values can be assigned. He describes a *concept* as an expression of abstraction formed by generalization from particulars (e.g., weight, heavy, light, mass). A *construct* is defined as a concept, with the added meaning of having been deliberately and consciously invented or adopted for scientific purposes. OM constructs can be items such as quality, flexibility, or competence.

Constructs can have a constitutive definition, meaning that the construct is defined in terms of other constructs, or they can have an operational definition, which assigns meaning by specifying the activities or operations necessary to measure it. An operational definition can be one of two types: measured or experimental. A measured operational definition describes how a variable will be measured. An experimental definition spells out the details of the investigator's manipulations (Kerlinger, 1986).

Bacharach (1989) presents a framework and two primary criteria (falsifiability and utility) for evaluating theories. The falsifiability criterion "determines whether a theory is constructed such that empirical refutation is possible" (Bacharach, 1989, p. 501). If it is not refutable, it is not a good theory. The utility criterion "refers to the usefulness of theoretical systems" (Bacharach, 1989, p. 501).

Falsifiability applies at three levels: variables, construct, and relationships. For a theory to be falsifiable, the operationalized *variables* must be valid, noncontinuous, and reliable. *Constructs* must have convergent validity (objects from alternative measurements must share variance) and discriminant validity (objects of analysis must be distinguishable from one another). Finally, the relationships among component constructs and variables must have logical adequacy and empirical adequacy.

Logical adequacy is "the implicit or explicit logic embedded in the hypotheses and propositions which ensures that the hypotheses and propositions are capable of being disconfirmed" (Bacharach, 1989, p. 505). Accordingly, the hypotheses and propositions must be non-tautological and the nature of the relationship between the antecedent and consequent must be specified (i.e., necessary and sufficient). Bacharach states that: "An *empirically adequate* theory is one in which the hypotheses and propositions may be operationalized in such a manner as to render the theory subject to disconfirmation" (Bacharach, 1989, p. 506).

Utility also applies to variables, constructs and relationships. For variables and constructs to have utility, they must be of adequate scope, or "must sufficiently, although parsimoniously, tap the domain of the constructs in question, while the constructs must, in turn, sufficiently, although parsimoniously, tap the domain of the phenomenon in question" (Bacharach, 1989, pp. 506-507). Utility of relationships refers to the ability of the theory to fully explain the phenomenon.

To summarize Bacharach (1989) and Whetton (1989), good theory should—sufficiently and parsimoniously—describe and explain phenomena, while at the same time be constructed so that empirical research can test the relationships. This construction should allow for disconfirmation—that is, the theory should be able to be disproved. Finally, Van de Ven states that: "Good theory is practical precisely because it advances knowledge in a scientific discipline, guides research toward crucial questions, and enlightens the profession of management" (1989, p. 486).

Production Competence as Theory

Swamidass (1991), borrowing from the social and organizational sciences, relates three levels of theories that may exist: general theories, middle-range theories, and empirical generalizations. General theories are at the top of the hierarchy and explain some of the conflicts that may arise in the formation of midrange theories and empirical generalizations. Unprecedented in the field of operations management (OM), he places several OM theories into the three levels and relates the amount of testing of the theories in OM research. General theories include JIT principles and the economic theory of the firm. Midrange theories include waiting lines, the product-process ideas of Hayes and Wheelwright (1979), and focus (Skinner, 1974). Swamidass notes that of the theories presented, only waiting lines and JIT principles have had any amount of study. Production competence, a mid-range theory, had no testing prior to Cleveland, et al. (1989) and Vickery, et al. (1993).

Broadly stated, the theory of production competence (Cleveland, Schroeder and Anderson, 1989) explains that firms with production processes and structures properly matched to business strategy objectives will perform better than those with mismatched processes and structures. Cleveland et al. describe production competence as a continuous variable and as a:

> "...measure of the combined effects of a manufacturer's strengths and weaknesses in certain key performance areas. The degree of process sophistication relative to tools and equipment is the basis for determining strength in any particular area. The business strategy then determines how important it is to be strong in that area" (Cleveland, Schroeder and Anderson, 1989, p. 657).

Before testing Cleveland, Schroeder, and Anderson's (1989) theory of production competence, it should first be evaluated according to the criteria developed by Bacharach (1989) and Whetten (1989). In all fairness to the authors, it should be pointed out that they indeed realized their research to be the very first step in developing a theory of production competence, and in no way state that what they had developed was the definitive answer. In fact, they call for additional development before widespread testing.

For a theory to be classified as a "good" theory, it must have two basic characteristics—it must be falsifiable and it must have utility. The utility of the PC theory stems from the desire of manufacturing practitioners and researchers to contribute to business success. Production competence helps to explain what manufacturing must do and the skills it must possess for a firm to be successful. If American firms become more successful, then the country as a whole will be more successful. As such, it has tremendous utility.

In the CSA model, production competence is, in part, determined by analyzing the strength or weakness of the support provided by manufacturing with respect to the nine critical manufacturing performance areas. The relative importance of the performance areas is subjectively determined by ranking the areas according to their importance to the business strategy of the firm. The business strategy is determined by classifying the firm according to Porter's (1980) model. The strength of the support provided by manufacturing is determined by first categorizing the production process in place as either a job shop, batch, connected line flow or continuous flow process. Once categorized, the relative strength provided by the process to each of the nine performance areas is subjectively evaluated and then assigning a numerical value (+1 if strong support, 0 if neutral, -1 if weak support).

Determining the level of support provided by manufacturing using the production process in place, especially with broad categories (four), limits the usefulness and explanatory power of the theory by not "establishing the substantive meaning of the constructs and variables" (Bacharach, 1989, p. 501). Categorizing the type of production processes is extremely difficult for two reasons. First, most firms use hybrid systems, which are by definition a combination of more than one process type. Second, there are tremendous differences between processes, even those that are classified into the same categories. Thus, the substantive meaning of the strength provided by manufacturing to a particular performance area is difficult to ascertain.

Falsifiability refers to the ability of a theory to be empirically refuted. In the CSA model, performance scores were determined using some of the same measures used to in the construction of the competence measure. This oversight makes it unlikely that competence can ever be refuted. Due to the nature of the measures, competence and performance will almost always be positively related. This severely limits the usefulness of production competence—as characterized by Cleveland, et al.—as a theory.

As mentioned earlier, these errors were identified and corrected by Vickery (1991). In this new method of measuring competence, the performance within specific competitive dimensions is directly ascertained, thereby removing inconsistencies. Second, performance of a firm is described only through measures not included in the competence construct, namely financial indicators. Finally, the scale regarding performance on particular competitive priorities was increased to better capture differences.

This new way of characterizing production competence should also be evaluated using the method described by Whetten (1989), which seeks to determine whether or not a theory is "complete". First, Whetten asks *what* factors are involved in the theory, seeking to be as comprehensive and parsimonious as possible. Included as variables in the Vickery, Droge, and Markland (1993) model are the importance of competitive priorities to the business strategy of a firm, the performance of the firm in regards to the priorities, and manufacturing's responsibility for each priority, expressed as a percentage. Using 31 competitive priorities in the model helps to ensure comprehensiveness. The authors state that completeness and parsimony were the objectives in selecting the 31 priorities.

One of the major tenets of manufacturing strategy is that firms providing the best manufacturing support to the business strategy should outperform those firms receiving less support. Production competence is a construct designed to evaluate the degree of support provided. This addresses Whetten's second question, which seeks to determine the relationships in the model or *how* the factors are related. In the model of production competence, more support is theorized to be better. For example, firms differentiating (or winning orders) based on conformance quality must have processes in place to control for quality. Firms that have process control systems in place will provide more support to this priority and, therefore, the firm should perform well in its market.

Whetten's third question relates to the justification for including the various factors in the model. Building on the work of Sharma (1987) and Roth (1987), using competitive priorities to describe the business in manufacturing terms has proven to be extremely valid. The stream of research conducted on the use of "action plans" and strategies by the Manufacturing Futures Team has also provided grounded impetus to include this type of construct in models.

The process model of manufacturing strategy proposed by Vickery (1991) is used to present the production competence construct. This model fails, however, to adequately capture the "how" question asked by Whetten, which is concerned with how the various factors are related, or, in the words of Whetten: "involves using arrows to connect the boxes" (1989, p. 491). In the Vickery model, production competence is determined by the relationship between (1) the importance of a set of priorities to the business strategy, and (2) the performance of the manufacturing function with respect to the support provided the priorities. What is missing from the model is *how* that performance is brought about.

Cleveland et al. (1989) substituted the production process of a firm as a proxy for strategic actions taken by a firm. Vickery uses a straight measure of performance to capture this variable. In both paradigms, the question remains—to add explanatory power to the theory—as to just how performance in a particular competitive priority is attained?

What is being proposed in this research is to determine the specific manufacturing strategies, programs, and techniques applied by firms to be competitive or to achieve high performance levels within particular competitive dimensions. For example, the production competence theory will be expanded with the ability to explain how firms become successful in specific competitive priorities. This necessitates understanding which manufacturing strategies and programs are used by firms successfully competing along the dimensions of cost, quality, flexibility, or delivery/time.

This is precisely what this research will attempt to discover, thereby adding explanatory power to the theory of production competence.

Ward, Miller and Vollmann (1990) have criticized OM researchers for failing to build on the work of previous studies. They observe that to facilitate faster theory development and testing, building and improving upon the work of others has been used repeatedly in disciplines such as marketing and organizational behavior. The study being proposed here builds on the Cleveland et al. (1989) and Vickery (1991) models, the work of Vickery, Droge, and Markland (1993), as well as that of the Manufacturing Futures Project. It is hoped that this study will facilitate the acceptance and "completion" of the production competence theory.

III. RESEARCH METHODOLOGY

This chapter will describe an extended model of production competence, discuss data collection issues, present specific testable hypotheses based on the models, and discuss the methodologies and techniques that will be used to test the hypotheses.

Overview

The central tenet of manufacturing strategy is that proper strategic alignment of the manufacturing function and operations capabilities with the objectives of the business strategy can significantly affect firm performance and competitive position (Fine and Hax, 1985; Anderson, Cleveland and Schroeder, 1989).

Anderson, et al. (1989) noted that this tenet, while prevalent in the literature, had only recently been tested. Swamidass and Newell's (1987) study was one of the first to analyze the relationship between manufacturing strategy variables (flexibility and manufacturing managers' role in decision making) and firm performance, finding that increased flexibility was related to improved performance. Roth and Miller (1990) presented results showing that business performance was greatest in firms that were strong in both manufacturing and in managerial capability. Tunalv (1992) observed that firms with a formulated manufacturing strategy significantly outperformed firms that did not have such a strategy.

To further study the relationship between firm performance and manufacturing strategy, the construct of production competence was introduced (Cleveland, Schroeder, and Anderson, 1989). Production competence relates to the level and appropriateness of the support being provided by manufacturing to the business strategy of a firm. Cleveland, et al. (1989) presented results showing a strong relationship between production competence and performance. Vickery, Droge, and Markland (1993) improved the original production competence construct and tested their model on 65 firms. Their results also indicated a strong positive relationship between production competence and firm performance.

This study will extend the work of others, specifically Vickery, et al. (1993), in the area of production competence by identifying the manufacturing strategies, programs, and techniques firms are using to support the business strategy (i.e., being competent).

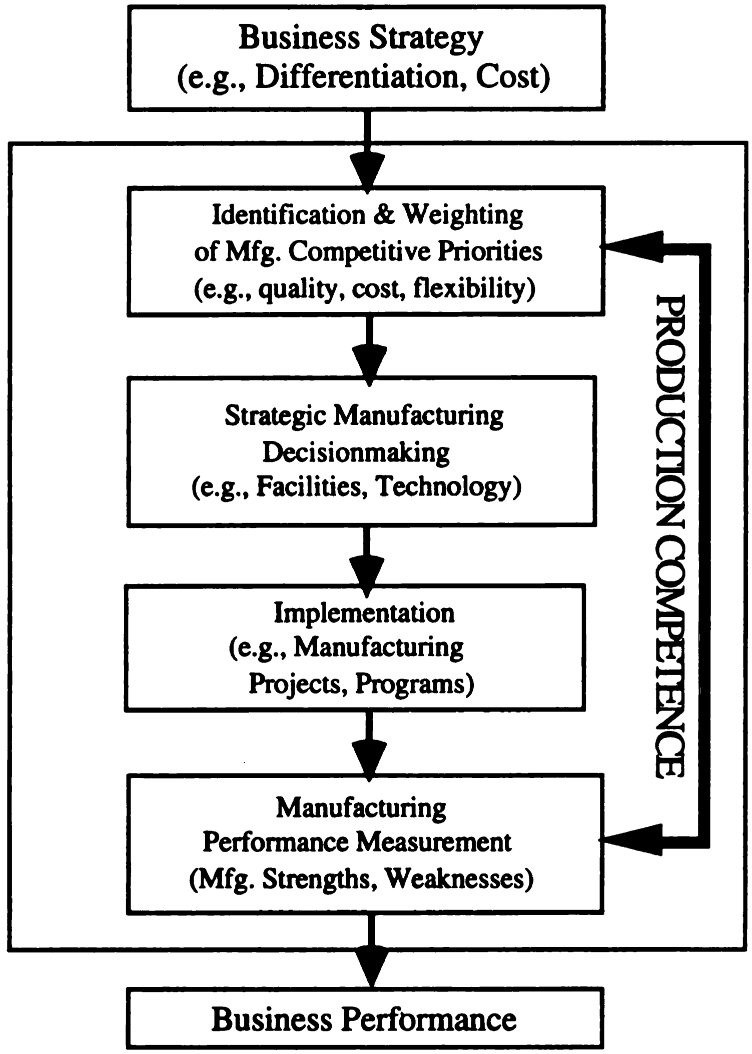
Model Development

The research being proposed is an extension of previous work in the production competence area. Still a very young area of research, most of the work thus far can be called "theory building" as researchers are merely trying to understand the relationships and complexities involved in manufacturing strategy and firm performance (Dubin, 1969). As such, one of the objectives of this research is to further investigate linkages appearing in previous models. This has the added benefit of strengthening previous models by adding to their comprehensiveness (Whetten, 1989) and utility (Bacharach, 1989).

The model of production competence that will be tested in this study was first presented by Vickery (1991) in a response to the research of Cleveland, et al. (1989). Vickery presented a process model of manufacturing strategy (see Figure 3.1) in which the business strategy objectives of a firm are translated into manufacturing objectives through a procedure that assigns weights (based on strategic importance) to manufacturing competitive priorities.

After the weights have been assigned to the competitive priorities, a firm can begin to formulate how the manufacturing function can best support the priorities. Strategic decisions regarding the structural and infrastructural elements of manufacturing must be made such that the deployment of resources is in alignment with the business strategy (Hayes and Wheelwright, 1984; Skinner, 1985). The decision categories included in this framework can include capacity, facilities, technology, vertical integration, workforce, quality, production planning and control, and organizational issues. The next step in the process is to implement the appropriate strategies, programs, and techniques as required by the previous step. Finally, the performance of the manufacturing function—in terms of its ability to support competitive priorities—is measured. Using the performance data and the weighted importance of the competitive priorities, a production competence score can be calculated.

Several researchers have previously studied the appropriateness of using competitive priorities in the manner described above, showing priorities to be a viable method of operationalizing organizational objectives as they relate to manufacturing (Roth, 1987; Sharma, 1987; Wood, Ritzman, and Sharma, 1990;



Source: Adapted from Vickery (1991)

Figure 3.1: A Process Model of Production Competence

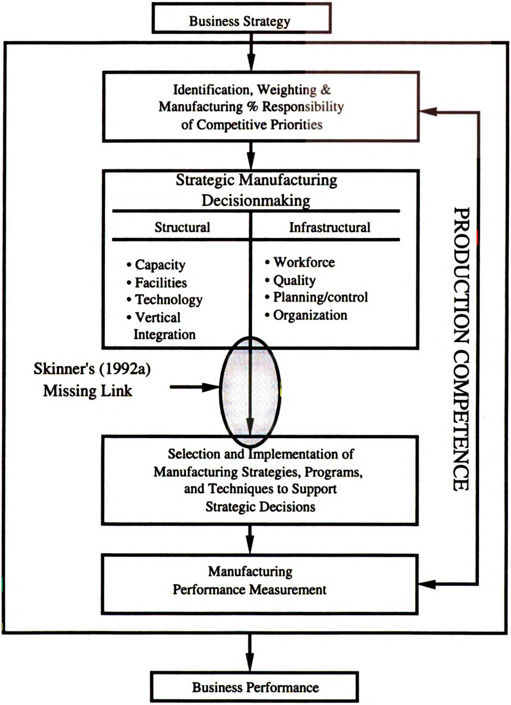
Roth and Miller, 1990; Ferdows and De Meyer, 1990). Many of the studies involving competitive priorities, especially those involved with the Manufacturing Futures Project (MFP), have incorporated the manufacturing techniques and programs firms use to support a particular competitive dimension. Swamidass (1991) noted, however, that the overwhelming majority of this previous research is descriptive in nature and not linked to performance in any way.

Skinner (1992a) has observed that, while validating the relationship between manufacturing strategy and performance, the academic community has not responded very well in terms of providing practitioners with specific mechanisms for improvement. For example, academics have provided decision categories (structural and infrastructural) but have not provided insight as to what decisions to make and how to implement them. Skinner writes:

> "There is no textbook or article that helps managers make these decisions to design the structure to meet the manufacturing task. We say that manufacturing policy decisions must be made such that the system designed meets the manufacturing task. But the manager is left to figure out how to get from task to structure without much specific guidance" (1992, p. 22).

Skinner has reported this to be another "missing link" in OM research—the identification of the strategies and techniques firms should implement to achieve specific business objectives (see Figure 3.2).

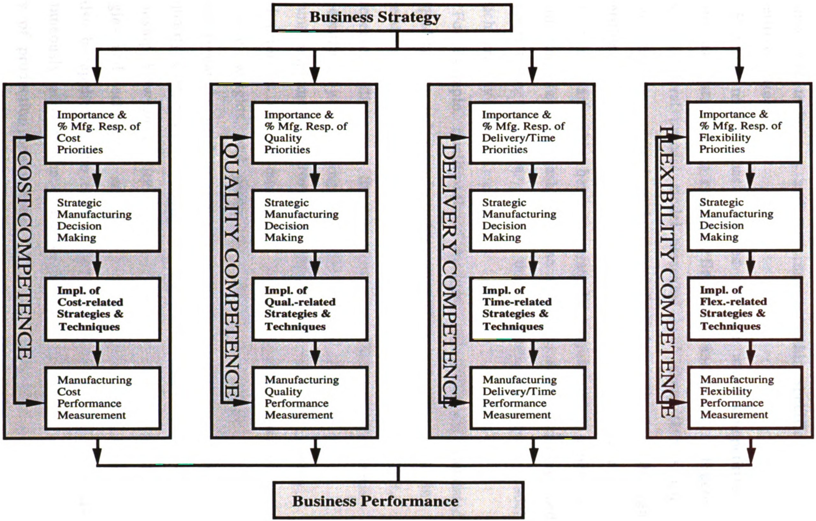
The general model of production competence (Figure 3.1) can be adapted to directly address the issue identified by Skinner (1992a). The adapted model (see Figure 3.3) allows for the analysis



Source: Adapted from Vickery (1991)

Figure 3.2: Production Competence and Skinner's Missing Link

FIGURE 3.3: A Process Model of Competitive Priority Competence



of the relationship between the use of manufacturing strategies, programs, and techniques and performance within specific competitive priorities.

Previous research has identified the four major competitive priorities as cost, delivery response, flexibility, and quality. Figure 3.1 is the general process model presented by Vickery (1991) that translates business objectives into manufacturing objectives through competitive priorities. Figure 3.3 extends this model to better capture the relationship between strategic manufacturing objectives (i.e., the manufacturing task) and the structures and techniques used to support those objectives. It does this by creating a process model for each priority area.

For example, quality-related business objectives are translated into quality oriented manufacturing competitive priorities such as conformance quality and performance/features. Using Figure 3.3, this research will capture the outcomes of the formulation process (i.e., content) by identifying the quality related strategies and programs implemented. Note that performance along the quality related priorities can be measured. The information regarding importance, weights, and performance—within the quality dimension—can be used to construct a "quality competence" score. The quality competence score can be used to evaluate the relationship between quality objectives, the use of quality-related strategies and techniques, and quality performance. This approach can also be applied to the other competitive priorities. This analysis simultaneously adds to the comprehensiveness and utility of the theory of production competence, while also addressing an urgent research need in the field.

In the study by Vickery et al. (1993), the production competence construct strengthened by improving the measurement of business objectives and performance. Strategic objectives were identified using a comprehensive list of 31 competitive priorities. Recognition was also given to the functional coordination necessary to implement business strategy through a weighting of the priorities by function. Production competence was measured by (1) obtaining a strategic profile of the firm (gathering data on the strategic importance of 31 competitive priorities), (2) determining the proportion of each priority for which manufacturing is responsible, and (3) measuring firm performance across each competitive priority. The production competence score is the product of (1), (2), and (3) summed across 31 priorities. This can be expressed in the following equation:

$$PC = \sum_{1}^{31} CP_{imp} \times CP_{perf} \times \%\ \text{mfg resp.} \qquad \text{(Eq. 3.1)}$$

where,

PC = Firm production competence score
CP_{imp} = Competitive priority importance (1 to 7)
CP_{perf} = Competitive priority performance (Adjusted to reflect excellent and poor performance: -3 to +3)
% mfg resp. = percent of priority for which manufacturing is responsible.

As previously discussed, the ability of manufacturing to support the objectives of the business strategy is, in part, determined by the strategies, programs and techniques a firm elects to implement. Therefore, manufacturing support—and production competence—is influenced by the selection and implementation of manufacturing techniques.

Strategies, Techniques and Programs

The manufacturing strategies, techniques and programs that firms implement vary widely depending on the business strategy of the firm, resources available and competitive position. The business strategy of a firm dictates the particular manufacturing techniques and programs implemented. A company following a strategy of low cost will implement a much different bundle of techniques and programs than would a firm using a strategy based on time or service.

The multitude of strategies and programs available to firms has increased the complexity of the decision. Many of these strategies can be expensive and time-consuming to implement, adding pressure to make the correct decision. As Hill (1994) observes, these strategies may be irreversible, or at minimum, take several years to change. Some require tremendous outlays in training, information technology, or manufacturing equipment and often involve multiple functions in the company.

The manufacturing strategies, techniques and programs included in this study were selected after a thorough search of both the practitioner and academic literature. Due to the wide differences in business strategies and available resources, the strategies and techniques included in this study are quite diverse, ranging from very specific techniques such as value analysis to broad programs such as employee involvement.

Most of the research in this area has been conducted by the Manufacturing Futures Project (Ferdows, Miller, Nakane, and Vollmann, 1986; Roth, De Meyer, and Amano, 1989; Ferdows and De Meyer, 1990). All of the strategies identified by that team were included (36 action plans). The Boston University Manufacturing Roundtable performance measurement project (Dixon, Nanni, and Vollmann, 1990) was also a source of strategies and objective performance measures.

Several practitioner-oriented books contributed to the list of manufacturing improvement programs. Books related to cost reduction (Harmon and Peterson, 1987), Japanese manufacturing techniques (Abegglen and Stalk, 1985; Schonberger, 1982; Imai, 1986; Suzaki, 1987), manufacturing strategy (Hayes and Wheelwright, 1984; Skinner, 1985; Hayes, Wheelwright, and Clark, 1988; Hall, 1987; Gunn, 1987), quality (Rogerson, 1986; Juran and Gryna, 1980; Juran, 1988; Walton, 1986), and time (Blackburn, 1990; Stalk and Hout, 1990) were consulted.

Numerous research articles were also used as sources of strategies and techniques (Hopp, Spearman and Woodruff, 1990; Chan, Samson and Sohal, 1990; De Toni, Caputo and Vinelli, 1988; Gerwin and Tarandeau, 1989; Gilbert, 1990; Im and Lee, 1989; Modarress and Ansari, 1989; Oakland and Sohal, 1987; Ross and Georgoff, 1991; Saraph, Benson and Schroeder, 1989; Schlie and Goldhar, 1989; Schmenner, 1982, 1988b; Suzaki, 1985; White and Flores, 1987). Although most of these articles did not relate the use of the strategies to overall performance, they were techniques that the authors considered relevant to competitiveness. Several practitioner-oriented journals were also consulted, including *Quality, Quality Progress, Industry Week, Manufacturing Review, Purchasing,* and *Management Accountant.*

Once the comprehensive set of techniques and programs were identified from the literature, they were shown to academics in operations management and to several furniture manufacturing executives. The majority of the executives indicated that several of the strategies and programs presented to them were not currently used in the furniture industry. Most of these involved computerized manufacturing and planning techniques. Many of these techniques remained in the survey, however, because some of the firms interviewed were using these technologies. The interviews ensured that the strategies and techniques included in the study maintained a high degree of relevance to the field and the furniture industry. The techniques appearing in the questionnaire are presented in Table 3.1. Each technique was defined in a glossary that accompanied the survey

Data Collection

The research being proposed is an extension of research started by Vickery, Droge, and Markland (1993). The firms that participated in their study were drawn from a pool of firms that met two criteria. First, they had to be in one of four Standard Industry Codes (SIC) relevant to the furniture industry: wood office furniture (2521), office furniture other (2522), wood house furniture (2511), and upholstered wood house furniture (2512). Second, each firm had to have at least $10 million in annual sales. Firms that met these criteria were mailed a letter and questionnaire, and received a phone call (or calls) to secure participation. Their sample consisted of 65 firms in the furniture industry, which represented about 20% of the total number of questionnaires mailed. The respondents to their survey were mainly chief executive officers, with an occasional respondent from the Vice-president or Director level.

Using information regarding competitive priority importance, competitive priority performance, percentage manufacturing responsibility, and firm performance, a production competence score was calculated for each firm using Equation 3.1. The production competence scores for each firm become inputs to the analysis in this study.

This research extends the work of Vickery et al. by addressing the decisions and actions of the manufacturing function within the firms studied. Each of the 65 firms that participated in the earlier study provided the name, address and title of the individual responsible for the manufacturing function. This individual received a questionnaire designed to obtain information regarding the use of the manufacturing strategies, programs, and techniques appearing in Table 3.1—a critical component of the models presented in Figures 3.1 and 3.3 and directly related to the research need identified by Skinner (1992a), portrayed in Figure 3.2.

The questionnaire mailed to the manufacturing personnel was validated through a process that included conversations with academics in the operations management field and personal

Table 3.1: Manufacturing SPTs Appearing in Questionnaire

Matl. Requirements Planning (MRP)	Mfg. Resource Planning (MRPII)
Capacity Requirements Planning (CRP)	Just-In-Time (JIT)
Automation	Total Quality Control (TQC)
Training For Executives and Managers	Training For Workers
Zero Defects	Design For Manufacturability
Group Technology	Cellular Manufacturing
Backward Integration	Forward Integration
Capital Investment	Computer Integrated Manufacturing
Functional Integration	Goalsetting
Activity-Based Costing	ABC Analysis
Worker Motivation	Gainsharing
Quality Of Work Life Initiatives	Product-Focused Factory
Process-Focused Factory	Variety Reduction
Reduce Engineering Change Orders	Simplified Material Flow
Product Simplification	Computer-Aided Design (CAD)
Synchronous Manufacturing	General Purpose Equipment
Dedicated Equipment	Large Batch Production
Cross-Training Workers	Employee Suggestions
Reduction In Throughput Times	Quality Circles
Product Standardization	Vertical Job Enlargement
Reduction In Raw Materials Inventory	Reduction In WIP Inventory
Reduction In Finished Goods Inventory	Purchase In Large Quantities
Supplier Selection Based On Quality	Supplier Selection Based On Price
Advanced Forecasting	Work Measurement
Value Analysis	Reducing Setup Times
Preventive Maintenance	Failsafing Or Foolproofing
Lot Splitting	Electronic Data Interchange (EDI)
Worker Specialization	Quality Function Deployment (QFD)
Total Productive Maintenance (TPM)	Mean and Range Control Charts
Advanced Statistical Techniques	Use of Seven Basic Qual. Improvement Tools
Inspection Of Incoming Materials	Inspection Of In-Process Work
Inspection Of Finished Goods	100% Inspection
Acceptance Sampling	Workplace Orderliness
Quality Audit	Product Reliability Testing
Measuring Product Reliability	Avail. Of Qual. Related Data To Managers
Avail. Of Cost Of Qual. Data To Managers	Avail. Of Qual. Related Data To Workers
Benchmarking	Employee Involvement
Employees Responsible For Quality	Timely Feedback Of Quality Data
Employee Recognition	Visible Performance Charts

Table 3.1 (cont'd).

Adoption Of Quality Standards	Emphasis On "Doing It Right The First Time"
Coordination Among Depts. In Prod. Design	Supplier Certification
Training Provided To Suppliers	Reliance On Fewer Suppliers
Involve Suppliers In Product Design	Separate Mfg. Lead Time Into Components
Common Manufacturing Database	Concurrent Engineering
Advanced Manufacturing Technology	Mixed-Model Production Scheduling
Line Balancing	Automated Monitoring Devices
Maintain Excess Equipment Capacity	Reducing Size of Work Force
Self-Directed Work Teams	Subcontracting
Programmable Technology	Flexible Manufacturing System (FMS)
Cross-Functional Teams	Worker Safety
Product Teams	Proprietary Technology
Produce Same Part on Same Machine	Color Coding of Parts and Machines

interviews with furniture industry manufacturing managers. The academics provided feedback regarding the survey design and the strategies and programs that were included (see Table 3.1). Three personal interviews with manufacturing managers from respondent firms were completed, which resulted in the removal of a limited number of techniques from the list. Other minor changes were made regarding wording and survey layout. A glossary of terms was also included with each questionnaire, so that respondents would be clear on the meaning of each strategy, program and technique. The survey instrument and glossary are included in Appendix 1.

Each respondent was asked to rate the "extent of use" of each of the manufacturing strategies, programs, and techniques appearing in Table 3.1. Extent of use was measured on a seven-point Likert scale with (1) indicating low use and (7) indicating high use. As in the Vickery, et al. study, all data pertain to 1990. Questions regarding the level of integration between functional managers, also using a seven-point Likert scale, were included. Finally, respondents were also asked to provide data pertaining to objective performance measures in the areas of quality, delivery response, flexibility and cost.

Hypotheses Development

1. Production competence

To investigate the relationship between manufacturing support and firm performance, the theory of production competence was proposed (Cleveland, et al., 1989). Vickery (1991) presented a model of production competence in the context of a process model of manufacturing strategy. This model indicated that manufacturing performance was influenced by the selection and implementation of manufacturing programs and techniques. Vickery, et al. (1993) revised the original theory and measurement of the construct and identified a positive relationship between firm performance and production competence.

This research extends the previous work of Vickery (1991) and Vickery, et al. (1993) by investigating the relationship between manufacturing strategies, programs, and techniques and production competence. Ultimately, it seeks to identify if there exists a set of techniques and programs that is common to those firms experiencing the greatest success in supporting their business strategy (i.e., most competent). This research objective is aligned with the objectives of theory building, in that the research seeks to describe the behavior of the variables and constructs in the model and not to predict behavior. This objective can be expressed in the following hypothesis:

> **Hypothesis 1: There is a positive relationship between the extent of use of individual manufacturing strategies, programs and techniques (SPTs), and production competence .**
>
> For each of the strategies, programs and techniques appearing in Table 3.1, regress the production competence score onto the extent of use (EOU) score of the SPT.
>
> $Y = \beta_0 + \beta_1 X_1$
>
> where: Y = production competence score,
> and X_1 = extent of use of SPT.
>
> Perform a t-test to see if β_1 is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1 is positive and different from zero, we can claim that there might exist a positive relationship between production competence and the use of the particular strategy, program, or technique.

This analysis will result in a bundle of manufacturing strategies, programs, and techniques that are associated with production competence. Since, in this case, competence is a general term and not related to any particular competitive priority, the strategies and programs identified could serve as a base for companies upon which to develop differentiated strategies.

2. Competitive priority competence

The production competence score for a firm is comprised of three elements—the importance of the competitive priorities to the business strategy, manufacturing's responsibility for a particular priority (expressed as a percentage), and the performance of manufacturing in that area. The mathematical formula is listed in Equation 3.1. In Vickery, et al. (1993), production competence was determined by applying this formula across 31 different competitive priorities. The result is an overall production competence score for a firm's manufacturing function. Analysis at this level does not, however, reveal any relationships between the firm's manufacturing task and the strategies and programs implemented to achieve strategic objectives.

Just as a competence score can be calculated for the entire manufacturing function, a competence score can also be constructed for each broad competitive priority (i.e., quality, cost, delivery, and flexibility). This analysis would directly address the research need expressed by Skinner (1992a), in which he calls for academics to provide guidance for the structural and infrastructural decisions practitioners must make. Figure 3.3 indicates how this refinement expands Vickery's (1991) original model.

The next set of hypotheses addresses the relationship between each strategy, program, and technique and the four major competitive priorities. One method to group the 31 sub-priorities into major priorities would be to factor analyze them. This analysis would result in statistically different groups being created. One requirement for the use of factor analysis is a fairly large sample size, one that has about 10 responses per sub-factor (Nunnally, 1978). The sample sizes to be used in this study are too small to support the use of factor analysis.

In the absence of a factor analysis, a combination of methods was used. First, a literature-based analysis was conducted. Previous studies involving competitive priorities have been synthesized in Table 3.2. In this table, the stars indicate that the sub-priority has been linked to the main priority by the author(s). Second, in collecting the data for the production competence score, firms were asked to assign responsibility, expressed as a percentage, to manufacturing. When manufacturing's share was at least 25%, the priority was assigned to a manufacturing-related priority. For example, the literature suggests that responsiveness to target markets is the responsibility of the marketing function. Respondents assigned an average of 27% to the manufacturing function. That priority was moved from the marketing group to the flexibility group. Likewise, several of the quality priorities moved to marketing (image, customer service).

Using the data in Table 3.2 and early survey results, Table 3.3 displays the manner in which the 31 competitive priorities are to be arranged to generate competence and performance scores for the four major priority areas.

An example of how to determine a competence score for a competitive priority follows. Using Table 3.3, the delivery-response competence score would be calculated by summing the product of (importance)•(% manufacturing responsibility)•(performance) across the three delivery-related competitive sub-priorities: delivery speed, delivery dependability, and production lead time. As in Vickery, et al. (1993), the peformance scores will be adjusted from a 1 to 7 scale to a -3 to +3 scale.

TABLE 3.2: Previous Studies Involving Competitive Priorities

NOTE: "M" indicates link to Market priority, "F" indicates link to Flexibility.

Competitive Priority	Sub-Priority	Krajewski and Ritzman (1993)	Roth, De Meyer, and Amano (1989)	Zeithaml, Parasuraman, and Berry (1990)	Tunalv (1992)	Roth and Miller (1989)	Huete and Roth (1987)	Hayes and Wheelwright (1984)	Wallace (1992)	Saik and Hout (1990)	Kleindorfer and Partovi (1990)	Fine and Hax (1985)	Ward, Leong, and Snyder (1990)	Wood, Ritzman, and Sharma (1990)	Gopal and Cahill (1992)
Flexibility	Product Flexibility	*	*					*		*	*	*	*		*
	Volume Flexibility	*	*			*	*	*	*	*	*	*	*		*
	Process Flexibility								*	*	*	*	*		
	Broad Product Line					M			*						
	New Product Introduction				*	*	*	*			*				
Cost	Low Production Cost	*						*		*	*		*	*	
	Competitive Pricing								*						
	Low Price		*		*	*	*	*	*					*	
	Low Cost Distribution														*
Delivery	Delivery Speed	*	*			*	*		F	*		*	*	*	*
Response	Delivery Dependability	*	*		*	*	*	*	*	*	*	*	*	*	*
	Production Lead Time								F	*					*
	Product Dev't. Cycle Time	*				F				*					
Quality	Product Reliability		*	*		*		*	*		*	*		*	*
	Product Durability		*			*		*			*			*	
	Quality (Conformance)	*	*		*	*		*	*		*	*	*	*	
	Design Quality	*				*		*	*		*			*	*
	Pre-Sale Cust. Service		*	*											
	Post-Sale Cust. Service		*	*		M					*				*
	Brand Image										*				
Marketing &	Advertising and Promo.					*									
Distribution	Target Market(s) Ident.														
	and Selection														
	Respons. to Target Mkt(s)														
	Widespread Dist. Coverage					*									
	Selective Dist. Coverage														
	Pers. Selling Proficiency														
	Company Reputation														
Design	Original Product Dev't.														
	Product Tech'l. Innov.														
	Product Improvement														
	New Product Development						F			F					

Table 3.3: 31 Competitive Priorities Categorized into Priority Groups

FLEXIBILITY
Product Flexibility (Customization)
Volume Flexibility
Process Flexibility
Broad Product Line
Responsiveness to Target Market(s)
Product Development Cycle Time

QUALITY
Product Reliability
Product Durability
Quality (Conformance)
Design Quality
Product Improvement/Refinement

MARKETING/DISTRIBUTION
Brand Image
Pre-Sale Customer Service
Post-Sale Customer Service
Advertising and Promotion
Target Market(s) Identification and Selection
Low Cost Distribution
Widespread Distribution Coverage
Selective Distribution Coverage
Personal Selling Proficiency
Company Reputation

DELIVERY RESPONSE
Delivery Speed
Delivery Dependability
Production Lead Time

COST
Low Production Cost
Competitive Pricing
Low Price

DESIGN
Original Product Development
Product Technological Innovation
New Product Development
New Product Introduction

Characterizing competence in this manner raises the following research hypotheses:

Hypothesis 2a-2d: There is a positive relationship between the use of individual manufacturing strategies, programs and techniques, and (a) cost competence, (b) delivery competence, (c) flexibility competence, and (d) quality competence.

For each of the strategies, programs and techniques appearing in Table 3.1, regress the competitive priority competence score onto the extent of use (EOU) score of the technique.

Model: $Y = \beta_0 + \beta_1 X_1$

where: Y = competitive priority competence (e.g., cost),
and X_1 = extent of use of technique.

Perform a t-test to see if β_1 is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1 is positive and different from zero, we can claim that there might exist a positive relationship between competitive priority competence and the use of the particular strategy, program, or technique.

3. Competitive priority performance

In addition to analyzing the relationship between the competence of a firm and the use of manufacturing strategies, programs, and techniques, investigating the relationship between the use of manufacturing techniques and performance would also be useful.

Using the arrangement of priorities in Table 3.2, the subjective performance in each priority/competence area (e.g., quality competence) is determined by taking an average of the performance scores for the priorities listed in each category.

The following hypotheses test for relationships between subjective firm performance within each main priority/competence area and the use of manufacturing strategies, programs, and techniques:

> **Hypothesis 3a-3d: There is a positive relationship between the use of manufacturing strategies, programs, and techniques (SPTs) and the performance component of (a) cost competence, (b) delivery competence, (c) flexibility competence, and (d) quality competence.**
>
> For each of the strategies, programs, and techniques appearing in Table 3.1, regress the subjective performance component of competitive priority competence (see above and Table 3.2 for calculation) onto the extent of use score of the techniques.
>
> Model: $Y = \beta_0 + \beta_1 X_1$
>
> where: Y = performance component of competitive priority competence,
> and X_1 = extent of use of SPT.
>
> Perform a t-test to see if β_1 is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1 is positive and different from zero, we can claim that there might exist a positive relationship between competitive priority performance and the use of the particular strategy, program, or technique.

4. <u>Overall firm performance</u>

Researchers in business strategy often study the relationship between the use of strategies and firm overall performance (Hitt and

Ireland, 1985; Snow and Hrebiniak, 1980). The performance measures used in these studies are usually global measures such as stock price return (if available), return on assets, return on sales, etc.

Vickery, et al. (1993) measured business performance using the financial measures of return on assets before tax (ROA before tax), return on assets after tax (ROA after tax), return on investment after tax (ROI), and return on sales (ROS). They obtained data for each of these measures in three forms—a firm's performance relative to competitors, a firm's performance relative to its historic performance, and actual data. Not all firms provided actual data to the study, therefore, subjective measures were used for final analysis. Of the subjective performance measures, ROA after tax relative to historic performance (internal assessment) and ROA before tax relative to historic performance (internal assessment) had the highest correlations with actual ROA data.

Investigating the relationship between the use of manufacturing strategies, programs, and techniques and overall firm performance, while not leading to causality, will provide information regarding the strategies that the highest overall performing firms feel are important. This will add to the body of knowledge being created regarding manufacturing strategies.

Overall firm performance will be measured using ROA pretax relative to historic performance (internal assessment). The following hypothesis will serve to identify the strategies implemented by high performers:

> **Hypothesis 4: There is a positive relationship between the extent of use of manufacturing**

strategies, programs, and techniques, and subjective overall firm performance.

For each of the strategies, programs, and techniques appearing in Table 3.1, regress the subjective "ROA pretax" firm performance measures from Vickery, Droge, and Markland (1993) onto the extent of use (EOU) score of the techniques.

Model: $Y = \beta_0 + \beta_1 X_1$

where: Y = subjective ROA pretax
and X_1 = extent of use of technique.

Perform a t-test to see if β_1 is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1 is positive and different from zero, we can claim that there might exist a positive relationship between overall firm performance and the use of the particular strategy, program, or technique.

5. Quality-Related SPTs and Competence/Performance

One drawback of the large number of individual manufacturing SPTs tested in the first four sets of hypotheses and the large alpha (.10) is that confidence is lost when interpreting results. For example, if 80 SPTs are tested at an alpha of .10, chance alone would produce eight significant SPTs. One method to overcome this problem is to reduce the alpha level to .05, which would reduce the effects of chance by half. That, however, would detract from the exploratory nature of the study.

An alternative method would be to assemble the SPTs into logical groups so that fewer tests are needed. Given the structure of the model being tested in this study, using the four competitive priorities of quality, cost, delivery, and flexibility as group headings is logical.

To guide the assignment of SPTs to a quality group, an underlying theory or framework is appropriate. The Malcolm Baldrige National Quality Award program, administered by the National Institute of Standards and Technology (NIST), "was established to stimulate American organizations to improve quality through a well-conceived and well-defined quality system" (George, 1992, p. 1). The Baldrige criteria serve as a guide for companies to design and implement quality improvement programs and to change quality systems (George, 1992). Table 3.4 lists the categories and items of the Baldrige criteria, which are divided into seven categories: leadership, information and analysis, strategic quality planning, human resource development and management, management of process quality, customer focus and satisfaction, and quality and operational results. Except for the measurement of results, the categories concern changes to a firm's quality system, which can lower costs, help to retain a firm's customers and employees, and improve profitability. Of those categories, Information and Analysis, Human Resource Development and Management, and Management of Process Quality directly concern the implementation of quality changes.

A search of quality improvement literature relating to the Baldrige award (Ross, 1993; George, 1992; Brocka and Brocka, 1992) reveals that there are several strategies and techniques firms can use to improve performance within a category. Table 3.5 lists the manufacturing SPTs from Table 3.1 that these authors have suggested are appropriate for the Baldrige categories and items.

Table 3.4: Malcolm Baldrige Quality Categories and Items

1.0 Leadership
- Senior Executive Leadership
- Management for Quality
- Public Responsibility

2.0 Information and Analysis
- Scope and Management of Quality Information and Performance Data and Information
- Competitive Comparisons and Benchmarks
- Analysis and Uses of Company-Level Data

3.0 Strategic Quality Planning
- Strategic Quality Planning and Company Performance Planning Process
- Quality and Performance Plans

4.0 Human Resources Development and Management
- Human Resource Management
- Employee Involvement
- Employee Education and Training
- Employee Performance and Recognition
- Employee Well-Being and Morale

5.0 Management of Process Quality
- Design and Introduction of Quality Products and Services
- Process Management—Product and Service Production and Delivery Processes
- Process Management—Business processes and Support Services
- Supplier Quality
- Quality Assessment

6.0 Quality and Operational Results
- Product and Service Quality Results
- Company Operational Results
- Business Process and Support Service results
- Supplier Quality results

7.0 Customer Focus and Satisfaction
- Customer Relationship Management
- Commitment to Customers
- Customer Satisfaction Determination
- Customer Satisfaction Results
- Customer Satisfaction Comparisons
- Future Requirements and Expectations of Customers

SOURCE: George (1992)

Table 3.5: Baldrige Criteria (BOLD)/Items and Related SPTs

BALDRIGE CRITERIA & ITEMS	RELATED MANUFACTURING SPTs
Information and Analysis	Avail. Of Cost Of Qual. Data To Managers
	Avail. Of Qual. Related Data To Workers
	Timely Feedback Of Quality Data
	Avail. Of Qual. Related Data To Managers
	Benchmarking
HR Development and Management	
Employee Involvement	Employee Suggestions
	Self-Directed Work Teams
	Employees Responsible For Quality
	Employee Involvement
Employee Education and Training	Training For Executives and Managers
	Training For Workers
Human Resource Management	Product Teams
	Vertical Job Enlargement
	Worker Motivation
	Cross-Training Workers
	Quality Circles
	Visible Performance Charts
	Cross-Functional Teams
Employee Performance and Recognition	Employee Recognition
	Goalsetting
	Gainsharing
Employee Well-Being and Morale	Quality Of Work Life Initiatives
	Worker Safety
Process Quality	
Product Production and Deliv. Processes	Failsafing Or Foolproofing
	Total Productive Maintenance (TPM)
	Preventive Maintenance
	Emphasis On "Right The First Time"
	Mean and Range Control Charts
	Use of 7 Basic Qual. Improvement Tools
Quality Assessment	Product Reliability Testing
	Measuring Product Reliability
	Quality Audit
Process Management—Business Processes	Functional Integration
Design and Intro. of Quality Products	Coord. Among Depts. In Product Design
	Quality Function Deployment (QFD)
	Concurrent Engineering
	Involve Suppliers In Product Design
	Design For Manufacturability
Supplier Quality	Supplier Certification
	Supplier Selection Based On Quality
	Training Provided To Suppliers

For each category and item in Table 3.5, the extent of use score for the related manufacturing SPTs are summed to create new variables. For example, the score for the category "information and analysis" would be the sum of the extent of use scores for the manufacturing SPTs in Table 3.5 associated with that category: availability of cost of quality data to managers through benchmarking. For the second category—HR development and management—the manufacturing SPTs have been grouped by item, not category. The score for the item "employee involvement" is the summation of the extent of use scores for the SPTs from employee suggestions to employee involvement. Finally, the item-level variables can be summed to construct category-level variables. For example, the HR development and management score is the sum of the score of the items related to the HR criteria, including employee involvement, education and training, human resource management, performance and recognition, and employee well-being and morale.

The collection and assignment of manufacturing SPTs into groups organized by Baldrige categories can assist firms in selecting and implementing the SPTs that can aid in the quality improvement process. George (1992, p. xi) quotes Curt Reimann, director of the Baldrige program, as stating that the Baldrige criteria are something of a "do-it yourself kit" for quality improvement. Identification of critical manufacturing SPTs can aid firms by suggesting the SPTs that are most effective in achieving Baldrige criteria. In addition, improvements in the quality area have been suggested as requirements for operating in many environments and markets (Ferdows and De Meyer, 1990; The Economist, 1994). Regardless of the direction of strategic objectives, quality improvement is necessary.

Ferdows and De Meyer (1990) presented their sand-cone model which stated that capability in quality is achieved before capabilities in delivery, flexibility, and cost can be attained. Hill (1994) intimates that quality is now a qualifying criterion to enter many global markets, especially automobiles. The quality movement has educated many companies and consumers on the benefits of higher quality. Competitors have raised the level of quality that is acceptable to consumers. Because of this, quality is now a basic element of the strategies of many companies.

Competence, as stated already, measures support provided to strategic objectives. If quality is now becoming a qualifying criterion, quality improvement programs should be an element of strategy regardless of the particular strategic direction. Given this, the use of quality-related SPTs should be positively related to production competence. Furthermore, when firms compete on other dimensions (delivery, flexibility), the use of quality SPTs will be critical (Ferdows and De Meyer, 1990). Therefore, the use of quality-related SPTs should be positively related to competence within the four priorities of cost, delivery, flexibility, and quality. Given the requirement for quality in many markets, the association between the Baldrige categories and the manufacturing SPTs presented in the literature, and the sequence of capability acquisition suggested by Ferdows and De Meyer (1990), the following hypotheses can be presented:

Hypotheses 5a-5e: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige criteria and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, and (e) quality competence.

Regress the competence score onto the summated extent of use scores of the three criteria.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2 + \beta_3 X_3$

where: Y = production, cost, delivery, flexibility, or quality competence, and the independent variables are the summation of extent of use scores of the SPTs related to the criteria and items (see Table 3.5).

X_1 = information and analysis
X_2 = HR development and management
X_3 = process quality

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = \beta_3 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Earlier it was noted that the competence scores may obscure a performance relationship present between the use SPTs and a competitive priority. To address this issue, a performance score for the competitive priorities was constructed by summing the performance scores for the individual priorities associated with a particular priority (see Table 3.3). Investigating the relationship between the use of manufacturing SPTs and performance may reveal SPTs that are hidden by the competence analyses. Just as a performance score was determined for the priorities of cost, delivery, flexibility, and quality, an overall performance score can be determined. Production competence is calculated by taking the product of the importance and performance of individual competitive priorities. Production performance—the summation of the performance scores for all 31 priorities—can serve as an overall performance measure that can be used to detect relationships between SPTs and performance. Production performance will be included as an overall performance measure in several of the subsequent hypotheses.

The following hypotheses seek to investigate the existence of a relationship between SPTs associated with the Baldrige criteria and performance.

> **Hypotheses 5f-5j: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige criteria and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, and (j) quality performance.**
>
> Regress the performance score onto the summated extent of use scores of the three criteria.
>
> Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2 + \beta_3 X_3$
>
> where: Y = production, cost, delivery, flexibility, or quality performance, and the independent variables are the summation of extent of use scores of the SPTs related to the criteria and items (see Table 3.5).
>
> X_1 = information and analysis
> X_2 = HR development and management
> X_3 = process quality

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = \beta_3 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Firm performance can also be measured using financial measures. Vickery, Droge, and Markland (1993) measured several different financial indicators and discovered that subjective measures of ROA correlated highly with actual ROA. The subjective measures included internally assessed and externally assessed pretax and aftertax measures of ROA. Deming (1982) indicated that quality improvement can lead to lower costs and increased share. This combination will lead to increased profits. George (1992) indicates that the journey to quality improvement and implementation of plans to pursue the Baldrige Award has produced financial gains. The following hypotheses test this notion:

Hypotheses 5k-5n: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige <u>criteria</u> and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (n) aftertax ROA-external assessment, (o) aftertax ROA-internal assessment.

Regress the performance score onto the summated extent of use scores of the three criteria.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2 + \beta_3 X_3$

where: Y = pretax ROA-external assessment, pretax

ROA-internal assessment, aftertax ROA-external assessment, or aftertax ROA-internal assessment, and the independent variables are the summation of extent of use scores of the SPTs related to the criteria and items (see Table 3.5).

X_1 = information and analysis
X_2 = HR development and management
X_3 = process quality

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = \beta_3 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Alternatively, the individual *items* included in each Baldrige *criteria* may be more important to competence (see Table 3.5). The macro analysis of the criteria-related hypotheses may obscure any relation between competence and the lower-level Baldrige items. The relationships between quality-related SPTs and the various competitive thrusts are still of interest. Therefore, the following competence- and performance-related hypotheses are suggested:

Hypotheses 5p-5t: There is a positive relationship between the extent of use manufacturing SPTs associated with Baldrige <u>items</u>, and (p) production competence, (q) cost competence, (r) delivery competence, (s) flexibility competence, or (t) quality competence.

Regress the competence score onto the summated extent of use scores of the Baldrige items.

Model: $Y = \beta_0 + \beta_1 X_1$

where: Y = production, cost, delivery, flexibility, or quality competence,
and X_1 = Baldrige item (e.g., employee involvement). The item scores are the summation of extent of use scores of the SPTs related to the Baldrige items (see Table 3.5).

Perform a t-test to see if β_1, is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1, is positive and different from zero, we can claim that there might exist a positive relationship between that particular Baldrige item and the associated competence measure.

Hypotheses 5u-5y: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige items and (u) production performance, (v) cost performance, (w) delivery performance, (x) flexibility performance, or (y) quality performance.

Regress the performance score onto the summated extent of use scores of the Baldrige items.

Model: $Y = \beta_0 + \beta_1 X_1$

where: Y = production, cost, delivery, flexibility, or quality performance,
and X_1 = Baldrige item (e.g., employee involvement). The item scores are the summation of extent of use scores of the SPTs related to the Baldrige items (see Table 3.5).

Perform a t-test to see if β_1, is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1, is positive and different from zero, we can claim that there might exist a positive relationship between that particular Baldrige item and the associated performance measure.

Hypotheses 5z-5ac: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige items and (z) pretax ROA-external assessment, (aa) pretax ROA-internal assessment, (ab) aftertax ROA-external assessment, (ac) aftertax ROA-internal assessment.

Regress the ROA score onto the summated extent of use scores of the Baldrige items.

Model: $Y = \beta_0 + \beta_1 X_1$

where: Y = pretax ROA-external assessment, pretax ROA-internal assessment, aftertax ROA-external assessment, or aftertax ROA-internal assessment, and
X_1 = Baldrige item (e.g., employee involvement). The item scores are the summation of extent of use scores of the SPTs related to the Baldrige **items** (see Table 3.5).

Perform a t-test to see if β_1, is different from zero. Since this is exploratory research, a generous alpha of .10 will be used. If β_1, is positive and different from zero, we can claim that there might exist a positive relationship between that particular Baldrige item and the associated performance measure.

6. Delivery-Related SPTs and Competence/Performance

To overcome problems in identifying manufacturing SPTs related to competitive priorities mentioned in section five above (i.e., large number of tests and alpha=.10), it was suggested that the SPTs can be grouped together. In general, the delivery component of a firm's strategy can be sub-divided into delivery speed and delivery reliability. In this study, however, the delivery competence and delivery performance constructs do not differentiate between speed and reliability (see Table 3.3). Therefore, manufacturing SPTs related to both speed and reliability are grouped together.

The literature is somewhat lacking in empirical research relating to delivery performance. Several articles suggest methods of improving delivery performance, but there are few which have empirically tested or identified the suggested techniques. Three articles that have addressed the issue (Roth, De Meyer, and Amano, 1989; De Meyer and Ferdows, 1990; and Handfield and Pannesi, 1992) have identified several manufacturing strategies and techniques that were found to be associated with superior delivery performance.

The most common techniques related to delivery appear in Table 3.6. The division of the techniques in Table 3.6 into the categories of "process" and "infrastructure" was not made by the cited authors and was not done in a statistical manner. They do, however, represent a logical breakdown of the SPTs into categories similar to Hayes and Wheelwright's (1984) structural and infrastructural categories. The new variables created (DELPROCS and DELINFRA) are equal to the sum of the extent of use scores of the SPTs in each category.

Production competence measures the support provided to the business strategy by manufacturing. One of the major objectives of this study is to identify the relationship between production competence and manufacturing strategies, programs and techniques. Grouping delivery-related SPTs together improves the ability of the model to identify potential relationships between the SPTs and competence, and to determine if delivery-related SPTs are important

Table 3.6: Manufacturing SPTs Related to **Delivery**

Infrastructural SPTs	Process SPTs
Coordination Among Departments in Product Design	Dedicated Equipment
Cross-Functional Teams	Group Technology
Cross-Training Workers	Just-in-Time
Design For Manufacturability	Preventive Maintenance
Reliance on Fewer Suppliers	Reducing Setup times
Supplier Certification	Reduction in Throughput Times
Supplier Selection Based on Quality	Simplified Material Flow
Workplace Orderliness	

Sources: Roth, De Meyer, and Amano, 1989; De Meyer and Ferdows, 1990; and Handfield and Pannesi, 1992.

to all firms, regardless of strategic direction.

According to the sand cone model presented by Ferdows and De Meyer (1990), capability in delivery follows quality and precedes flexibility and cost. Increasingly, writers are observing that companies can and must compete on several dimensions (Wallace, 1992). For these reasons, it seems that delivery skills are becoming important for firms in many industries. Since delivery capability is becoming necessary for more companies, use of delivery-related SPTs should be related to production competence.

Additionally, as previous research indicates, use of delivery-related SPTs should be related to the delivery constructs of delivery competence and delivery performance.

The priority of delivery speed is related to the idea of responsiveness—the ability to respond to changing customer needs.

Flexibility definitions also indicate some propensity to quickly respond to customer needs (Gerwin, 1989, 1993). Therefore, improvements in delivery capability might add to flexibility capability.

Also, the suggested delivery-related SPTs indicate improvements in quality and efficiency. These benefits suggest that the use of delivery-related SPTs may be related to the cost constructs of competence and performance.

Finally, the affect of the use of delivery-related SPTs on overall firm performance is of interest, due to the increasing importance of this priority (Hill, 1994; Giffi, Roth, and Seal, 199; Stalk and Hout, 1990).

The following hypotheses capture the above arguments and investigate the relationship between delivery SPTs, production competence, competence and performance within the other competitive priorities, and overall firm performance.

Hypotheses 6a-6e: There is a positive relationship between the extent of use of manufacturing SPTs associated with delivery and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, or (e) quality competence.

Regress the competence score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = production, cost, delivery, flexibility, or quality competence, and the independent variables are the summation of extent of use scores of the SPTs related to delivery (see Table 3.6).

X_1 = delivery infrastructure (DELINFRA)
X_2 = delivery process (DELPROCS)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 6f-6j: There is a positive relationship between the extent of use of manufacturing SPTs associated with delivery and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, or (j) quality performance.

Regress the performance score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = production, cost, delivery, flexibility, or quality performance, and the independent variables are the summation of extent of use scores of the SPTs related to delivery (see Table 3.6).

X_1 = delivery infrastructure (DELINFRA)
X_2 = delivery process (DELPROCS)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 6k-6n: There is a positive relationship between the extent of use of manufacturing SPTs associated with delivery and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.

Regress the ROA score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = pretax ROA-external assessment, pretax ROA-internal assessment, aftertax ROA-external assessment, aftertax ROA-internal assessment, and the independent variables are the summation of extent of use scores of the SPTs related to delivery (see Table 3.6).

X_1 = delivery infrastructure (DELINFRA)
X_2 = delivery process (DELPROCS)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

7. Flexibility-Related SPTs and Competence/Performance

As in the above discussions of quality and delivery, the SPTs related to flexibility can be grouped together. Research in flexibility is less developed than even delivery research. Roth, De Meyer, and Amano (1989) have published one of the few studies relating the use of techniques and strategies to flexibility. Other writers in the area include Gerwin (1993), who discussed several ways to define flexibility, Stalk and Hout (1990) and Wallace (1992), who discussed the strategic advantages of time and flexibility, and Parthasarthy and Sethi (1993), who studied the fit with flexible automation of strategy and organizational structure choices.

Table 3.7 lists the manufacturing SPTs that the above authors suggest are related to achieving improved performance in the flexibility arena. As in the case of delivery, the SPTs were divided into the categories of "process" and "infrastructure". This breakdown was not made by the cited authors and was not done in a statistical manner. They again represent Hayes and Wheelwright's (1984) structural and infrastructural categories. The new variables created (FLEXPROC and FLEXINFR) are equal to the sum of the extent of use scores of the SPTs in each category.

The SPTs in Table 3.7 are purported by the cited authors to improve flexibility performance. If they do, the use of the SPTs should be positively related to flexibility competence and flexibility performance.

As previously stated, one objective of this study is to identify relationships between SPTs and production competence. The contribution that flexibility-related SPTs can make, especially in very competitive markets, can be critical. Investigating their use and relationship to production competence can contribute to the bundle of important SPTs.

Flexibility capability, according to Ferdows and De Meyer (1990), is acquired after quality and delivery. Therefore, the use of flexibility-related SPTs should be positively related to competence

Table 3.7: Manufacturing SPTs Related to **Flexibility**

Infrastructural SPTs	Process SPTs
Coordination In Product Design	Advanced Manufacturing Technology
Cross Functional Teams	CIM
Cross Training Workers	FMS
Employee Involvement	General Purpose Equipment
Supplier Certification	Group Technology
TQC	JIT
Use Of 7 Basic Quality Tools	Maintain Excess Equipment Capacity
Workplace Orderliness	Product Focused Factory
	Reduce Setup Times
	Reduction In Throughput Times
	Simplified Material Flow

Sources: Roth, De Meyer, and Amano (1989); Gerwin (1993); Wallace (1992); Stalk and Hout (1990); and Parthasarthy and Sethi (1993).

and performance within those two competitive dimensions.

Additionally, the suggested flexibility-related SPTs indicate improvements in quality and efficiency, and also indicate the use of technology to increase efficiency. As in the delivery case, these benefits suggest that the use of flexibility-related SPTs may be related to the cost constructs of competence and performance.

Finally, as with delivery, flexibility is increasingly becoming an important competitive advantage that firms can leverage into increased profits (Pine, Victor, and Boynton, 1993). Investigating the benefits of the use of flexibility-related SPTs can give insight into this important source of competitive advantage.

The following hypotheses capture the above arguments and investigate the relationship between flexibility SPTs, production competence, and competence and performance within the other competitive priorities.

Hypotheses 7a-7e: There is a positive relationship between the extent of use of manufacturing SPTs associated with <u>flexibility</u> and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, or (e) quality competence.

Regress the competence score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = production, cost, delivery, flexibility, or quality competence, and the independent variables are the summation of extent of use scores of the SPTs related to flexibility (see Table 3.7).

X_1 = flexibility infrastructure (FLEXINFR)
X_2 = flexibility process (FLEXPROC)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 7f-7j: There is a positive relationship between the extent of use of manufacturing SPTs associated with <u>flexibility</u> and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, or (j) quality performance.

Regress the performance score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = production, cost, delivery, flexibility, or quality performance, and the independent variables are the summation of extent of use scores of the SPTs related to flexibility (see Table 3.7).

X_1 = flexibility infrastructure (FLEXINFR)
X_2 = flexibility process (FLEXPROC)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 7k-7n: There is a positive relationship between the extent of use of manufacturing SPTs associated with flexibility and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.

Regress the ROA score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = pretax ROA-external assessment, pretax ROA-internal assessment, aftertax ROA-external assessment, aftertax ROA-internal assessment, and the independent variables are the summation of extent of use scores of the SPTs related to flexibility (see Table 3.7).

X_1 = flexibility infrastructure (FLEXINFR)
X_2 = flexibility process (FLEXPROC)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

8. Cost-Related SPTs and Competence/Performance

In the practitioner literature, achieving cost reductions is of paramount importance. Over time both the academic and practitioner thinking on cost reduction has changed—from a hierarchical, mechanistic organization emphasizing high volumes and economies of scale, to a more organic structure that emphasizes improved quality, in addition to obtaining economies where possible, as a source of cost reduction.

In the manufacturing and policy/strategy literature, several authors have written about methods of cost reduction. Porter (1980) observed that low cost was a viable strategy and indicated several economies of scale-type strategies and techniques that could support the low cost business objective. Dess and Davis (1984) tested Porter's model and also identified cost reducing techniques. Kim and Lee (1993) observed several characteristics of production systems that support lower costs. Harmon (1987) mentioned some new ways of thinking about cost reductions in factory settings that included quality improvements. Several operations management texts also highlight the economies/quality approach to lowering costs (Krajewski and Ritzman, 1993; Meredith, 1992). Ward, Miller, and Vollmann (1988) and Roth, De Meyer, and Amano (1989) conducted

Table 3.8: Manufacturing SPTs Related to **Cost**

Quality SPTs	Efficiency SPTs
Failsafing Or Foolproofing	Automation
Total Quality Control (TQC)	Backward Integration
Use of Seven Basic Quality Improvement Tools	Dedicated Equipment
Zero Defects	Forward Integration
	Large Batch Production
Design SPTs	Proprietary Technology
Design For Manufacturability	Purchase In Large Quantities
Product Simplification	Reducing Size of Work Force
Product Standardization	Work Measurement
Value Analysis	Worker Safety
Variety Reduction	Worker Specialization

Sources: Krajewski and Ritzman (1993); Meredith (1992); Kim and Lee (1993); Ward, Miller, and Vollmann (1988); Roth, De Meyer, and Amano (1989); Harmon and Peterson (1987); Dess and Davis (1984); and Porter (1980).

empirical analyses that observed the use of manufacturing strategies and techniques that were related to lower costs.

Table 3.8 lists the manufacturing SPTs from Table 3.1 that the literature suggests are related to lower costs. The literature suggests that costs can be lowered by improving quality, improving product designs, or operating more efficiently. These categories form new variables (COSTQUAL, COSTDES, and COSTEFF) that are equal to the sum of the extent of use scores of the SPTs in each category.

The SPTs in Table 3.8 are cost-reduction approaches culled from the policy/strategy and operations literature. Therefore, the use of these SPTs should be positively related to the constructs of cost competence and cost performance. Additionally, as cost becomes more important to consumers, cost reductions become an important component to business strategies. In a mature industry such as furniture, cost issues are important and companies must develop new methods of lowering costs. Production competence and the use of cost-related SPTs might be related, given this late stage in the life cycle.

The final step in the sand cone model (Ferdows and De Meyer, 1990) says that cost capability is acquired after quality, delivery, and flexibility capabilities. Therefore, the use of cost-related SPTs should be associated with competence and performance in those three areas.

Cost reduction strategies are considered one of the basic strategies firms can use to compete (Hill and Jones, 1989; Porter, 1980). Firms in a mature industry such as the furniture will face cost pressure and the firms that successfully implement cost reducing strategies should fare better than firms that are less successful (Hill, 1994).

The following hypotheses capture the above arguments and investigate the relationship between cost-related SPTs, production competence, and competence and performance within the competitive priorities.

> **Hypotheses 8a-8e: There is a positive relationship between the extent of use of manufacturing SPTs associated with <u>cost</u> and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, and (e) quality competence.**
>
> Regress the competence score onto the summated extent of use scores of the new variables.
>
> Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2 + \beta_3 X_3$

where: Y = production, cost, delivery, flexibility, or quality competence, and the independent variables are the summation of extent of use scores of the SPTs related to cost (see Table 3.8).

X_1 = quality oriented SPTs (COSTQUAL)
X_2 = design oriented SPTs (COSTDES)
X_3 = efficiency oriented SPTs (COSTEFF)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = \beta_3 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 8f-8j: There is a positive relationship between the extent of use of manufacturing SPTs associated with <u>cost</u> and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, and (j) quality performance.

Regress the performance score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2 + \beta_3 X3$

where: Y = production, cost, delivery, flexibility, or quality performance, and the independent variables are the summation of extent of use scores of the SPTs related to cost (see Table 3.8).

X_1 = quality oriented SPTs (COSTQUAL)
X_2 = design oriented SPTs (COSTDES)
X_3 = efficiency oriented SPTs (COSTEFF)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = \beta_3 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 8k-8n: There is a positive relationship between the extent of use of manufacturing SPTs associated with cost and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.

Regress the ROA score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2 + \beta_3 X_3$

where: Y = pretax ROA-external assessment, pretax ROA-internal assessment, aftertax ROA-external assessment, aftertax ROA-internal assessment, and the independent variables are the summation of extent of use scores of the SPTs related to cost (see Table 3.8).

X_1 = quality oriented SPTs (COSTQUAL)
X_2 = design oriented SPTs (COSTDES)
X_3 = efficiency oriented SPTs (COSTEFF)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = \beta_3 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

9. Just-in-Time Related SPTs and Competence/Performance

One response to increased competitive pressures is for firms to implement the latest "hot" technique. Skinner (1992a) notes that this is not an effective approach. However, just-in-time (JIT) is one of these new approaches that has received an extraordinary amount of attention. Both the academic (*Journal of Operations Management, Decision Sciences, International Journal of Operations & Production Management, Production and Inventory Management Journal*) and practitioner literature (*Production, NAPM Insights, and APICS' The Performance Advantage*) have published many articles on the subject. Reported benefits include improvements in cost, quality, delivery and flexibility. Gunn (1992) suggests that, along with total quality management (TQM) and CIM, JIT is one of the cornerstones of manufacturing strategy.

Given the growing popularity of JIT, it would be interesting to investigate the relationship between JIT and competence. Heiko (1991) discussed several aspects of JIT and Gilbert (1990) investigated the manner in which US firms implemented their JIT programs. Recently, two empirical studies were published that presented results of studies that were directed at identifying the basic elements of JIT (Davy, White, Meritt, and Gritzmacher, 1992; Mehra and Inman, 1992).

Table 3.9 lists the manufacturing SPTs from Table 3.1 that the above authors identified as elements of JIT. As in the cases above, the SPTs are grouped into process and infrastructure categories. The variables created are called JITINFRA and JITPROCS.

The benefits of JIT can impact all of the competitive priorities.

Table 3.9: Manufacturing SPTs Related to **Just-in-Time (JIT)**

Infrastructural SPTs	Process SPTs
Product Simplification	Group Technology
Reduction in WIP Inventory	Just-in-Time
Supplier Certification	Preventive Maintenance
Cross-Training Workers	Total Productive Maintenance
Employee Involvement	Workplace Orderliness
Training for Workers	Simplified Material Flow
	Reducing Setup Times

Sources: Heiko (1991); Gilbert (1990); Davy, White, Meritt, and Gritzmacher (1992); and Mehra and Inman (1992).

JIT is being suggested and written about by several authors (see above). Examining the SPTs in Table 3.9, it can be seen that they include many of the most common suggestions for improving competitiveness (Gunn, 1992; Stalk and Hout, 1990; Wallace, 1992). Given this, the JIT-related SPTs should be positively related to production competence and performance, as well as competence and performance within the priorities of cost, quality, delivery, and flexibility. The reported benefits of JIT are widespread and can affect several elements of a balance sheet (e.g., cash flow). Given this widespread impact, it is logical that the use of JIT-related SPTs should have a positive affect of a firm's financial indicators.

The following hypotheses capture the above arguments and investigate the relationship between JIT SPTs, production competence, and competence and performance within the competitive priorities.

> **Hypotheses 9a-9e: There is a positive relationship between the extent of use of manufacturing SPTs associated with JIT and (a) production**

competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, and (e) quality competence.

Regress the competence score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = production, cost, delivery, flexibility, or quality competence, and the independent variables are the summation of extent of use scores of the SPTs related to JIT (see Table 3.9).

X_1 = JIT infrastructure (JITINFRA)
X_2 = JIT process (JITPROCS)

An F-test will be used to investigate the inappropriateness of the model (i.e., $\beta_1 = \beta_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 9f-9j: There is a positive relationship between the extent of use of manufacturing SPTs associated with JIT and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, and (j) quality performance.

Regress the performance score onto the summated extent of use scores of the new variables.

Model: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X2$

where: Y = production, cost, delivery, flexibility, or quality performance, and the independent variables are the summation of extent of use scores of the SPTs related to JIT (see Table 3.9).

X_1 = JIT infrastructure (JITINFRA)
X_2 = JIT process (JITPROCS)

An F-test will be used to investigate the inappropriateness of the model (i.e., $ß_1 = ß_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

Hypotheses 9k-9n: There is a positive relationship between the extent of use of manufacturing SPTs associated with JIT and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.

Regress the ROA score onto the summated extent of use scores of the new variables.

Model: $Y = ß_0 + ß_1X_1 + ß_2X2$

where: Y = pretax ROA-external assessment, pretax ROA-internal assessment, aftertax ROA-external assessment, aftertax ROA-internal assessment, and the independent variables are the summation of extent of use scores of the SPTs related to JIT (see Table 3.9).

X_1 = JIT infrastructure (JITINFRA)
X_2 = JIT process (JITPROCS)

An F-test will be used to investigate the inappropriateness of the model (i.e., $ß_1 = ß_2 = 0$). As in earlier tests, an alpha level of .10 will be enforced. Stepwise regression will be used to test the above model and to determine if the individual ßs are related to competence. If multiple coefficients appear, partial correlation coefficients will be tested using the t-statistic (Cohen and Cohen, 1983, pp. 172-173).

The hypotheses listed above will be tested on the collected data using SPSS (4.0) for the Macintosh. The hypotheses requiring multiple regression analysis will be tested using the stepwise method (Neter and Wasserman, 1974).

IV. RESULTS AND ANALYSIS

This chapter will present results and analysis of the study described in Chapter 3. The first section discusses the relationship between the production competence construct and individual manufacturing strategies, programs, and techniques (SPTs). That will be followed by results of the investigation of the relationship between competence within the four main competitive priority areas (cost, delivery, flexibility, and quality) and the individual manufacturing SPTs. The third area of analysis involves the relationship between the use of manufacturing SPTs and performance within the four main competitive priority areas. The fourth section presents results investigating the relationship between overall firm performance and manufacturing SPTs.

Following the results of the analysis of individual manufacturing SPTs will be several sections that analyze the results of hypotheses five through nine—those that analyze collections of SPTs that have been grouped according to competitive priority (cost, delivery, flexibility, and quality). The final section presents results from the analysis of just-in-time (JIT) related SPTs, which were included because of the tremendous interest in JIT and its published benefits.

Production Competence and Individual Manufacturing Strategies

The theory of manufacturing strategy states that firms with manufacturing resources aligned with business strategy objectives will outperform those whose manufacturing resources are not in alignment (Anderson, Cleveland, and Schroeder, 1989). The production competence construct was developed to measure the alignment or degree of fit between manufacturing resources and business strategy objectives (Cleveland, Schroeder, and Anderson, 1989). Recently, Vickery, Droge, and Markland (1993) improved the measurement of the production competence construct and discovered a positive relationship between firm performance and production competence.

This study is an attempt to expand previous research in the production competence area by investigating relationships between production competence and the use of particular manufacturing strategies, programs, and techniques. A potential result of this section of the study is the development of a bundle or core set of strategies that are associated with production competence.

Hypothesis 1 was developed to test the relationship between production competence and the use of individual manufacturing strategies, programs, and techniques. It appears below:

> **Hypothesis 1: There is a positive relationship between the extent of use of individual manufacturing strategies, programs and techniques and production competence.**

The manufacturing strategies, programs and techniques tested by this hypothesis are listed in Table 3.1. To test this hypothesis, a series of simple regression analyses were conducted with production competence as the dependent variable and the extent of use of the manufacturing SPTs as the independent variable. A t-test was performed to test if the regression coefficient was significantly different from zero in the positive direction (one-way test). Given that this is theory-building research, an alpha-level of .10 was used, resulting in a critical t-value of 1.319 (n=24) (Emory, 1985).

Table 4.1 presents the manufacturing SPTs with regression coefficients that are significantly and positively related to production competence. To add an underlying structure to the analysis, the significant SPTs can be further classified according to Hayes and Wheelwright's structural and infrastructural factors of manufacturing strategy (Hayes and Wheelwright, 1984). This classification is not statistically driven (due to small sample size), and therefore is merely an estimate of how the SPTs *might* be classified. The estimate, however, should be adequate for the purposes of discussion.

The structural factors appearing in Table 4.1 include proprietary technology, product-focused factory, synchronous manufacturing, process-focused factory, and flexible manufacturing systems. These SPTs are similar in that, except for proprietary technology, they are concerned with the integration and flow of product through an entire facility. This might indicate that firms taking a total systems approach to the manufacturing process possess greater understanding of the linked nature of the function. As a result, the manufacturing function is better aligned with business objectives.

The presence of both product- and process-focused factories in Table 4.1 is interesting in that it might not matter which process position a firm takes, as long as they clearly understand their

Table 4.1: Individual SPTs Related to Production Competence

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Proprietary Technology	.571	0.002	3.189
2	Worker Specialization	.533	0.004	2.889
3	Workplace Orderliness	.532	0.004	2.881
4	Supplier Selection Based On Price	.441	0.018	2.249
5	Product-Focused Factory	.435	0.019	2.213
6	Synchronous Manufacturing	.413	0.025	2.078
7	Worker Motivation	.405	0.028	2.031
8	Process-Focused Factory	.367	0.043	1.808
9	Worker Safety	.345	0.053	1.685
10	Product Standardization	.340	0.056	1.659
11	Reduce Num. Of Eng. Change Orders	.337	0.058	1.643
12	Employee Involvement	.325	0.065	1.576
13	Total Productive Maintenance	.325	0.065	1.573
14	Vertical Job Enlargement	.299	0.083	1.434
15	Training For Workers	.293	0.087	1.406
16	Flexible Manufacturing System	.285	0.094	1.364

business and appropriately position the manufacturing process. Krajewski and Ritzman (1993) observe that this decision is critical—one that determines many of the subsequent downstream decisions.

The furniture industry is one experiencing rapid change brought on by increased competition and a slowing global economy. A response many firms are choosing is to develop and implement a new technology, allowing the firm a competitive advantage that is difficult to imitate. For furniture manufacturers, this may be a machine that improves productivity, increases quality, or accomplishes both objectives. These results show that, in this study, firms that have developed their own technology are providing tremendous support to their business strategies. This might be a situation where the manufacturing function, instead of supporting the business strategy, is actually the source of distinctive competence for the firm (Hayes and Wheelwright, 1984).

Upon analyzing the manufacturing SPTs appearing in Table 4.1, one is struck by the predominance of SPTs that are related to the employees. Five of the sixteen significant SPTs directly concern worker-related/empowerment issues, including motivation, safety, involvement, job enlargement, and training. Total productive maintenance (TPM), a program that bestows responsibility for maintenance on the operator, can be thought of as employee-related as it broadens job requirements and is often accompanied by pushing decision-making and authority lower in firm hierarchies (Giffi, Roth, and Seal, 1990; Maggard and Rhyne, 1992).

The presence of employee-related issues is an important result—regardless of strategic direction, employee involvement and support play an important role in strategy implementation. For the firms included in the survey, there is strong evidence of a relationship between production competence and giving attention to workers, either through taking to steps to ensure their safety or involving workers in decision processes. If so, this result lends credence to statements many firms make concerning the importance of people to their firm and their value as an asset.

The remaining infrastructural SPTs include workplace orderliness and design issues (reduce engineering change notices and product standardization). Hayes and Wheelwright (1984) note that the cumulative affect of infrastructural factors can be just as important to manufacturing strategy as the structural factors. The results of this analysis indicate that the infrastructural factors of people-management and management of the manufacturing system are critical to production competence.

In summary, the manufacturing SPTs that are associated with production competence indicate two general areas are critical to supporting the business strategy. First, the importance of employees to the system and the experience, knowledge, and creativity that they contribute is evident. Second, the particular positioning of the manufacturing process—either product or process—is not as important as having the vision to see the process as a linked system. The ability to understand the linked nature of the system might be related to having the strategic vision to tie manufacturing resources to business strategy objectives.

Competitive Priority Competence and Related Manufacturing Strategies, Programs, and Techniques

Skinner (1992a) observes that one of the problems with research in manufacturing strategy is that it is not prescriptive. He indicates that practitioners are not receiving adequate guidance from the research community regarding the strategic decisions they make. Specifically, Skinner mentions that linkages between competitive thrusts and the manufacturing strategic decision categories are missing (see Figure 3.2). While the results in the previous section suggest manufacturing SPTs that relate to production competence, they do not give guidance regarding decision making within a particular competitive thrust or priority. This section presents results that link the manufacturing SPTs to a particular competitive priority.

This section begins the analyses of the second group of hypotheses—those relating to competitive priority competence. Hypotheses 2a-2d were constructed to address the issue of linking results to specific competitive thrusts. Hypotheses 2a is listed below:

> **Hypothesis 2a: There is a positive relationship between the extent of use of individual manufacturing strategies, programs and techniques, and cost competence.**

Chapter 3 introduced the competitive priority constructs and described their construction. As a brief review, that process will again be discussed. In the study by Vickery, Droge, and Markland (1993), the production competence score was determined by summing the product of [competitive priority *importance* * competitive priority *performance* (adjusted) * percent manufacturing responsibility] across 31 competitive priorities (see Table 2.1 for the full list of priorities). Table 3.3 lists (exclusive, not exhaustive) the categorization of those 31 priorities into the familiar cost, delivery, flexibility, and quality priority areas. Applying the same logic as in the production competence construct, a competence score can be determined for each of the four main priority areas.

Cost Competence and Individual Manufacturing Strategies

Table 4.2 displays the manufacturing SPTs that are positively related to cost competence (as in the production competence analysis, a critical t-statistic of 1.319 was used). The individual competitive priorities of *low production cost, competitive pricing, and low price* were used to create the cost competence construct (see Table 3.3). A series of simple regression analyses was conducted with cost competence as the dependent variable, while the individual manufacturing SPTs were included as independent variables.

Using Hayes and Wheelwright's (1984) categories, four of the SPTs in Table 4.2 can be roughly (without statistical analysis) classified as structural factors—backward integration, computer integrated manufacturing (CIM), advanced manufacturing technology (AMT), and forward integration. The integration SPTs are classic cost-reduction strategies, so it is no surprise that they appear (Porter, 1980). Forward integration might be more crucial to the furniture industry as distribution channels can be critical to the business. Backward integration can include wood-related technologies such as rough mills to reduce raw lumber and other input material costs. The presence of the technology SPTs—CIM and AMT—indicates that advanced technologies are very important to cost-reduction efforts.

The infrastructural SPTs in Table 4.2 can be roughly (without statistical analysis) divided into the categories of quality, purchasing, and production planning and control. The quality-related SPTs are benchmarking, 100% inspection, failsafing, a "do-it-right-the-first-time" emphasis, and timely feedback of quality data. At one time, it was thought that quality and cost objectives were in conflict. Firms are now understanding the true relationship—quality improvement leads to cost reduction. Ferdows and De Meyer (1990) observed that quality improvement was a prerequisite to cost reduction. Given the

Table 4.2: Individual SPTs Related to Cost Competence

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Backward Integration	0.520	0.006	2.791
2	Computer Integrated Manufacturing	0.508	0.007	2.703
3	Benchmarking	0.482	0.010	2.520
4	Advanced Mfg. Technology (AMT)	0.468	0.012	2.433
5	100 % Inspection	0.450	0.016	2.313
6	Purchase In Large Quantities	0.428	0.021	2.176
7	Failsafing Or Foolproofing	0.409	0.026	2.058
8	Reliance On Fewer Suppliers	0.370	0.041	1.829
9	Emphasis On “Right-The-First-Time”	0.365	0.043	1.800
10	Advanced Forecasting	0.365	0.043	1.798
11	Supplier Selection Based On Quality	0.358	0.047	1.759
12	Preventive Maintenance	0.349	0.051	1.710
13	Large Batch Production	0.329	0.062	1.602
14	Forward Integration	0.317	0.070	1.534
15	Training Provided To Suppliers	0.316	0.071	1.527
16	Supplier Certification	0.312	0.073	1.509
17	Departmental Coord. In Prod. Design	0.298	0.083	1.433
18	Timely Feedback Of Quality Data	0.296	0.085	1.421

new understanding, one would expect to see more of the quality SPTs associated with cost competence than appear in Table 4.2.

The purchasing-related SPTs in Table 4.2 include buying in large quantities, reliance on fewer suppliers, supplier selection based on quality, supplier training, and supplier certification. The large number of purchasing strategies highlights the importance of sound purchasing to low cost strategies, and to cost reduction in general. These results reflect a general trend where many firms are reducing their supplier base and rewarding those that remain with increased volumes. Quantity discounts are important to cost savings and can be easier to achieve if fewer vendors are used. Supplier training can reduce variation of inputs, which improves quality which leads to cost reduction. Once suppliers have achieved adequate quality levels, they can be certified, removing the need for costly inspections. In the long term, certification can reduce incoming variation, as well as establish relationships that move beyond variation to incorporate other cost-reducing methods and strategic alternatives (Ellram, 1991).

The production planning and control SPTs appearing in Table 4.2 include advanced forecasting, maintenance programs, and large batch production. In high volume product industries—as some furniture products are—line flow production systems are often employed. Capacity changes can be difficult and expensive, which increases the importance of reliable forecasts (Hill, 1994). Additionally, furniture can be expensive to hold in inventory, again indicating the importance of good forecasting. In line-flow systems, machine breakdowns can close down entire lines. Therefore, preventive maintenance programs work to keep equipment operating, lines moving and utilization rates high—all critical to managing line-flow production. Finally, departmental design coordination ensures that products can be produced efficiently, further reducing unnecessary manufacturing costs.

In summary, cost competence is accomplished through a combination of standard vertical integration strategies, advanced machine technologies, purchasing and production planning strategies directed at economies of scale, and an emphasis on quality improvement.

Delivery Competence and Individual Manufacturing SPTs

Table 4.3 displays the manufacturing SPTs related to delivery competence. The delivery competence construct is comprised of the individual competitive priorities of *delivery speed, delivery dependability, and production lead time* (see Table 3.3). A series of simple regression analyses was conducted with delivery competence as the dependent variable, while the individual manufacturing SPTs were included as independent variables.

The manufacturing SPTs that are related to delivery competence can be further divided into structural and infrastructural factors. The structural SPTs include product-focused factory, flexible manufacturing system, proprietary technology, process-focused factory, and simplified material flow. These SPTs are almost identical to the structural factors related to production competence. Again, the presence of these structural SPTs indicates an understanding of the entire manufacturing system, which is very important to reducing system variability. The reduction in variability can be accomplished through establishing product-focused factories, installing dedicated proprietary technology, and simplifying material flow. Finally, reducing system variability makes it easier to meet due dates, which improves delivery performance.

Table 4.3: Individual SPTs Related to Delivery Competence

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Worker Safety	0.468	0.012	2.430
2	Product-Focused Factory	0.448	0.016	2.297
3	Workplace Orderliness	0.439	0.018	2.242
4	Flexible Manufacturing System	0.402	0.028	2.016
5	Proprietary Technology	0.398	0.030	1.991
6	Employee Involvement	0.346	0.053	1.691
7	Total Productive Maintenance	0.326	0.065	1.578
8	Employees Resp. For Output Quality	0.324	0.066	1.570
9	Self-Directed Work Teams	0.323	0.066	1.563
10	Process-Focused Factory	0.293	0.087	1.405
11	Reduction In Work-In-Process Inv.	0.281	0.097	1.342
12	Supplier Selection Based On Price	0.278	0.100	1.326
13	Simplified Material Flow	0.277	0.100	1.323

The infrastructural SPTs related to delivery competence include worker safety, workplace orderliness, employee involvement, total productive maintenance (TPM), employee responsibility for their output quality, self-directed work teams, reduction in WIP inventory, and supplier selection based on price. Worker safety, workplace orderliness, employee involvement, and total productive maintenance also are related to production competence. Maintenance programs keep machinery and equipment running and dependable, which also reduces system variability. Orderliness and reducing WIP levels are related the structural SPT of simplified material flow in that they each address the smooth, swift movement of materials through the facility.

Increasing employee responsibility for quality, coupled with increasing their authority in the system—through the use of TPM and self-directed work teams—and showing respect by caring for employee safety might help to engender ownership of products and orders by the workforce. This ownership can be critical to maintaining excellent delivery records.

Flexibility Competence and Individual Manufacturing SPTs

Table 4.4 lists the manufacturing SPTs related to flexibility competence. The flexibility competence construct is comprised of the competitive priorities of *product flexibility, volume flexibility, process flexibility, product development cycle time, and responsiveness to target markets* (see Table 3.3).

The structural SPTs in Table 4.4 related to flexibility competence include group technology, synchronous manufacturing, just-in-time, product-focused factory, proprietary technology, and general purpose equipment. This collection of SPTs indicates the application of technologies directed at simultaneously achieving the benefits of low- and high-volume manufacturing processes. The use of general purpose equipment following a line-flow arrangement allows the application of synchronous and just-in-time manufacturing principles (Hill, 1994). While this group of technologies does not contribute the highest degree of flexibility possible, it does provide the opportunity to impart moderate flexibility levels while simultaneously keeping costs in line. This a method of achieving flexibility without incurring great expense.

The infrastructural SPTs in Table 4.4 that support flexibility can be roughly divided into five categories, including quality, training, design, workforce management, and material flow. Quality-related SPTs include zero defects, use of the seven basic quality improvement tools (flowcharting, pareto charts, fishbone diagrams, etc.), acceptance sampling, control charts, reliability measurement and testing, and advanced statistical tools. Whereas quality SPTs were missing in the delivery and cost competence analyses, they are strongly represented in these results. The quality SPTs include both defect detection and prevention techniques, perhaps reflecting the transitional period for the industry. Inspection has been used extensively in the furniture industry, and, as of 1990, firms were just beginning to see the benefits of prevention techniques appearing in their inspection results.

Training of workers, suppliers and management is also critical to flexibility competence. Due to the integrated nature of competing on flexibility, members at several stages of the value-added chain need to be trained in new methodologies. The quality initiatives also require training support. Product design SPTs include reducing change notices, computer-aided-design (CAD), and standardizing designs and products. Improving the design process through the use of CAD and ensuring designs are correct early on, can assist firms in planning process technology and layout arrangements required to make the products.

Workforce management SPTs include worker specialization, safety, motivation, and vertical job enlargement. These are very similar to the worker-related SPTs that are associated with production competence and delivery competence. Expanding duties and proactively improving the workplace through safety improvements can instill the feeling of ownership required to support flexibility initiatives

Material flow SPTs include shop orderliness and reducing setup times. Setup time reduction is the among the most important improvements that can be made to improve low-volume production (Shingo, 1986; Hill, 1994). Faster changeovers allow for a wider range of products to be produced in a facility by improving utilization rates of the process equipment and reducing total costs. Shop orderliness is also related to production competence and delivery competence, and is a requirement for smooth material flows and world-class competitiveness (Schonberger, 1986).

Two of the infrastructural SPTs—worker specialization and product standardization—appear to be in conflict with flexibility thrusts. Given the structural SPTs, however, one can argue that they are in harmony. For example, worker specialization supports product-focused factories, just-in-time and group technology manufacturing. Each of these is directed at higher volume production of product families with limited options. Specialization and standardization support process choice decisions that attempt to attain benefits of both low- and high-volume manufacturing (Hill, 1994).

Table 4.4: Individual SPTs Related to Flexibility Competence

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Workplace Orderliness	0.537	0.004	2.920
2	Worker Specialization	0.507	0.007	2.693
3	Training For Workers	0.492	0.009	2.593
4	Reduce Num. Of Eng. Change Orders	0.487	0.009	2.554
5	Group Technology	0.000	0.000	2.493
6	Synchronous Manufacturing	0.463	0.013	2.395
7	Just-In-Time	0.461	0.013	2.382
8	Zero Defects	0.458	0.014	2.360
9	Worker Safety	0.452	0.015	2.325
10	Product-Focused Factory	0.447	0.016	2.288
11	Use Of The Seven Basic Quality Tools	0.438	0.018	2.235
12	Computer-Aided Design	0.407	0.027	2.042
13	Acceptance Sampling	0.406	0.027	2.037
14	Use Of Control Charts	0.396	0.031	1.978
15	Worker Motivation	0.396	0.031	1.974
16	Proprietary Technology	0.395	0.031	1.973
17	Measuring Product Reliability	0.381	0.036	1.890
18	Vertical Job Enlargement	0.372	0.040	1.839
19	Setup Time Reduction	0.327	0.064	1.587
20	Product Standardization	0.325	0.065	1.576
21	General Purpose Equipment	0.323	0.067	1.562
22	Advanced Statistical Tech. (Quality)	0.316	0.071	1.524
23	Training for Execs. and Managers	0.311	0.075	1.497
24	Product Reliability Testing	0.302	0.081	1.452
25	Training Provided To Suppliers	0.293	0.087	1.404

Quality Competence and Individual Manufacturing SPTs

Table 4.5 contains results of a series of simple regression analyses with quality competence as the dependent variable and individual manufacturing SPTs as the independent variables. The quality competitive priorities comprising the construct are *product reliability, product durability, conformance quality, design quality, and product improvement/refinement* (see Table 3.3).

The structural SPTs identified include synchronous manufacturing, flexible manufacturing systems (FMS), process-focused factory, and automation. Process-focused factories and flexible systems are generally not associated with the highest levels of quality. Because of the wider product ranges and lower volumes produced on these technologies, they do not achieve levels of repeatability that are normally associated with quality. Synchronous manufacturing and automation can be associated with quality, if procedures and responsibility are clearly delineated (Umble and Srikanth, 1990).

The infrastructural SPTs associated with quality competence are striking due to the paucity of traditional quality-related SPTs. The infrastructural SPTs could be roughly categorized into suppliers, material flow, workforce management, and design. The individual SPTs in these categories are indirectly related to quality, but there are very few SPTs that are directly quality oriented. The supplier oriented SPTs include electronic data interchange (EDI) and selection of suppliers based on price. It is difficult to relate the use of these to quality, except that EDI might be an indicator of partnering or related to reducing paperwork errors. Selecting vendors on price, however, is certainly not associated with the partnering model.

Material flow SPTs include total productive maintenance, preventive maintenance, and failsafing. These SPTs are most related to quality. Maintenance programs keep equipment running and operating at specification. Ensuring that equipment is operable, especially machinery that is used most often for high-volume components, can contribute to quality improvement. Failsafing involves the implementation of small, inexpensive additions to processes that prevent mistakes from occurring and reduce the need for corrective action (Shingo, 1986).

Table 4.5: Individual SPTs Related to Quality Competence

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Supplier Selection Based On Price	0.492	0.009	2.591
2	Synchronous Manufacturing	0.434	0.019	2.209
3	Electronic Data Interchange	0.418	0.023	2.111
4	Flexible Manufacturing System	0.416	0.024	2.097
5	Total Productive Maintenance	0.397	0.031	1.980
6	Process-Focused Factory	0.387	0.034	1.926
7	Failsafing or Foolproofing	0.381	0.037	1.887
8	Preventive Maintenance	0.365	0.044	1.795
9	Employee Involvement	0.352	0.050	1.726
10	Automation	0.340	0.056	1.657
11	Product Standardization	0.325	0.065	1.575
12	Quality Function Deployment (QFD)	0.307	0.077	1.479
13	Worker Motivation	0.406	0.081	1.448

Workforce management SPTs include employee involvement and motivation. Unfortunately, other management-oriented SPTs are not included here, such as employee responsibility for output quality, use of quality improvement tools, etc. Involvement and motivation, while important, cannot and do not place enough authority with the workers to make true process improvements (Walton, 1986).

Product design SPTs include product standardization and quality function deployment (QFD). Standardization reduces variety and increases repeatability, which increases quality levels. QFD is a methodology directed at capturing customer requirements and assigning responsibility for fulfilling these needs (Hauser and Clausing, 1987). It is a marketing/design tool that can ensure customer requirements are being met by production personnel.

To summarize the quality competence analysis, poor performance and support is being offered to quality competitive initiatives, mostly due to an insufficient number of quality-related SPTs—both structural and infrastructural—being implemented. Perhaps Table 4.5 is most striking for what is missing from the table, rather than what is contained.

COMPETITIVE PRIORITY PERFORMANCE AND RELATED INDIVIDUAL MANUFACTURING STRATEGIES, PROGRAMS, AND TECHNIQUES

This section begins the analyses of the third group of hypotheses—those relating to competitive priority performance. As stated in the previous section regarding competitive priority competence, Skinner (1992a) indicates that linkages between competitive initiatives and the manufacturing strategic decision categories are not being established for practitioners. While results from the earlier sections indicated relationships between individual manufacturing SPTs and competence, results from this section will indicate the manufacturing

SPTs that are related to performance. These are the SPTs respondent firms are implementing—without the pretense of strategic direction—and achieving excellent performance within a competitive priority.

Analysis of the relationship between the use of manufacturing SPTs and performance within the competitive priorities may reveal an association beyond the competence constructs. If companies are not emphasizing a particular competitive priority (quality, cost, etc.), but are performing well in that area, they might have lower competence scores while still achieving excellent performance results. In fact, investigating the relationship between the SPTs and performance may reveal a clearer picture—one that is not affected by importance scores—of the SPTs that have a direct impact on performance within a competitive priority.

Hypotheses 3a-3d were constructed to address the issue of linking results to specific competitive thrusts. Hypotheses 3a is listed below:

> **Hypothesis 3a: There is a positive relationship between the extent of use of individual manufacturing strategies, programs and techniques, and cost performance.**

This section will analyze the relationships between performance within the competitive priority constructs and the use of manufacturing SPTs. The performance values for each major priority are the sum of the performance scores for the individual competitive priorities combined to form the cost, delivery, flexibility, and quality constructs (see Table 3.3).

Cost Performance and Individual Manufacturing SPTs

Table 4.6 displays the manufacturing SPTs that are related to cost performance. The individual competitive priorities comprising the cost performance construct are *low production cost, competitive pricing, and low price*. Cost performance is the sum of the subjective performance scores for the three priorities.

Comparing Table 4.6 to Table 4.2 reveals that, of the nine SPTs related to cost performance, only the infrastructural SPT of reducing finished goods inventory is not related to cost competence. Reducing the level of finished goods can have a significant impact on costs, as FGS inventory is held when the value added is highest. Savings here releases cash for other purposes, which can be extremely important for smaller and medium size companies. The other eight SPTs also appear in Table 4.2.

The structural factors that are related to cost competence and not related to cost performance are advanced manufacturing technology and backward integration. Perhaps these SPTs were only marginally contributing to cost reductions, due to the inherent risks each carries. Computer-integrated-manufacturing (CIM) and forward integration are related to both cost competence and performance. At its most basic level, CIM is a hybrid process that combines the benefits of process and product layouts for mid-volume production. Perhaps companies that have advanced to the stage where CIM is a realistic option have an adequate understanding of the complexities involved in managing a CIM operation. Forward integration is a likely cost-related SPT and firms in the sample were successful in implementing this strategy to achieve cost reductions. As stated earlier, distribution of furniture products can be a costly activity and firms that integrate into this industry can control distribution and do not have to add the profits of the transportation firm into their price structure, allowing for lower retail prices.

The infrastructural SPTs that are related directly to cost performance can be classified as related to production planning, purchasing and quality. Planning SPTs include forecasting, reducing finished goods inventory, and producing in large batches. The first two relate to efficiency and reducing wastes due to overproduction, one of Ohno's (1988) seven waste categories. The third is associated with achieving economies of scale.

The purchasing SPTs include purchasing in large quantities and selecting quality suppliers. Cost savings can be generated through quantity discounts and a reduction in inspection and rework costs. Finally, the quality SPTs of "doing things right the first time" and a heavy amount of inspection are related to cost performance. Based on several plant visits, the 100% inspection technique appears to be standard in the furniture industry, especially for large products. This detection approach is, however, expensive and conflicts with the prevention approach to quality.

In summary, cost performance is a difficult area for firms to achieve performance improvement (Ferdows and De Meyer, 1990). The sample firms that are earning cost reductions have used standard approaches—vertical integration and economies of scale in production. They have not, however, successfully implemented many quality-oriented SPTs to support cost reduction.

Table 4.6: Individual SPTs Related to Cost Performance

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Advanced Forecasting	0.507	0.007	2.693
2	Emphasis on "Right-The-First-Time"	0.424	0.022	2.143
3	Purchase in Large Quantities	0.423	0.022	2.138
4	Reduction in Finished Goods Invent.	0.395	0.031	1.973
5	100% Inspection	0.390	0.033	1.940
6	Computer-Integrated-Manufacturing	0.375	0.039	1.856
7	Large Batch Production	0.365	0.044	1.794
8	Forward Integration	0.346	0.053	1.687
9	Supplier Selection Based On Quality	0.304	0.079	1.461

Delivery Performance and Individual Manufacturing SPTs

Table 4.7 displays the competitive priority constructs that are related to delivery performance. The individual competitive priorities comprising the delivery performance construct are *delivery speed, delivery dependability, and production lead time* (see Table 3.3). The delivery performance score for a firm is the sum of the subjective performance scores for the individual competitive priorities above.

The manufacturing SPTs associated with delivery performance are very similar to those associated with delivery competence. Therefore, this analysis will be brief. A more detailed discussion appears in the section regarding delivery competence.

All of the structural SPTs related to delivery competence (see Table 4.3) also appear in Table 4.7. They include product-focused factory, flexible manufacturing system, proprietary technology, process-focused factory, and simplified material flow. As stated earlier, these factors are very closely related to the structural factors associated with production competence. These SPTs are directed at reducing system variability to improve delivery performance, while maintaining the capability to produce wider ranges of products and varying quantities.

All of the infrastructural SPTs in Table 4.7 related to delivery performance appear in the analysis of delivery competence—except for reducing workforce size. Perhaps the firms that were downsizing were forced to improve processes and reducing waste in the system. Reduced variability and faster throughputs may have resulted from the process improvements. The majority of the infrastructural SPTs are related to workforce management issues, particularly in the area of granting increased responsibility to workers and decision-making authority to work teams.

The increased worker responsibility and authority can have two benefits. First, workers feel more ownership of the product and process and, therefore, will make the extra effort required to overcome problems and meet due dates. Secondly, the workers might finally have the authority and opportunity to make suggestions directed at improving process flow, which can dramatically improve cycle times and improve delivery performance.

Flexibility Performance and Individual Manufacturing SPTs

Table 4.8 displays results of a series of simple regression analyses with flexibility performance as the dependent variable and the individual manufacturing SPTs as the independent variables. The

Table 4.7: Individual SPTs Related to Delivery Performance

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Product-Focused Factory	0.392	0.032	1.955
2	Worker Safety	0.391	0.033	1.947
3	Employee Involvement	0.364	0.044	1.792
4	Employees Respons. for Output Qual.	0.348	0.052	1.699
5	Workplace Orderliness	0.334	0.060	1.624
6	Proprietary Technology	0.318	0.070	1.538
7	Reducing Size Of Workforce	0.313	0.073	1.508
8	Flexible Manufacturing System	0.304	0.079	1.465
9	Self-Directed Work Teams	0.290	0.090	1.388
10	Process-Focused Factory	0.288	0.092	1.377
11	Total Productive Maintenance	0.278	0.100	1.326

individual competitive priorities (from Table 3.3) that comprise the flexibility performance construct are *product flexibility, volume flexibility, process flexibility, product development cycle time, and responsiveness to target markets*. Flexibility performance is calculated by summing the subjective performance scores for the five priorities above.

The six structural SPTs related to flexibility performance are identical to those related to flexibility competence. They include product-focused factory, just-in-time, group technology, synchronous manufacturing, proprietary technology, and general purpose equipment. This collection of SPTs is directed at obtaining the flexibility benefits of a process approach to manufacturing while maintaining the competitive cost structures of the product approach (Hill, 1994). This is made possible by dedicating general purpose equipment to the production of product families in a product-focused factory approach. The group technology/synchronous approach, combined with general purpose equipment, allows companies to accomplish this difficult combination. It is interesting that JIT appears in Table 4.8, as it can provide some, but limited flexibility. JIT works best in situation with limited product flexibility and stable volumes.

The infrastructural SPTs in Table 4.8 can be roughly (without statistical analysis) classified into the categories of workforce management, quality, product design, production planning, material flow, and supplier management. The workforce and organizational management oriented SPTs include specialization, training (for workers, executives, and managers), motivation, safety, vertical job enlargement, employment involvement, self-directed work teams, and cross-functional teams. These SPTs emphasize including workers in decision-making and implementing process improvements. The cross-functional team approach helps to improve horizontal processes such as completing delivery and providing flexibility (Byrne, 1993). Placing the workforce in teams and enlarging responsibilities can improve motivation levels and engender a culture that embraces the organizational change that accompanies strategies that emphasize flexibility. Worker specialization may appear counter-intuitive, but it is in alignment with the structural SPTs in Table 4.8 that emphasize the product-focused approach.

The abilities of a trained and motivated workforce are capitalized by the many quality-oriented SPTs related to flexibility performance. These SPTs include employing the seven basic quality tools (flow diagrams, check sheets, histograms, pareto charts, fishbone diagrams, scatterplots, and control charts), using advanced statistical techniques, measuring and testing product reliability, zero defects programs, and acceptance sampling. Less obvious quality SPTs include the use of color coding machines and parts to minimize time wasted during changeovers. This is largest representation of quality-related SPTs in any of the previous analyses, indicating the crucial importance of quality improvement when competing on flexibility. This substantiates the sand cone model presented by Ferdows and De Meyer (1990), in which quality is the building block for other strategic initiatives.

The material flow/planning SPTs related to flexibility performance include setup reduction, which may be the most important SPT in the entire table (Shingo, 1986). Reducing setup times allows firms to economically produce smaller batches of products. This contributes to the support of all of the individual priorities comprising the delivery performance construct, indicating the critical importance of setup reduction. The planning SPT in Table 4.8 is mixed model production scheduling. Capitalizing on the synchronous and JIT capabilities, and the short setup times, this SPT greatly contributes to flexibility by running small quantities of goods through the flexible facility, rounding out the entire system.

In summary, flexibility performance is being achieved by respondent firms through several critical channels. First, general purpose equipment is combined with other product-oriented technologies, allowing firms to simultaneously obtain the benefits of product and process layouts. Reduced setup times and mixed model scheduling, which can improve the effective capacity of a factory,

Table 4.8: Individual SPTs Related to Flexibility Performance

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Worker Specialization	0.584	0.002	3.298
2	Product-Focused Factory	0.547	0.004	2.991
3	Workplace Orderliness	0.539	0.004	2.933
4	Training For Workers	0.537	0.004	2.918
5	Just-In-Time	0.524	0.005	2.822
6	Group Technology	0.490	0.009	2.576
7	Worker Motivation	0.479	0.010	2.498
8	Worker Safety	0.458	0.014	2.363
9	Synchronous Manufacturing	0.434	0.019	2.210
10	Proprietary Technology	0.421	0.023	2.125
11	Use Of The Seven Basic Quality Tools	0.414	0.025	2.085
12	Computer-Aided Design	0.404	0.028	2.026
13	Product Reliability Testing	0.397	0.030	1.982
14	Reduce Num. Of Eng. Change Orders	0.396	0.031	1.976
15	Training For Execs. And Managers	0.391	0.032	1.949
16	Acceptance Sampling	0.389	0.033	1.937
17	Vertical Job Enlargement	0.383	0.036	1.901
18	Product Standardization	0.373	0.040	1.842
19	Zero Defects	0.355	0.048	1.740
20	Self-Directed Work Teams	0.351	0.050	1.718
21	Measuring Product Reliability	0.342	0.055	1.668
22	Setup Time Reduction	0.326	0.065	1.578
23	Employee Involvement	0.310	0.075	1.497
24	Mixed-Model Production Scheduling	0.307	0.077	1.480
25	Adv. Statistical Techniques (Quality)	0.302	0.081	1.451
26	Cross-Functional Teams	0.298	0.083	1.433
27	General Purpose Equipment	0.289	0.090	1.385
28	Supplier Selection Based On Price	0.289	0.091	1.383
29	Color Coding Of Machines And Parts	0.286	0.093	1.370

also allow for increased responsiveness. Second, the management style in firms with high flexibility performance appears to be oriented toward pushing authority and responsibility down the organization. Employees work in cross functional and self-directed teams to solve process related-problems. Third, taking advantage of the motivated workforce, quality SPTs are widely implemented to support process improvements. Finally, scheduling and planning SPTs emphasize the efficient flow of materials through a facility, while also using the flexibility of the process and employees to schedule a variety of products.

Quality Performance and Individual Manufacturing SPTs

This section discusses the results of a series of simple regressions with quality performance as the dependent variable and the individual manufacturing SPTs as independent variables. The quality competitive priorities comprising the quality performance construct are *product reliability, product durability, conformance quality, design quality, and product improvement/refinement* (see Table 3.3). Quality performance is determined by summing the subjective performance scores for the five individual priorities above.

The structural SPTs that are related to quality performance are dominated by technologies used in high-volume, repetitive manufacturing. Automation is used to replace more variable humans in tasks that are repetitive. Proprietary technology can include that which accomplishes several tasks in a short period, all with minimal variability. Except for automation, the structural SPTs are different for quality competence, an inconsistency not found in the delivery and flexibility analyses.

The infrastructural SPTs related to quality performance can be roughly classified into the categories of quality, design, workforce management, and suppliers. The quality SPTs are reliability testing,

Table 4.9: Individual SPTs Related to Quality Performance

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Supplier Selection Based On Price	0.585	0.002	3.308
2	Product Reliability Testing	0.546	0.004	2.983
3	Acceptance Sampling	0.469	0.012	2.436
4	Product Standardization	0.437	0.019	2.225
5	Design For Manufacturability	0.412	0.025	2.071
6	Proprietary Technology	0.404	0.028	2.021
7	Product-Focused Factory	0.401	0.029	2.004
8	Automation	0.379	0.037	1.875
9	Worker Motivation	0.372	0.040	1.839
10	Inspection Of Incoming Materials	0.367	0.042	1.808
11	Worker Specialization	0.350	0.051	1.714
12	Variety Reduction	0.307	0.077	1.476
13	Quality Function Deployment (QFD)	0.300	0.082	1.441

acceptance sampling, and inspection of incoming materials. The emphasis on quality SPTs was much stronger in the areas of delivery and flexibility, and fairly weak in the areas of quality and cost.

As with quality competence, the SPTs in Table 4.9 should be noted for their emphasis on detection rather than prevention. This indicates the lack of maturity and transitional state of the furniture industry, with respect to production quality. Design-oriented SPTs include design for manufacturability, quality function deployment, and product standardization. Variety reduction, essentially a business issue, is also related to design. These SPTs indicate a movement toward preventing quality problems and increasing repeatability, while keeping customers satisfied. Finally, the workforce SPTs—motivation and specialization—should have a far greater representation. It is in this area that the majority of the quality-oriented SPTs that are related to delivery and flexibility appear.

In summary, respondent firms afforded relatively weak support to quality strategic initiatives. When compared to the nature of support provided delivery and flexibility, the SPTs supporting quality performance are too few, too focused on detection, and not oriented enough toward employee involvement.

RETURN ON ASSETS (ROA) AND RELATED INDIVIDUAL MANUFACTURING STRATEGIES, PROGRAMS, AND TECHNIQUES

This section begins the analyses of the fourth hypothesis, which investigates the relationship between firm performance and the use of manufacturing SPTs.

Investigating the relationship between the use of manufacturing strategies, programs, and techniques and overall firm performance provides information regarding the strategies that the highest overall performing firms feel are important. This will add to the body of knowledge being created regarding manufacturing strategies.

Overall firm performance was measured using the ROA before tax relative to historic performance (internal assessment). The following hypothesis was tested in this analysis:

> **Hypothesis 4: There is a positive relationship between subjective overall firm performance and the use of manufacturing strategies, programs, and techniques.**

Table 4.10 presents results from a series of simple regression analyses, in which pretax ROA (internal assessment) was the dependent variable, and the manufacturing SPTs were the independent variables.

The highest performing firms used dedicated and proprietary equipment, combined with workers who performed narrow, specialized tasks to obtain advantages. Quality tools such as control charts were used by high performers to maintain quality levels and take full advantage of economies of scale. High performers motivated the employees in narrow jobs through gainsharing programs.

The manufacturing SPTs related to overall performance are fewer in number than in the previous analyses. This may be due, in part, to the small sample and that the performance scores were on a seven point Likert scale, which does not have the variability of the combined measures (production competence, and competitive priority competence and performance).

Table 4.10: Individual SPTs Related to ROA (Internal Assessment)

	Manufacturing Strategies, Programs, and Techniques	Beta	p-value	t-stat
1	Use of Control Charts	.470	.014	2.379
2	Proprietary Technology	.408	.029	1.999
3	Use of the Seven Basic Quality Tools	.382	.039	1.849
4	Worker Motivation	.379	.049	1.833
5	Worker Specialization	.338	.062	1.608
6	Gainsharing	.303	.085	1.424
7	Dedicated Equipment	.296	.091	1.383

MANUFACTURING STRATEGIES, PROGRAMS, AND TECHNIQUES GROUPED BY COMPETITIVE PRIORITY/JIT

Previously, the relationship between individual manufacturing SPTs and production competence, competitive priority competence, competitive priority performance, and overall firm performance was discussed. This section begins analyses between the competence and performance constructs, and SPTs arranged into logical groups. Specifically, the groups are arranged according to competitive priority (cost, delivery, flexibility, and quality). Additionally, due to rapidly growing importance, manufacturing SPTs related to just-in-time have also been grouped together to test their association with competence and performance.

Quality-Related Manufacturing SPTs

Table 4.11 lists the arrangement of individual manufacturing SPTs into groups according to the *criteria* and *items* of the Malcolm Baldrige National Quality Award. The left column indicates the variable name for each criteria and item (in parentheses). The variable names are used in all of the subsequent tables presenting results. The criteria are listed in **bold** and the items are in regular type. The right column lists the associated manufacturing SPTs determined through a literature search. The scores for the items (e.g., employee involvement) are equal to the sum of the extent of use scores of the individual SPTs associated with the item. The scores for the criteria are equal to the sum of the associated item-level scores.

Hypotheses 5a through 5n are constructed to investigate the existence of relationships between the use of SPTs associated with Baldrige *criteria*, and competence and performance. The first analysis is directed at the relationship between the Baldrige criteria and competence. The hypotheses are listed below:

> **Hypotheses 5a-5e: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige criteria and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, and (e) quality competence.**

> **Hypotheses 5f-5j: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige criteria and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, and (j) quality performance.**

> **Hypotheses 5k-5n: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige criteria and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (n) aftertax ROA-external assessment, (o) aftertax ROA-internal assessment.**

Table 4.12 displays the results of the multiple regression analyses used to test the hypotheses concerning the Baldrige criteria. Table 4.12 only displays results of models with significant results (significant F-test). The stepwise regression technique was used. Each cell in the table (defined by bold borders) represents one test. For example, the first cell represents the model with production competence as the dependent variable and the three Baldrige Criteria as the independent variables (see Hypothesis 5a).

Contrary to claims of Baldrige and quality management proponents, the results do not indicate any relationship between production competence and the Baldrige criteria (and associated SPTs). This result indicates that firms that provide manufacturing support to their strategic objectives are doing so without focusing on quality initiatives relating to Baldrige criteria—either information-, human resource-, or process-oriented.

Table 4.12 indicates some support for the for the sand cone model presented by Ferdows and De Meyer (1990). The model suggests that quality programs must be in place before capability in other areas can be achieved. These results indicate that SPTs related to quality processes and human resources contribute positively to the support of cost and flexibility initiatives. The QPROCESS criterion is comprised of several traditional quality improvement tools, including maintenance, the seven basic improvement tools, failsafing, vendor issues, and design issues (see Table 4.11). These SPTs provide operable, reliable equipment upon which well-designed products can be produced. Results linking quality tools with cost reduction substantiates the claim that these items are

Table 4.11: Baldrige Criteria/Items & Manufacturing SPTs

Baldrige criteria (BOLD) & items	Related manufacturing SPTs
Information & analysis (QINFO)	Avail. of cost of qual. data to managers Avail. of quality related data to workers Timely feedback of quality data Avail. of qual. related data to managers Benchmarking
HR devt. and mgt. (HRDM)	
Employee involvement (HREI)	Employee suggestions Self-directed work teams Employees responsible for quality Employee involvement
Employee education and training (HRET)	Training for executives and managers Training for workers
HR management HRM	Product teams Vertical job enlargement Worker motivation Cross-training workers Quality circles Visible performance charts Cross-functional teams
Emp. perform. & recognition (HRPR)	Employee recognition Goalsetting Gainsharing
Employee well being/morale (HRWB)	Quality of work life initiatives Worker safety
Process quality (QPROCESS)	
Product production and deliv. processes (PQP)	Failsafing or foolproofing Total productive maintenance (tpm) Preventive maintenance Emphasis on "right the first time" Mean and range control charts Use of 7 basic qual. Improvement tools
Quality assessment (PQA)	Product reliability testing Measuring product reliability Quality audit
Process mgt.—business processes (PQB)	Functional integration
Design and intro. of quality prod. (PQD)	Coord. Among depts. In product design Quality function deployment (qfd) Concurrent engineering Involve suppliers in product design Design for manufacturability
Supplier quality (PQS)	Supplier certification Supplier selection based on quality Training provided to suppliers

Table 4.12: Competence/Performance Variables & Baldrige Criteria

Depend. Variable	Production Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
Indep.	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
QInfo										
QHrdm			-.37	.08			.285	.090		
QProcess			.474	.03						
R^2			.229				.081			
	Production Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
QInfo										
QHrdm							.445	.02		
QProcess	.410	.03								
R^2	.168						.200			
	Pretax ROA External		Pretax ROA Internal		Aftertax ROA-Ext.		Aftertax ROA-Int.			
	Beta	p	Beta	p	Beta	p	Beta	p		
QInfo										
QHrdm										
QProcess										
R^2										

complementary, not contradictory. Although it was not hypothesized, the human resource criteria was negatively related to cost competence, perhaps indicating that sample firms felt that more rigid, mechanistic structures were more conducive to low costs that structures that promote teams.

The criterion concerning human issues (QHRDM) contains SPTs related to increasing the level of authority given to workers, team-centered approaches, training, and rewards. A happy, well-trained workforce with the authority to make process changes is able to provide excellent support to flexibility initiatives. The Baldrige criteria were not related to delivery or, more surprisingly, quality competence.

The competitive priority performance constructs are slightly similar to the competence constructs, except that they do not account for the importance of a competitive dimension to a firm's strategy or manufacturing's contribution. They are simply the sum of the performance scores of the individual included in the construct. The performance scores can indicate relationships between SPTs and particular competitive dimensions that may be obscured by strategic direction.

Regarding the performance models, Table 4.12 indicates that the QPROCESS criterion is positively related to production performance, negatively related to flexibility performance, and that the QHRDM criterion is positively related to flexibility. These results differ slightly from the competence results. First, sample firms that scored highest across the 31 competitive priorities employed the SPTs associated with QPROCESS. This indicates that there may be a relationship between the use of quality-related SPTs and general strategies. The competence construct did not support this. The second difference is that a relationship to cost performance is not supported, perhaps indicating that quality programs may not be related to lower costs.

The SPTs associated with the Baldrige criteria were not related to overall firm performance (as measured by ROA). Again, this result may be attributed to low variance within the performance measures, rather than the absence of true relationships.

It was observed in Chapter 3 that, due to aggregation, the variables representing the Baldrige criteria may obscure relationships between the quality-related SPTs and competence/performance. It was suggested that simple regression analysis using the Baldrige *items* may reveal additional information. The hypotheses investigating this approach are below.

> **Hypotheses 5p-5t: There is a positive relationship between the extent of use manufacturing SPTs associated with Baldrige <u>items</u>, and (p) production competence, (q) cost competence, (r) delivery competence, (s) flexibility competence, or (t) quality competence.**
>
> **Hypotheses 5u-5y: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige <u>items</u> and (u) production performance, (v) cost performance, (w) delivery performance, (x) flexibility performance, or (y) quality performance.**
>
> **Hypotheses 5z-5ac: There is a positive relationship between the extent of use of manufacturing SPTs associated with Baldrige <u>items</u> and (z) pretax ROA-external assessment, (aa) pretax ROA-internal assessment, (ab) aftertax ROA-external assessment, (ac) aftertax ROA-internal assessment.**

Table 4.13 presents the results of the simple regression conducted to test the above hypotheses (analyses of the relationship between the SPTs associated with Baldrige items, and competence/performance). The Baldrige items range from employee issues to design to process issues (see Table 4.11). The section of the table concerning competence reveals that, similar to the Baldrige criteria, there are no significant relationships between the Baldrige items and production competence. This result contradicts much of the current thinking regarding the necessity to improve the overall quality of products and processes. This result may be due to the fact that sample firms have not yet realized the importance of the quality issue.

The discussion regarding Baldrige criteria indicate that the QPROCESS criterion was related to cost competence. Of the five Baldrige items associated with the criterion, only items relating to process quality (PQP) issues and vendor issues (PQS) are related to cost competence. The SPTs included in the process quality item are traditional items such as maintenance and basic quality improvement tools. This result also supports the writings of many authors claiming that quality improvement and lower costs are not to be traded off against each other, but, instead are complementary. Vendor issues are also quality-related in that they strive to reduce the variability of incoming parts from suppliers. This is accomplished by eliminating marginal suppliers and granting the selected suppliers increased volumes and training. This move to a partnership model can reduce costs, as these results indicate (Ellram, 1991). The analysis does not indicate support for the claim that improving the design process or quality assessment are positively associated with cost competence.

Delivery competence is associated with the Baldrige items of employee involvement (HREI) and employee well-being and morale (HRWB). Involvement includes SPTs concerning placing decision-making authority with the workforce through self-directed teams or allowing worker direct accountability for their own output. These changes may provide a feeling of product ownership to the

Table 4.13: Competence/Performance Variables & Baldrige Items

Depend. Variable	Production Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
Indep.	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
HREI					.309	.075				
HRET							.442	.018		
HRM										
HPR										
HRWB					.291	.089	.385	.035		
PQP			.445	.017						
PQA							.322	.067		
PQB										
PQD										
PQS			.498	.008					.333	.060
	Production Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
HREI	.358	.031			.309	.076	.282	.096		
HRET	.568	.002					.508	.007		
HRM	.299	.083					.328	.063	.294	.087
HPR										
HRWB	.360	.046					.316	.071		
PQP										
PQA	.607	.001					.348	.052	.311	.075
PQB										
PQD									.360	.046
PQS			.287	.093						
	Pretax ROA External		Pretax ROA Internal		Aftertax ROA-Ext.		Aftertax ROA-Int.			
	Beta	p	Beta	p	Beta	p	Beta	p		
HREI										
HRET										
HRM							.314	.077		
HPR										
HRWB										
PQP							.294	.092		
PQA										
PQB										
PQD										
PQS										

NOTE: see Table 4.11 for Variable Definitions & Associated SPTs employees, who may then work to ensure that delivery dates are met. Alternatively, placing authority lower in an organization can speed up decision making cycles by eliminating the need for management approval. Perhaps the other items related to the criterion HRDM obscured the association between delivery and the employee involvement and morale issues.

Flexibility competence can be achieved by implementing employee education and training programs (HRET), keeping a safe workplace (HRWB), and periodically ensuring quality through testing (PQA). These quality items can assist firms by training both employees and management to improve processes. Improved levels of safety can serve to motivate workers to learn new skills.

The only Baldrige item related to quality competence was vendor related (PQS). This relationship indicates the critical nature of the supply base and its impact on the quality system of a company. The quality of incoming parts is a critical input to the quality of a firm's end product.

Production performance is a very broad measure of performance, equal to the sum of the performance scores of the priorities listed in Table 2.1. The Baldrige items that are associated with production performance, except for the assessment item, primarily concern employee-related issues. The use of SPTs related to employee involvement (HREI), training (HRET), team approaches (HRM), and safety concerns (HRWB) appear to be implemented by firms who feel they perform well across the 31 dimensions. This is an important result as human issues are often the most difficult for firms to overcome when implementing quality improvement programs, and can frequently derail improvement efforts (Walton, 1986). These results indicate that firms must work extremely hard at successfully increasing employee responsibilities.

The same Baldrige items are also related to flexibility performance. It is apparent that firms competing on this dimension must place a substantial investment in its employees.

The Baldrige items related to quality performance are the team-oriented approaches (HRM), improved designs (PQD), and periodic testing (PQA). The SPTs associated with design concern cross-functional efforts directed at reducing downstream problems by including several functions, including suppliers, into the design process.

Finally, the only association between the Baldrige items and ROA occurred in the items related to team building (HRM), motivation and an expanded role for employees. Also, the use of traditional quality tools (PQP) is related to improved returns. Again, these two items—people issues and the use of traditional improvement tools—are not radical ideas, but, instead are the building blocks of quality improvement (Brocka and Brocka, 1992).

Delivery-Related Manufacturing SPTs

In a recent article (The Economist, 1994), it was noted that as quality becomes an order qualifier, or a requirement to do business in a particular market, companies are winning orders or gaining competitive advantage by reducing the time it takes to deliver products. This section presents results of multiple regression analyses conducted to test a series of hypotheses relating to the contribution of delivery-related SPTs to competence and performance. The hypotheses are listed below.

> **Hypotheses 6a-6e: There is a positive relationship between the use of manufacturing SPTs associated with delivery and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, or (e) quality competence.**
>
> **Hypotheses 6f-6j: There is a positive relationship between the use of manufacturing SPTs associated with delivery and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, or (j) quality performance.**
>
> **Hypotheses 6k-6n: There is a positive relationship between the use of manufacturing SPTs associated with delivery and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.**

Table 4.14 displays the manufacturing SPTs that comprise the delivery variables (DelProcs and DelInfra). Table 4.15 displays the results of the regressions. Stepwise regression was used and only the results of significant models (determined through an F-test) appear. As in previous analyses, an alpha level of .10 was used.

The results of the tests indicate that, of the first set of hypotheses, only 6c and 6e are rejected. The data indicate a relationship between the two delivery variables and production, cost, and flexibility competence. The DelProcs variable was positively related to both production and flexibility competence.

The process-oriented SPTs include items directed at improving

Table 4.14: Delivery Variables and Related Manufacturing SPTs

DelInfra SPTs	DelProcs SPTs
Depart. coordination in design	Dedicated equipment
Cross-functional teams	Group technology
Cross-training workers	Just-in-time
Design for manufacturability	Preventive maintenance
Reliance on fewer suppliers	Reducing setup times
Supplier certification	Reduction in throughput times
Supplier selection - quality	Simplified material flow
Workplace orderliness	

Table 4.15: Competence/Performance & Delivery Variables

Depend. Variable	Production Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
Indep.	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
DelProcs	.462	.02					.615	.001		
DelInfra	-.32	.07	.287	.09			-.432	.02		
R^2	.213		.082				.379	.01		
	Production Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
DelProcs	.359	.05					.650	.005		
DelInfra							-.459	.02		
R^2	.129						.423	.004		
	Pretax ROA External		Pretax ROA Internal		Aftertax ROA-Ext.		Aftertax ROA-Int.			
	Beta	p	Beta	p	Beta	p	Beta	p		
DelProcs										
DelInfra										
R^2										

Note: Betas are standardized.

material flow, either through layout design or operating policies (see Table 4.15). The association of these SPTs with production competence indicates that they may represent a core set of SPTs firms should implement, regardless of strategic direction. It does seem that simplifying flows and reducing set-up times can be beneficial to all firms.

Flexibility competence is defined as the measure of support provided to flexibility-directed competitive thrusts. These include product, volume, and process flexibility, offering a broad product line, quick product development of products, and being responsive to target markets see Table 3.3). By reducing setup times and improving throughput times, firms can be more responsive to customers and handle a wider variety of products—critical benefits to a firm competing on flexibility. Ensuring that equipment is operable increases processing alternatives for firms.

The relationship between the infrastructural elements of delivery and cost competence is interesting. It indicates that eliminating waste in systems, improving the design process, implementing a vendor management program, and keeping the facility clean can contribute to cost reduction initiatives. Many of these SPTs are related to elements of just-in-time which has been linked to lowering costs (Schonberger, 1986).

Table 4.14 also indicates that the delivery variables are related to production performance and flexibility performance. The hypotheses regarding relationships between performance in the priorities of cost, delivery, and quality, and the delivery variables were not supported. Again, the variable DelProcs was positively

Table 4.16: Flexibility Variables and Manufacturing SPTs

FlexInfr SPTs	FlexProc SPTs
Coordination in product design	Advanced mfg. technology
Cross functional teams	CIM
Cross training workers	FMS
Employee involvement	General purpose equipment
Supplier certification	Group technology
TQC	Just-in-Time
Use of 7 basic quality tools	Maintain excess capacity
Workplace orderliness	Product focused factory
	Reduce setup times
	Reduction in throughput times
	Simplified material flow

Table 4.17: Competence/Performance and Flexibility Variables

Depend. Variable	Production Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
Indep.	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
FlexProc							.457	.01		
FlexInfr										
R^2							.209			
	Production Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
FlexProc							.415	.03		
FlexInfr	.372	.04								
R^2	.138						.173			
	Pretax ROA External		Pretax ROA Internal		Aftertax ROA-Ext.		Aftertax ROA-Int.			
	Beta	p	Beta	p	Beta	p	Beta	p		
FlexProc										
FlexInfr										
R^2										

Note: Betas are standardized)

related to both production and flexibility—this time with performance.

The hypotheses claiming a relationship to ROA measures were not supported. As stated several times, this may be more due to the ROA measure than the affects of the delivery variables.

Flexibility-Related Manufacturing SPTs

Flexibility is a complicated construct that has many meanings (Gerwin, 1993). The new flexibility variables created by grouping related SPTs are called FlexProc (process-related) and FlexInfr (infrastructural) (see Table 4.16). The SPTs associated with FlexInfr concern management, design, and quality issues, while FlexProc concerns layout and technology issues. The hypotheses related to the flexibility variables and SPTs are listed below.

> **Hypotheses 7a-7e: There is a positive relationship between the extent of use of manufacturing SPTs associated with flexibility and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, or (e) quality competence.**

> **Hypotheses 7f-7j: There is a positive relationship between the extent of use of manufacturing SPTs associated with flexibility and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, or (j) quality performance.**

> **Hypotheses 7k-7n: There is a positive relationship between the extent of use of manufacturing SPTs associated with flexibility and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax**

ROA-external assessment, (n) aftertax ROA-internal assessment.

Table 4.17 indicates that the only competence construct related to a flexibility variable is flexibility competence. The remaining hypotheses in the first set were not supported. The significant model explains about 21% of the variance in the flexibility competence construct, all of that from the process-oriented variable. The combination of technology and efficient material flow provides a powerful capability for firms. The SPTs, identified through a literature search, are shown to be supportive of a flexibility strategy, just as the authors of the studies suggested they would be.

The table also reveals that the flexibility variables are related to production performance and flexibility performance, just as the case with the delivery variables. The DelProcs and FlexProc variables share a couple of SPTs and are highly correlated (r=.88), so it is not surprising that they are related to the same constructs. Again, just as with the delivery variables, there is no relationship between the two flexibility variables and the ROA variables.

Cost-Related Manufacturing SPTs

In the sand cone model presented by Ferdows and De Meyer (1990), cost capability is the last to be acquired by firms. This indicates that cost reduction is a difficult endeavor, requiring abilities in several areas. Table 4.18 lists the cost variables and associated manufacturing SPTs indicated by the literature to be effective tools to reduce costs. These new variables (CostQual, CostDes, and CostEff) contain elements related to quality, design, and economies of scale.

Given this broad scope of capabilities represented, the cost variables may have implications for competence and performance along other competitive dimensions. The hypotheses below express this potential.

> **Hypotheses 8a-8e: There is a positive relationship between the extent of use of manufacturing SPTs associated with cost and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, and (e) quality competence.**

> **Hypotheses 8f-8j: There is a positive relationship between the extent of use of manufacturing SPTs associated with cost and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, and (j) quality performance.**

> **Hypotheses 8k-8n: There is a positive relationship between the extent of use of manufacturing SPTs associated with cost and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.**

Table 4.19 displays results of the stepwise regression analyses used to test the hypotheses related to the cost variables. Regarding competence, the results support the hypotheses stating a relationship between cost variables, and production, cost, and flexibility competence. The other competence hypotheses were not supported. CostEff, which is comprised of traditional economies of scale SPTs (see Table 4.18), is the only variable related to production and cost competence.

The SPTs associated with CostEff include automation, buying

Table 4.18: Cost Variables and Related Manufacturing SPTs

CostQual SPTs	CostEff SPTs
Failsafing Or Foolproofing	Automation
Total Quality Control (TQC)	Backward Integration
Seven Quality Improvement Tools	Dedicated Equipment
Zero Defects	Forward Integration
	Large Batch Production
CostDes SPTs	Proprietary Technology
Design For Manufacturability	Purchase In Large Quantities
Product Simplification	Reducing Size of Work Force
Product Standardization	Work Measurement
Value Analysis	Worker Safety
Variety Reduction	Worker Specialization
	Simplified material flow

Table 4.19: Competence/Performance and Cost Variables

Depend. Variable	Production Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
Indep.	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
Costeff	.329	.06	.383	.04						
Costqual							.456	.01		
Costdes										
R^2	.109		.147				.208			
	Production Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
Costeff	.524	.01					.346	.06		
Costqual										
Costdes									.392	.03
R^2	.275						.120		.154	
	Pretax ROA External		Pretax ROA Internal		Aftertax ROA-Ext.		Aftertax ROA-Int.			
	Beta	p	Beta	p	Beta	p	Beta	p		
Costeff										
Costqual										
Costdes										
R^2										

Note: Betas are standardized.

and producing in large quantities to achieve economies, and a specialized workforce utilizing dedicated equipment. These SPTs are most effective in situation requiring a line process, which would include standardized products in the latter stages of their life cycle (Hill, 1994). Many furniture products could be classified as mature, standard products, and furniture manufacturers have been able to achieve economies of scale in their facilities. For firms in the sample, traditional cost-related SPTs are implemented by firms providing the best support to cost objectives.

The variable related to flexibility competence—CostDes—is comprised of SPTs concerned with design issues. These SPTs seek to simplify and standardize products, thereby increasing repeatability and allowing for larger order quantities. They also contribute to the design of products that are easier to manufacture, further reducing costs. The relationship between a cost variable to a flexibility construct may, at first, seem contradictory. However, firms that compete on flexibility do not solely rely on wide variety. Other dimensions are more concerned with responsiveness. Designing products that can be made quickly and without error are very much complementary to flexibility agendas.

The CostDes variable is also related to quality performance. It is, in fact, the only variable that is significantly related to either quality conformance or performance. The relationship of CostDes to both flexibility and quality is an important result. This indicates the critical nature of design issues and also supports the interrelatedness intimated by the sand cone model (Ferdows and De Meyer, 1990). Recent studies indicate that upwards of 80% of a product's cost is determined at the design stage (Giffi, Roth, and Seal, 1990). As long as the design in linked to customer demands, applying the SPTs contained within the CostDes variable can help in firms in several areas.

CostEff is also positively related to production competence and performance. This perhaps reflects the notion that, while many furniture products are in the mature stage of the product life cycle, the technology-oriented SPTs associated with CostEff may be contributing to performance within other competitive dimensions included in the production constructs.

JIT-Related Manufacturing SPTs

The just-in-time (JIT) variables were included because of the growing base of literature that suggests JIT-type systems can greatly improve performance (Schonberger, 1982; Finch, 1986; Gunn, 1992). The SPTs found to be associated with the JIT variables (JitProcs and JitInfra) are listed in Table 4.20. The potential benefits of JIT implementation include lower costs, improved quality, timely production, and better competitive performance (Heiko, 1991; Walleigh, 1986; Schonberger, 1986). The tested hypotheses related to these benefits are below:

> **Hypotheses 9a-9e: There is a positive relationship between the extent of use of manufacturing SPTs associated with JIT and (a) production competence, (b) cost competence, (c) delivery competence, (d) flexibility competence, and (e) quality competence.**

> **Hypotheses 9f-9j: There is a positive relationship**

between the extent of use of manufacturing SPTs associated with JIT and (f) production performance, (g) cost performance, (h) delivery performance, (i) flexibility performance, and (j) quality performance.

Hypotheses 9k-9n: There is a positive relationship between the extent of use of manufacturing SPTs associated with JIT and (k) pretax ROA-external assessment, (l) pretax ROA-internal assessment, (m) aftertax ROA-external assessment, (n) aftertax ROA-internal assessment.

Table 4.21 displays the significant results of the series of (stepwise) multiple regressions conducted to test the above hypotheses. The JIT models are significantly related to production, delivery, and flexibility competence. In each model, only the JitProcs variable is significant.

The SPTs associated with JitProcs are very similar to those associated with DelProcs (r=.92). The SPTs include maintenance, reducing setup times, and workflow issues (see Table 4.20). Relative to DelProcs, this set of SPTs is also related to production and flexibility competence. However, the JitProcs variable is also related to delivery competence, while the DelProcs variable is related to flexibility competence. These results further indicate the wide variety of capabilities generated by these SPTs.

JIT is concerned with eliminating waste and improving material flow (Ohno, 1984). The results indicate that the use of these SPTs can support strategic objectives related to delivery and flexibility.

The performance section reveals that the infrastructural

Table 4.20: JIT Variables and Related Manufacturing SPTs

JitInfra SPTs	JitProcs SPTs
Product Simplification	Group Technology
Reduction in WIP Inventory	Just-in-Time
Supplier Certification	Preventive Maintenance
Cross-Training Workers	Total Productive Maintenance
Employee Involvement	Workplace Orderliness
Training for Workers	Simplified Material Flow
	Reducing Setup Times

Table 4.21: Competence / Performance and JIT Variables

Depend. Variable	Production Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
Indep.	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
JitProcs	.429	.02			.357	.05	.484	.01		
JitInfra										
R^2	.184				.123		.234			
	Production Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
JitProcs							.521	.005		
JitInfra	.451	.02								
R^2	.203						.272			
	Pretax ROA External		Pretax ROA Internal		Aftertax ROA-Ext.		Aftertax ROA-Int.			
	Beta	p	Beta	p	Beta	p	Beta	p		
JitProcs	.416	.04			.415	.04				
JitInfra	-.59	.004			-.59	.005				
R^2	.347	.027			.351	.03				

Note: Betas are standardized.

variable—JitInfra—is related to production performance. The JitInfra variable is associated with SPTs concerning product design, workforce issues, and materials management issues. This result is interesting in that it indicates that issues beyond material flow and the process are important. Preparing the people and products to work in a JIT system also contributes to performance.

JitProcs, already related to flexibility competence, likewise is related to flexibility performance. This result increases the confidence in statements linking the use of JIT-related SPTs to supporting flexibility initiatives.

Finally, the JIT variables are related to the overall financial performance measures—pretax return on assets (ROA). JitProcs is positively related to financial performance. This, coupled with the relationship between JitProcs and production competence/performance, can be interpreted as providing further support for claiming that these SPTs form a core set of strategies.

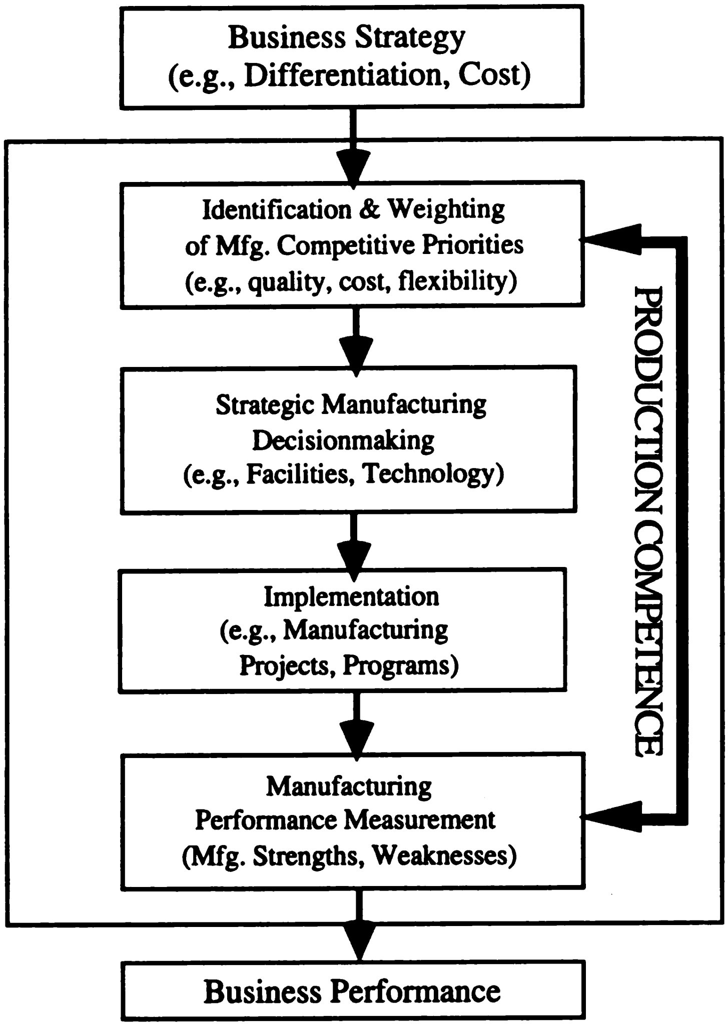
V. IMPLICATIONS

This chapter will review results of the previous chapter as they relate to the hypotheses presented in Chapter 3, highlight the contributions of the research, indicate the limitations of the research project, and finally, mention several extensions of the project.

Before reviewing the hypotheses, it should be noted that this study is an extension of the production competence work initiated by Cleveland, et al. (1989), which was extended by Vickery, et al., (1993). In the latter study, the production competence construct was expanded and the measurement of the production competence score was improved. In Vickery, et al. (1993), a significant relationship between production competence was identified.

This study extends that research by expanding the process model of manufacturing strategy presented by Vickery (1991) (see Figure 5.1). In this model, competence is a measure of the support (i.e., manufacturing performance) provided business strategic objectives. The extension of this study is the *identification* of the strategies, programs and techniques implemented to support the manufacturing competitive priorities. Previous research in the competence area emphasized the existence of the construct and its relationship to firm performance.

This study utilized a subset of the sample in Vickery, et al. (1993). Results presented in Table 4.10 indicate that, within the subset, a positive relationship between production competence and firm performance was again identified. Given the existence of the relationship, the discussion of the hypotheses follows. In all



Source: Adapted from Vickery (1991)

Figure 5.1: A Process Model of Production Competence

hypotheses, significance was determined using a t-test with an alpha-level of .10.

Review Of Hypotheses

This section will review the hypotheses presented in Chapter 3 and the associated results appearing in Chapter 4.

Production Competence

The first hypothesis is directed at the identification of the manufacturing strategies, programs, and techniques (SPTs) related to production competence. These SPTs are the strategic content (outcomes) of the decision making process as shown in Figure 5.1. Hypothesis 1 is restated below:

> **Hypothesis 1: There is a positive relationship between the extent of use of individual manufacturing strategies, programs and techniques, and production competence.**

Table 5.1 presents the SPTs that are significantly related to production competence. These SPTs can be further classified into Hayes and Wheelwright's (1984) categories of structural and infrastructural factors. The structural SPTs that relate to production competence are most concerned with the flow of product through a facility. It does not seem to matter if a facility employs a product-focus or a process-focus. What does matter is that firms understand the critical nature of the process positioning decision (Hill, 1994; Krajewski and Ritzman, 1993).

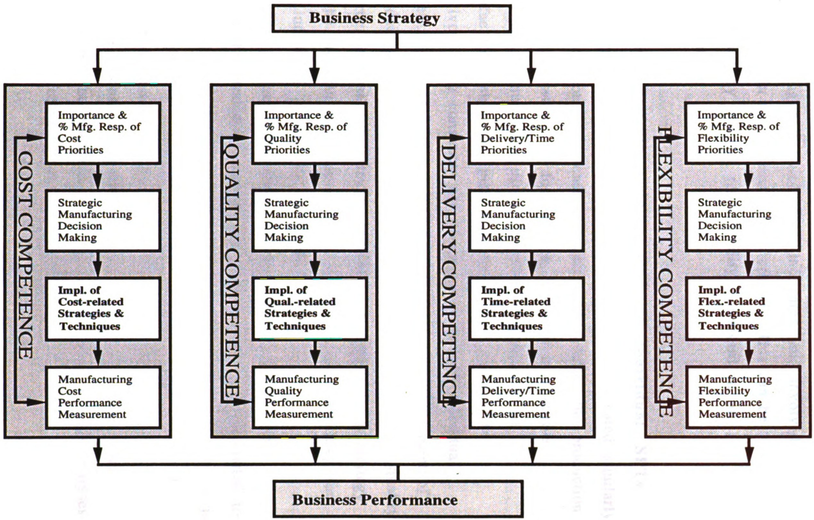
Table 5.1: Structural/Infrastructural SPTs & Production Competence

Structural SPTs	Infrastructural SPTs
Proprietary Technology	Worker Specialization
Product-Focused Factory	Workplace Orderliness
Synchronous Manufacturing	Worker Motivation
Process-Focused Factory	Employee Involvement
Flexible Manufacturing System	Vertical Job Enlargement
	Worker Safety
	Training For Workers
	Product Standardization
	Reduce Number Of Engineering Change Orders
	Supplier Selection Based On Price
	Total Productive Maintenance

The infrastructural SPTs related to production competence are dominated by those that directly relate to the workforce. The theme of the SPTs in Table 5.1 is one of pushing responsibility and authority down in a firm's hierarchy, while providing the training and knowledge necessary to accomplish new tasks. A different set of SPTs supports the structural SPTs by focusing on a clean, orderly shop and keeping machinery in working order.

To summarize, production competence measures the support a manufacturing function provides to business strategy objectives, regardless of their strategic direction. Given this general guideline, manufacturing support requires that firms have adequate communication structures so functional managers and executives can align resources with strategic objectives. In manufacturing, the

FIGURE 5.2: A Process Model of Competitive Priority Competence



important decision of process positioning is critical to providing that support. Having a knowledgeable, motivated, and involved workforce within this process is also critical. This can be accomplished by pushing responsibility downward in an organization.

Competitive Priority Competence and Individual SPTs

The competitive priority competence constructs are created similarly to the production competence construct. They refine the production competence construct by focusing on particular competitive dimensions. Thus, their use can reveal information about manufacturing strategies pertaining to specific competitive initiatives. The constructs are comprised of several individual competitive priorities (see Tables 2.1 and 3.3). The assignment of individual priorities to either the cost, delivery, flexibility, or quality construct is based on relevant literature in manufacturing strategy and the proportion of responsibility assigned to manufacturing for each individual priority by respondent firms.

The process model developed by Vickery (1991), which contains the production competence construct, has been expanded to include the competitive priority competence constructs. Figure 5.2 is a process model incorporating the four priorities and serves as a guide for discussion in this section. The relationship between individual manufacturing SPTs and each of the four competence constructs will be discussed. The nest four sections contain analyses related to the following set of hypotheses:

Hypothesis 2a-2d: There is a positive relationship between (a) cost competence, (b) delivery competence, (c) flexibility competence, and (d) quality competence, and the use of individual manufacturing strategies, programs and techniques.

Cost Competence

The cost-related constructs are comprised of the individual competitive priorities of *low production cost, competitive pricing, and low price* (see Table 3.3).

Table 5.2 presents the manufacturing SPTs positively related to cost competence. They, too, are categorized according to Hayes and Wheelwright's (1984) structural and infrastructural factors. This determination is merely subjective and was not performed using statistical grouping procedures.

The structural SPTs in Table 5.2 include both forward and backward integration, which are classic cost-reduction strategies. Porter (1980) and Harrigan (1985) observe several strategic benefits of vertical integration, including economies of integration (combined operations, control and coordination, information, and stable relationships), a tap into technology, assurance of supply and/or demand, offset bargaining power of suppliers, an enhanced ability to differentiate, and higher barriers to entry. Forward integration allows better access to market information and distribution channels, and an improved ability to differentiate products. The technology SPTs may have come to the respondent firms from value chain members either fully or partially owned. These technology SPTs are also indicative of firms with advanced manufacturing knowledge.

Table 5.2: Structural/Infrastructural SPTs & Cost Competence

Structural SPTs	Infrastructural SPTs
Backward Integration	Failsafing Or Foolproofing
Computer Integrated Mfg.	Preventive Maintenance
Advanced Manufacturing Technology	Emphasis On "Doing-It-Right-The-First-Time"
Forward Integration	Benchmarking
	Timely Feedback Of Quality Data
	100 % Inspection
	Purchase In Large Quantities
	Training Provided To Suppliers
	Reliance On Fewer Suppliers
	Supplier Certification
	Supplier Select. Based on Quality
	Large Batch Production
	Departmental Coordination In Product Design

The infrastructural SPTs are roughly organized into areas of quality, purchasing, planning and control, and design. The planning and purchasing SPTs focus on economies of scale by buying and producing in large quantities. Firms are also reducing their base of suppliers and rewarding those that become certified with larger volumes. The quality-oriented SPTs combine both detection and prevention techniques, with a heavier emphasis on prevention. Based on earlier visits to furniture companies, complete inspection seems to be an old standard in the industry, potentially indicating a lack of maturity.

Furniture firms use a combination of vertical integration, economies of scale, and new to the industry quality prevention techniques to support cost reducing initiatives.

Delivery Competence

The individual competitive priorities that comprise the delivery competence construct are *delivery speed, delivery dependability, and production lead time* (see Table 3.3). Table 5.3 presents the manufacturing SPTs positively related to delivery competence. They are categorized according to Hayes and Wheelwright's (1984) structural and infrastructural factors. This determination is merely subjective and was not performed using statistical grouping procedures.

The structural SPTs are similar those related to production competence. They are a combination of efficiency- and flexibility-oriented strategies, which are critical skills in supporting the speed and dependability requirements of the construct. Again, the process positioning decision appears to be important, not for its outcome, but because of its importance in shaping other strategic decisions (Hill, 1994). The flexibility and speed components provide an element of responsiveness to the firms, further aiding in delivery support.

The infrastructural SPTs in Table 5.3 are roughly organized into categories of workforce management and planning and control. Involving and empowering workers provides them with the feeling of ownership in the process that supports a delivery commitment. Maintenance, cleanliness and reducing WIP inventories keep factories running and efficient, which reduces waste and unnecessary delays.

Delivery competence, the measure of a firm's ability to support delivery-related competitive initiatives, requires firms be efficient, flexible, and instill authority in the workforce.

Table 5.3: Structural/Infrastructural SPTs & Delivery Competence

Structural SPTs	Infrastructural SPTs
Product-Focused Factory	Worker Safety
Flexible Manufacturing System	Workplace Orderliness
Proprietary Technology	Employee Involvement
Process-Focused Factory	Self-Directed Work Teams
Simplified Material Flow	Employees Responsible For Output Quality
	Total Productive Maintenance
	Reduction In Work-In-Process Inventory
	Supplier Selection Based On Price

Flexibility Competence

The flexibility constructs are comprised of the following individual competitive priorities: *product flexibility, volume flexibility, process flexibility, product development cycle time, and responsiveness to target markets*. Table 5.4 presents the manufacturing SPTs positively related to flexibility competence. They are categorized according to Hayes and Wheelwright's (1984) structural and infrastructural factors. This determination is merely subjective and was not performed using statistical grouping procedures.

The structural SPTs related to flexibility competence range from very flexible (general purpose equipment) to moderately flexible (just-in-time). The individual flexibility-related competitive priorities that form the flexibility constructs emphasize agility and responsiveness. The structural SPTs appear to contain elements of speed (synchronous manufacturing and JIT), efficiency (group technology and product-focused factory), and the ability to produce a

Table 5.4: Structural/Infrastructural SPTs & Flexibility Competence

Structural SPTs	Infrastructural SPTs
Group Technology	Worker Safety
Synchronous Manufacturing	Vertical Job Enlargement
Just-In-Time	Workplace Orderliness
Product-Focused Factory	Worker Specialization
Proprietary Technology	Worker Motivation
General Purpose Equipment	Training For Workers
	Advanced Statistical Techniques (Quality)
	Acceptance Sampling
	Use Of Control Charts
	Zero Defects
	Use Of The Seven Basic Quality Tools
	Measuring Product Reliability
	Product Reliability Testing
	Reduce Number Of Engineering Change Orders
	Computer-Aided Design
	Product Standardization
	Setup Time Reduction
	Training For Executives And Managers
	Training Provided To Suppliers

wide range of products (general purpose equipment and proprietary technology). Together, this collection of SPTs forms a powerful base upon which flexibility strategies can be implemented.

The infrastructural SPTs firms are using to support the structural SPTs are roughly organized in Table 5.4 into groups, including workforce management, quality, training, and design. Given the difficult manufacturing task associated with flexibility competence, the large number of infrastructural SPTs is justified. Firms following flexibility strategies must be committed to training programs for internal and external entities. The use of quality tools (seven tools, advanced techniques, zero defects) has a larger representation in flexibility competence than in any other analysis. To effectively utilize these techniques, new attitudes toward employees and increased responsibility for workers are characteristics of competent firms. Design SPTs are also well represented and focus on reducing rework, design cycle times, and changes to build schedules. This stability allows increased flexibility through improved planning. Setup time reduction allows smaller production lots and increased volume flexibility.

Flexibility competence is difficult to achieve and requires heavy investment in training, process technology, and design. Infrastructural support is broad-based and relies on worker involvement. Companies not prepared to make the financial or emotional investment to flexibility strategies would be best served by competing along other dimensions.

Quality Competence

The quality constructs are comprised of the individual competitive priorities of *product reliability, product durability, conformance quality, design quality, and product improvement/refinement..* Table 5.5 presents the manufacturing SPTs positively related to flexibility competence. They are categorized according to Hayes and Wheelwright's (1984) structural and infrastructural factors. This determination is merely subjective and was not performed using statistical grouping procedures.

The structural SPTs related to quality competence are somewhat surprising due to the emphasis on flexibility and low volume technologies. Process-focused factories are low volume, job-shop oriented facilities and flexible systems are best utilized for mid-volume production (Hill, 1994). Synchronous manufacturing has higher volume connotations, as does automation, but there is not the emphasis on high volume manufacturing one would expect to support quality initiatives.

The infrastructural SPTs associated with quality competence are few in number. Compared to the constructs associated with delivery and flexibility, the number of SPTs is surprisingly small. There are far fewer worker-related SPTs in Table 5.5 than on other analyses. Those that do appear provide support to the individual priority of conformance quality. The supplier-oriented SPTs are also surprising in that they appear to be associated with larger volume production that the structural SPTs indicate. Selecting suppliers based on their price is rarely advocated, especially when discussing quality improvement (Walton, 1986). Standardizing designs helps to

Table 5.5: Structural/Infrastructural SPTs & Quality Competence

Structural SPTs	Infrastructural SPTs
Synchronous Manufacturing	Employee Involvement
Automation	Worker Motivation
Flexible Manufacturing System	Electronic Data Interchange
Process-Focused Factory	Supplier Selection Based On Price
	Failsafing or Foolproofing
	Preventive Maintenance
	Total Productive Maintenance
	Product Standardization
	Quality Function Deployment (QFD)

increase repeatability, which aids in quality improvement. Failsafing and maintenance programs assure that machinery and process are operable and also work toward preventing defects before they occur.

The SPTs associated with quality competence are surprising due to their low numbers, their emphasis on low volume technology, and the lack of employee-related SPTs. Not allowing workers authority and responsibility for quality improvement is not the way to quality improvement.

Competitive Priority Performance and Individual SPTs

This section will review the third set of hypotheses—those relating to competitive priority performance and the use of individual manufacturing SPTs. Performance is calculated by summing the subjective performance scores for the individual competitive priorities comprising a construct. For example, cost performance is the sum of the performance scores of the individual competitive priorities of low production cost, competitive pricing, and low price. Tables 5.6 - 5.10 follow the same format as those in the competence section—the related manufacturing SPTs are roughly placed into structural and infrastructural categories.

Analysis of performance data may indicate relationships hidden by the competence scores. The performance scores may, in fact, reveal more direct relationships between strategic decisions and strategic direction than previous analyses involving competence. The hypotheses discussed in this section are:

> **Hypothesis 3a-3d: There is a positive relationship between the subjective performance component of (a) cost performance, b) delivery performance, (c) flexibility performance, and (d) quality performance, and the use of manufacturing strategies, programs, and techniques.**

Cost Performance

The cost-related constructs are comprised of the individual competitive priorities of *low production cost, competitive pricing, and low price* (see Table 3.3). As stated, performance analyses may reveal more direct results regarding the manufacturing SPTs firms must implement to properly support strategic initiatives.

In Table 5.6, the structural SPTs are quite sparse. The benefits of forward integration were described in the previous section. The appearance of CIM in the table is somewhat surprising as CIM is not often regarded as a cost reducing approach.

When compared to the other constructs, infrastructural SPTs relating to cost performance are also sparse. Ferdows and De Meyer

Table 5.6: Structural/Infrastructural SPTs & Cost Performance

Structural SPTs	Infrastructural SPTs
Forward Integration	Advanced Forecasting
Computer-Integrated-Manufacturing	Emphasis On "Doing-It-Right-The-First-Time"
	Supplier Selection Based On Quality
	Purchase In Large Quantities
	Reduction In Finished Goods Inventory
	100% Inspection
	Large Batch Production

(1990) observed that cost capabilities are the last to come to companies, which must first acquire capability in quality, then delivery, then flexibility before attaining true cost reductions. The SPTs in Table 5.6 are generally either quality related or economies of scale oriented. A firm's production relies heavily on the quality of incoming materials, and selecting quality suppliers is a critical step. The emphasis on "doing things right" does not have the same impact it might if employee-related SPTs were also related. The economies of scale SPTs are classically related to lower costs and need no further discussion. The presence of 100% inspection is curious in that it is very expensive for firms to inspect each product. This technique does not seem to fit cost reduction initiatives.

Delivery Performance

The individual competitive priorities that comprise the delivery performance construct are *delivery speed, delivery dependability,*

Table 5.7: Structural/Infrastructural SPTs & Delivery Performance

Structural SPTs	Infrastructural SPTs
Proprietary Technology	Employees Responsible For Output Quality
Process-Focused Factory	Self-Directed Work Teams
Flexible Manufacturing System	Workplace Orderliness
Product-Focused Factory	Employee Involvement
	Worker Safety
	Reducing Size Of Workforce
	Total Productive Maintenance

and production lead time (see Table 3.3).

Table 5.7 presents the structural and infrastructural SPTs associated with delivery performance. The structural SPTs again indicate the critical importance of understanding the nature of the process positioning decision (Hill, 1994; Krajewski and Ritzman, 1993). Having the vision and understanding to see how the entire facility works together aids in the movement of product throughout a factory. The reduced time variability and quicker throughputs of the product focus support speed and dependability. The process focus also supports the speed dimension, while adding to the confusion regarding "responsiveness".

There are fewer infrastructural SPTs related to delivery performance than competence. There remains, however, a commitment to employees (responsibility for quality and self-directed teams) and a clean, well-maintained facility. Keeping the workplace organized reduces chances of materials being misplaced or buried.

Delivery performance requires firms to make the critical decisions to properly position the facility and allow the employees to be involved in improving the system.

Flexibility Performance

The flexibility constructs are comprised of the following individual competitive priorities (from Table 3.3): *product flexibility, volume flexibility, process flexibility, product development cycle time, and responsiveness to target markets.*

Table 5.8 presents the manufacturing SPTs—structural and infrastructural—that are related to flexibility performance. This section contains the largest number of related SPTs. The structural SPTs concern a mixture of flexible equipment and higher volume technology. These technologies combine to form the base of responsiveness. They maintain the flexibility to adapt to varying product types and volumes, while also having the ability to quickly respond orders—a speed component. This approach—dedicating general purpose equipment to product families has been used by Japanese firms to achieve flexibility objectives (Hill, 1994). This arrangement appears to directed at mid-volume production, although keeping some general purpose equipment separate could fulfill this need.

The infrastructural SPTs are dominated by workforce management and quality SPTs. Motivation, training, the use of teams and involving workers is just what is needed to support the structural SPTs. The quality-related SPTs make heavy use of process improvement techniques, which adds to the responsiveness and

Table 5.8: Structural/Infrastructural SPTs & Flexibility Performance

Structural SPTs	Infrastructural SPTs
Product-Focused Factory	Worker Motivation
Synchronous Manufacturing	Worker Safety
Proprietary Technology	Worker Specialization
General Purpose Equipment	Training For Executives And Managers
Group Technology	Vertical Job Enlargement
Just-In-Time	Cross-Functional Teams
	Self-Directed Work Teams
	Vertical Job Enlargement
	Training For Workers
	Employee Involvement
	Workplace Orderliness
	Zero Defects
	Measuring Product Reliability
	Advanced Statistical Techniques (Quality)
	Use Of The Seven Basic Quality Tools
	Computer-Aided Design
	Product Reliability Testing
	Acceptance Sampling
	Reduce Number Of Engineering Change Orders
	Product Standardization
	Setup Time Reduction
	Mixed-Model Production Scheduling
	Color Coding Of Machines And Parts
	Supplier Selection Based On Price

flexibility of a system. Standardizing designs and limiting late change orders allows the planning system the stability required to maximize utilization and employ complex techniques such as mixed-model scheduling. Reducing setup times through color coding equipment adds flexibility and capacity to the system.

The ambitious collection of structural SPTs related to flexibility performance requires an infrastructure that is trained, motivated, and empowered to make changes. The infrastructural SPTs related to flexibility performance allow the structural elements to be effective. Only firms willing to push responsibility down the organization should compete along this dimension. A commitment to training and cross-functional communication is also necessary to support a flexibility strategy.

Quality Performance

This is the last segment regarding competitive priority performance. The quality competitive priorities comprising the quality performance construct are *product reliability, product durability, conformance quality, design quality, and product improvement/refinement* (see Table 3.3).

Table 5.9 presents the structural and infrastructural categorization of SPTs related to quality performance. The structural SPTs in Table 5.9, when compared to those related to flexibility and delivery, are few in number. A product-focus denoted higher volumes and a degree of repeatability conducive to quality improvement. The SPTs of automation and proprietary are too vague to make declarative statements, although it can be presumed that

Table 5.9: Structural/Infrastructural SPTs & Quality Performance

Structural SPTs	Infrastructural SPTs
Proprietary Technology	Supplier Selection Based On Price
Product-Focused Factory	Product Reliability Testing
Automation	Insp. Of Incoming Materials
	Acceptance Sampling
	Quality Function Deployment
	Product Standardization
	Design For Manufacturability
	Variety Reduction
	Worker Motivation
	Worker Specialization

they replace human labor and operate with less variation.

The infrastructural SPTs, as is the case with quality competence, are lacking in employee-oriented SPTs. Only worker motivation directly relates to the workers, and that technique does not provide the authority or responsibility required to improve quality levels. There is a preponderance of detection SPTs, rather than prevention. Again, this may indicate the novice state of quality management in the furniture industry at the time of the survey (1990). There are several design-related SPTs which are prevention-oriented. Improving the quality of designs and narrowing product ranges can improve quality dramatically by increasing repeatability.

Quality performance, perhaps due to the stage of development within the furniture industry, is being supported by a small number of SPTs. These are ignoring the employee and seem to be—except for the design SPTs—focused on detection rather than prevention.

Return on Assets

This section discusses the relationship between manufacturing SPTs and firm performance. Table 5.10 contains the related SPTs. This table is the smallest analyzed, most likely due to the nature of the measures. Firm performance was measured using a 7-point Likert scale (7 = high performance, 1 = low performance). This scale does not contain as much variance as the production competence, competitive priority competence, or competitive priority performance measures. Given the limited sample size, significant relationships will be more difficult to reveal.

Table 5.10 displays the structural and infrastructural SPTs related to firm performance. Three important items can be ascertained from the table. First, the best performers in the sample seem to be emphasizing high-volume technologies (dedicated equipment and worker specialization). Second, there is a movement toward becoming more quality-oriented in high performing firms, indicated by the use of control charts, the seven basic quality improvement tools, and motivating the workers through gainsharing programs. These are indicators of a move to granting workers increased authority and decision-making responsibility. Finally, high performers have all adopted or invented some proprietary technology to give the firm a competitive advantage.

High performing firms are continuing to use traditional manufacturing approaches (economies of scale oriented), but appear to be starting the move toward improving process quality through increased employee involvement.

Table 5.10: Structural/Infrastructural SPTs & ROA

Structural SPTs	Infrastructural SPTs
Proprietary Technology	Use of Control Charts
Dedicated Equipment	Use of the 7 Basic Quality Tools
	Worker Motivation
	Worker Specialization
	Gainsharing

Summary of Individual Manufacturing SPTs

Table 5.11 displays significant manufacturing SPTs and the constructs to which they are related. Some of the SPTs that are related to multiple constructs will be discussed. Proprietary technology (7), product-focused factory (6), and worker motivation (6) were the SPTs related to the most constructs. The SPTs related to five (5) constructs include employee involvement, workplace orderliness, product standardization, supplier selection based on price, synchronous manufacturing, worker safety, and worker specialization. These nine SPTs have provided the broadest support for sample firms.

This collection of SPTs appears to emphasize higher volume, structural elements (standardization, specialization, synchronous flow, low price vendors, and product-focused factory). One explanation might be that the skills required to produce furniture are best suited to high volume production. The cyclical nature of the industry also creates pressure for firms to contain costs. As the economy worsens, often furniture purchases are the first to be cut from consumer budgets. Proprietary technology, in the furniture

Table 5.11: Summary of SPTs and Competence/Performance

Manufacturing Strategy, Program, or Technique	Prod comp	Cost comp	Cost perf	Del comp	Del perf	Flex comp	Flex perf	Qual comp	Qual perf	pretx ROA	#
Advanced mfg. technology						1	1		1		3
Adoption of quality standards		1									1
100 % inspection		1	1			1	1				4
Automation								1	1		2
Backward integration		1									1
Benchmarking		1									1
Computer-aided design						1	1				2
Cross-functional teams							1				1
Computer-integrated-mfg.		1	1								2
Color coding of machines							1				1
Use of control charts						1				1	2
Dedicated equipment										1	1
Departmental coord. in design		1									1
Design for manufacturability									1		1
"Do-it-right-the-first-time"		1	1								2
Electronic data interchange								1			1
Employee involvement	1			1	1		1	1			5
Emp. responsible for quality				1	1						2
Failsafing or foolproofing		1						1			2
Reliance on fewer suppliers		1									1
Flexible mfg. system	1			1	1			1			4
Advanced forecasting		1	1								2
Forward integration		1	1								2
Gainsharing										1	1
General purpose equipment						1	1				2
Group technology						1	1				2
Inspect. of incoming mat'ls									1		1

Table 5.11 (cont'd).

Manufacturing Strategy, Program, or Technique	Prod comp	Cost comp	Cost perf	Del comp	Del perf	Flex comp	Flex perf	Qual comp	Qual perf	pretx ROA	#
Just-in-time						1	1				2
Large batch production		1	1								2
Purchase in large quantities		1	1								2
Simplified material flow				1							1
Mixed-model prod. sched.							1				1
Workplace orderliness	1			1	1	1	1				5
Preventive maintenance		1						1			2
Product standardization	1					1	1	1	1		5
Process-focused factory	1			1	1			1			4
Product-focused factory	1			1	1	1	1		1		6
Proprietary technology	1			1	1	1	1		1	1	7
Quality function deployment								1	1		2
Timely feed. of quality data		1									1
Red. # of eng. change orders	1					1	1				3
Reduction in FGS inv.			1								1
Setup time reduction						1	1				2
Reduction in WIP inventory				1							1
Reducing size of workforce					1						1
Measuring product reliability						1	1				2
Product reliability testing						1	1		1		3
Self-directed work teams				1	1		1				3
Supplier certification		1									1
Supplier selection - price	1			1			1	1	1		5
Supplier selection - quality		1	1								2
Training provided to suppliers		1				1					2
Use of 7 basic quality tools						1	1			1	3
Synchronous manufacturing	1					1	1	1			4
Total productive maintenance	1			1	1			1			4

Table 5.11 (cont'd).

Manufacturing Strategy, Program, or Technique	Prod comp	Cost comp	Cost perf	Del comp	Del perf	Flex comp	Flex perf	Qual comp	Qual perf	pretx ROA	#
Training - exec. and managers						1	1				2
Training for workers	1					1	1				3
Variety reduction									1		1
Vertical job enlargement	1					1	1				3
Worker motivation	1					1	1	1	1	1	6
Worker safety	1			1	1	1	1				5
Worker specialization	1					1	1		1	1	5
Zero defects						1	1				2
TOTAL	23	19	10	18	16	30	34	17	18	9	

industry, generally involves productivity enhancing improvements, further reducing total costs.

The remaining SPTs are directed at involving workers and housekeeping. Housekeeping is a first-glance indicator of world-class companies and is important to response-centered strategies (Giffi, Roth, and Seal, 1990). The furniture industry is moving toward involving workers in decision-making. There is not much focus, however, on including workers in process and quality improvement. Perhaps this has changed in the last two years.

MANUFACTURING SPTs GROUPED BY COMPETITIVE PRIORITY

A literature search was done in the areas of cost, delivery, flexibility, quality, and just-in-time (JIT), directed at identifying implementation strategies and techniques in each area. Empirical studies had highest priority, followed by general writings. Tables 4.11, 4.15, 4.17, 4.19, and 4.21 contain the resultant manufacturing SPTs associated with the competitive priorities noted above.

This section will discuss the implications of the results of the hypotheses (hypotheses five through nine) associated will collections of SPTs. First, the relationship between the variables constructed of several SPTs and production competence and performance will be discussed. Second, the relationship between the grouped SPTs and the various competitive priorities and the associated implications will be discussed. Finally, this section will address any relationship between the variables and overall firm performance. Tables 5.12 to 5.14 present the results for the competence, performance, and ROA, respectfully.

Table 5.12: Competence Constructs and Related Variables

Variable	Product. Comp.		Cost Comp.		Delivery Comp.		Flexibility Comp.		Quality Comp.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
QInfo										
QHrdm										
QProcess										
R^2										
JitProcs	.429	.02			.357	.05	.484	.01		
JitInfra										
R^2	.184				.123		.234			
CostEff			.383	.04						
CostQual							.456	.01		
CostDes										
R^2			.147				.208			
DelProcs							.615	.001		
DelInfra							-.432	.02		
R^2							.379	.01		
FlexProc							.457	.01		
FlexInfr										
R^2							.209			

Table 5.13: Performance Constructs and Related Variables

Variable	Product. Perform.		Cost Perform.		Delivery Perform.		Flexibility Perform.		Quality Perform.	
	Beta	p	Beta	p	Beta	p	Beta	p	Beta	p
QInfo										
QHrdm										
QProcess	.410	.03								
R^2	.168									
JitProcs							.521	.005		
JitInfra	.451	.02								
R^2	.203						.272			
CostEff	.524	.01								
CostQual										
CostDes									.392	.03
R^2	.275								.154	
DelProcs	.359	.05					.650	.005		
DelInfra							-.459	.02		
R^2	.129						.423	.004		
FlexProc							.415	.03		
FlexInfr	.372	.04								
R^2	.138						.173			

Table 5.14: Financial Indicators and Related Variables

Variable	Pretax ROA External		Aftertax ROA-Int.		Pretax ROA Internal		Aftertax ROA-Ext.	
	Beta	p	Beta	p	Beta	p	Beta	p
QInfo								
QHrdm								
QProcess								
R^2								
JitProcs	.416	.04			.415	.04		
JitInfra	-.59	.004			-.59	.005		
R^2	.347	.027			.351	.03		
CostEff								
CostQual								
CostDes								
R^2								
DelProcs								
DelInfra								
R^2								
FlexProc								
FlexInfr								
R^2								

The variables related to production competence—a general measure of manufacturing's support to business objectives—are those related to JIT (JitProcs), cost (CostEff), and delivery (DelProcs) (see Table 5.12). Common themes among the SPTs associated with each variable include simplified and efficient material flow, preventive maintenance, automation, and group technology-oriented layouts. Setup time reduction also appears to be a critical element. The relationship between these variables and production competence might indicate that these SPTs are sound practices that firms should implement regardless of strategic direction.

The variables related to production performance come from each of the four competitive priorities and JIT. Process-oriented variables include QProcess, CostEff, and DelProcs. These are, except for the quality variable, similar to the variables related to production competence. Common themes present in these variables include simplified material flow, maintenance, automation, traditional quality improvement tools, and design issues. The quality and design SPTs add a more rounded dimension to the production construct. This is logical in that it should take skills from several areas to support broadly defined strategies, which are captured by the performance construct.

The only infrastructural variable associated with production performance is FlexInfr. Themes in this variable center around team approaches, employee involvement, and a broad quality plan utilizing basic improvement tools. The combination of the process and infrastructural variables produces a strong base of skills and capabilities from which companies can support many strategies.

Capabilities concerning quality and simple material flows can be used in many strategic settings.

The support of cost objectives is best offered through these methods: implementation of SPTs related to economies of scale, quality improvement, design, and vendor issues. Buying and producing in large batches, assuming ownership in multiple phases of the value chain, and dedicating equipment and workers to narrow tasks all support cost objectives. In a mature industry such as furniture production, economies of scale can be critical to overall profitability. The presence of the traditional quality tools supports the writings of several authors (Crosby, 1979). Simplifying designs makes it easier to build products, reducing costs. Finally, the supply base can be used to reduce costs. These results provide fairly strong support to the sand cone model, which suggests that capability in several areas must be acquired before cost reduction can really be made. (Ferdows and De Meyer, 1990).

The JIT variable, JitProcs, is the only one significantly related to delivery competence. Again, centered around simple material flows, these SPTs ensure that equipment is operable and logically oriented. This allows for greater tracking ability and faster throughput, thereby contributing both reliability and speed issues.

Superior support and performance in flexibility requires contributions along several fronts. The five variables related to flexibility competence (QHrdm, JitProcs, CostQual, DelProcs, and FlexProc) contain several themes. First, a theme of equipment maintenance and orderliness is present. This suggests that equipment and shopkeeping can contribute to flexibility by providing consistent, organized resources that reduce the burden of managing the system. This allows managers to concentrate on the more complex tasks associated with flexibility.

Another theme associated with flexibility is simplicity. The study results indicate that simplifying layouts, reducing setup times and improving throughput times are repeatedly connected to flexibility. This theme is one often observed by manufacturing strategy writers (Gunn, 1992; Wallace, 1992;).

Quality items are also a theme related to flexibility. Use of the seven basic quality tools, failsafing, and an overall quality system provide the ability to continually improve the already simplified system. Process improvements made possible by the quality tools add a synergistic effect to the simplification theme. As defects are permanently removed from the system, the system becomes more straightforward. As the system becomes more straightforward, quality problems are more easily detected and removed. Another quality theme present is the increased responsibility given to workers so that the improvements can be achieved. Altering work structures and utilizing team approaches seem to be effective tools for supporting flexibility initiatives.

Flexibility objectives are best supported through a three-pronged approach: process simplification, rigorous maintenance, and continuous quality improvement. These three themes can combine to provide powerful support to one of the most complex competitive dimensions. Underlying this approach is a movement to push authority and decision making lower in an organization.

The grouped data were especially unsupportive of the quality constructs. Only the CostDes variable was related. This included SPTs concerned with reducing product complexity so that manufacturing of the product was easier to complete. While this is important, it is by no means sufficient to support a priority that has now become a qualifier to enter markets. As stated several times earlier, perhaps the sample firms (in 1990) had not yet been convinced of the necessity for process quality improvements.

Table 5.14 indicates that only the JitProcs variable is positively related to ROA. Remember that this variable is also the only one related to production competence. This relationship with ROA solidifies the perception that the SPTs associated with JitProcs can provide a substantial building block upon which to build a manufacturing strategy.

Managerial Implications

The results of the study can also give insight to managers who are interested in improving the competitiveness of their manufacturing functions. As stated earlier, there are numerous manufacturing strategies, programs, and techniques available to firms. The issue for managers is to determine which of the SPTs are most appropriate for their firms.

The first conclusion that can be drawn from the results is the importance of employee-oriented strategies. Across *all* of the competitive priorities, employee-oriented strategies were related to the associated competence and performance constructs. Many times, they accounted for the largest percentage of SPTs related to any one construct. Clearly, the role of the human in making the manufacturing operations system competitive is critical.

The employee-related strategies most frequently observed as significantly related to competence and performance include worker training/cross-training, involving workers in decision-making, worker motivation, and teaming. These SPTs are among those on Table 5.11 related to the largest number of constructs. They are also included in the infrastructural SPTs associated with JIT (see Table 4.20), which is important as the JIT variables are significantly related to several constructs across multiple competitive priorities. These results hint at the importance of well-trained, motivated, and empowered employees in helping a firm compete in a global economy.

Another set of infrastructural SPTs that was frequently observed as significantly related to multiple constructs concerned sourcing practices. Strategies such as reducing the number of suppliers, supplier certification programs, and selecting suppliers based on quality were often among the SPTs significantly related to the competence and performance constructs. Interestingly, these are among the purchasing practices cited in the literature as important for a move to a partnership approach (Ellram, 1991). For industries where cost and quality are important order qualifiers or winners—such as the furniture industry—the use of purchasing strategies such as these can help to keep a firm competitive.

The final set of implications can be classified as structural and are related to the general flow of materials through the production system. The SPTs involving technology, material flow, and maintenance practices were often observed to be significantly related to multiple priorities (i.e., delivery and flexibility). The technology SPTs include the use of proprietary technology, general-purpose equipment, and a strong emphasis on reducing setup times. Material flow SPTs include having a product-focus, simplifying material flow, and keeping the workplace orderly. Built on a foundation of regular maintenance, this collection of SPTs can contribute to the simultaneous pursuit of multiple competitive priorities (i.e., delivery, flexibility, and quality).

Contributions Of Research

This research makes several contributions to the manufacturing strategy literature. First, it is an empirical study that focuses on the relationship between manufacturing strategy and firm performance, and manufacturing strategy content, three previously identified research needs (Adam and Swamidass, 1989; Anderson, Cleveland and Schroeder, 1989).

A second major contribution is the expansion of an earlier manufacturing strategy process model (Vickery, 1991). The expansion is directed at identifying the manufacturing strategies, programs, and techniques (SPTs) firms implement to support business objectives. This contribution includes identifying a bundle of manufacturing SPTs that provide support to business objectives at a general or macro level. It also contributes by further verifying the relationship between production competence and firm performance.

While the production competence construct measures manufacturing support provided to business strategic objectives, it does not provide guidance to firms making decisions regarding competitive initiatives in specific dimensions. Skinner (1992a) observes that academics are not providing research results that assist managers in making decisions that link manufacturing resources to strategic objectives such as cost, quality, delivery and flexibility. This study makes a third major contribution by expanding the production competence construct through the creation of additional competence constructs in the areas of cost, quality, delivery and flexibility. These "competitive priority competence" constructs form the foundation to expand the competence construct in response to Skinner's observation. The new competence constructs have also been linked to particular manufacturing SPTs, thereby completing the link between specific competitive initiatives and manufacturing strategies.

A related contribution are the results that link particular manufacturing SPTs to *performance* within specific manufacturing competitive priorities. This also responds to the research need identified by Skinner (1992a). Finally, this research adds to the general body of knowledge concerning the use of individual manufacturing strategies.

To investigate relationships between *sets* of individual manufacturing SPTs, the SPTs were grouped according competitive priorities using existing literature as a guide. Another significant contribution is linking these groups of SPTs to the various competence and performance constructs. In several cases, the SPTs groupings suggested by the literature were in fact related to competence or performance within a competitive priority. These results validate previous work in the field.

Limitations Of Research

This research has several limitations. First, the sample size (n=24) is fairly small. This limits the confidence of statements regarding relationships between constructs and manufacturing SPTs. A larger sample would have alleviated this problem and increased the array of statistical tools available.

Another limitation is that the statistical tests were conducted with a large alpha (.10), which also reduces confidence. The reason for the large alpha was that the research was theory building in nature and not confirmatory. Nonetheless, the large alpha restricts generalizability.

Third, the sample was confined to one industry (furniture), which also limits generalizability. Approaches that work in the furniture indistry may not apply to other industries.

A problem with the sections using grouped SPTs is that the groupings were not based on statistical procedures such as factor analysis. The use of factor analysis or principal components analysis would allow for increased confidence in interpreting the results of these sections.

Future Research/Extensions

This project can be extended to include analysis of the use of manufacturing SPTs in a wider variety of industries. The furniture industry is one in transition. Therefore, many of the firms in the industry are not as developed regarding recent manufacturing initiatives such as quality improvement programs, JIT, etc. Replicating the experiment in a more mature industry might yield different results or perhaps validate findings of this study.

The research could also be extended by replicating the study on the same sample of firms. A longitudinal study such as this would provide the opportunity to identify the manufacturing SPTs that continue to be important in specific priority areas, while also indicating the new SPTs being implemented.

Another extension would be to further study the relationships between the competitive priority competence constructs and their relation to business strategies. This would include statistically constructing the constructs based on factor analysis of the individual competitive priorities (see Table 2.1). Borrowing well-developed strategic typing models such as Miles and Snow's strategic types and relating them to the priority competence constructs would strengthen the competence constructs.

The competitive priority competence constructs could also be expanded by applying them to several functions of the firm, not just the manufacturing function. Potential functions include marketing, design, and finance. The functional strategies identified could be linked together to form an integrated strategy model for the firm based on competitive priorities. For example, for a firm following a low cost strategy, each functional area would have a set of SPTs to implement and guide resource allocation. Integration of functional strategies is a difficult task for firms and linking mechanisms could aid in simplifying the job.

Skinner (1992b) has identified six critical areas of manufacturing strategy that need additional development—make or buy, capacity, equipment and process technology, workforce management, production scheduling and control, and quality management. Further studies that include manufacturing SPTs directed at these six areas would provide a more direct link between critical manufacturing decision areas and the strategies and programs firms are implementing to achieve success in supporting the business strategy or various competitive priorities. This would aid managers in making the link between strategic direction and strategy implementation.

More rigorous techniques could also be applied (with a larger sample) to study the relationship between the manufacturing SPTs and support provided to competitive priorities simultaneously. As the global environment continues to become more competitive, the ability to compete along multiple priorities will be critical.

Once the critical strategies and programs are identified, the research could change direction to investigate the implementation process associated with the particular strategies.

Hayes and Pisano (1994) claim that having strategic flexibility, or the ability to rapidly change strategic direction, will be critical in the future. Refinement of the survey instrument and longitudinal study could aid in identifying the manufacturing STPs that contribute to strategic flexibility.

Finally, the approach to identifying bundles of accepted strategies could be applied to service firms. The development of a service competence construct and associated competitive priority constructs may provide additional insight into the subtle differences between strategic management in manufacturing and service industries.

Appendix A

The Survey Instrument and Glossary

NAME:______________________ FIRM:______________________

TITLE:______________________ PHONE:______________________

RESEARCH QUESTIONNAIRE
MICHIGAN STATE UNIVERSITY

Part I. FUNCTIONAL COMPETENCIES

This section is designed to determine which functional competencies your firm feels are important to successful implementation of your business strategy. First, please indicate the degree of importance you attach to each of the following competencies with respect to their contribution to your overall business strategy for the year 1990. A seven point scale is provided below for use in assessing the degree of importance of each competency. Please specify the appropriate response by indicating a single scale value. If the item of interest is not applicable to your situation, please specify NA (Not Applicable) instead of a single scale value. Although we recognize that all of the competencies listed below may be important to your company's success, we request that you carefully assess each one's degree of importance with respect to the contribution it makes to the achievement of your company's overall business strategy.

Seven Point Scale for 1990 Importance Rating

Least Important 1 2 3 4 5 6 7 Extremely Important

Second, please specify the performance of your firm in relation to its major competitors for the past year (1990) for each competency. A seven point scale is provided below for you to use in assessing the performance of your firm with respect to a given competency. Please specify the appropriate response by indicating a single scale value. Do not respond for any competency that you marked "Not Applicable" in the Importance Rating section of the questionnaire.

Seven Point Scale for 1990 Performance Rating

Poor 1 2 3 4 5 6 7 Excellent

1. **Product Flexibility (Customization):** The ability to handle difficult, nonstandard orders, to meet special customer specifications and to produce products characterized by numerous features, options, sizes and/or colors.

Importance Rating ____ Performance Rating ____

2. **Volume Flexibility:** The ability to rapidly adjust capacity so as to accelerate or decelerate production in response to changes in customer demand.

Importance Rating ____ Performance Rating ____

3. **Process Flexibility:** The ability to produce low quantities of product cost efficiently so that product mix changes are easily accommodated.

Importance Rating ____ Performance Rating ____

4. **Low Production Cost:** The ability to minimize the total cost of production (inclusive of labor, materials, and operating costs) through efficient operations, process technology and/or scale economies.

Importance Rating ____ Performance Rating ____

Seven Point Scale for 1990 Importance Rating
Least Important 1 2 3 4 5 6 7 Extremely Important

Seven Point Scale for 1990 Performance Rating
Poor 1 2 3 4 5 6 7 Excellent

5. New Product Introduction: The ability to rapidly introduce large numbers of product improvements/variations or completely new products.

Importance Rating _____ Performance Rating _____

6. Delivery Speed: The ability to reduce the time between order taking and customer delivery to as close to zero as possible.

Importance Rating _____ Performance Rating _____

7. Delivery Dependability: The ability to exactly meet quoted or anticipated delivery dates and quantities.

Importance Rating _____ Performance Rating _____

8. Production Lead Time: The ability to reduce the time it takes to manufacture products.

Importance Rating _____ Performance Rating _____

9. Product Reliability: The ability to maximize the time to product failure or malfunction.

Importance Rating _____ Performance Rating _____

10. Product Durability: The ability to maximize the time to product replacement.

Importance Rating _____ Performance Rating _____

11. Quality (Conformance to Specifications): The ability to manufacture a product whose operating characteristics meet established performance standards.

Importance Rating _____ Performance Rating _____

12. Design Quality (Design Innovation): The ability to provide a product with capabilities, features, styling, and/or operating characteristics that are either superior to those of competing products or unavailable with competing products.

Importance Rating _____ Performance Rating _____

13. Product Development Cycle Time: The ability to minimize the time it takes to develop new products.

Importance Rating _____ Performance Rating _____

14. Product Technological Innovation: The ability to engage in new product development involving major advances in product technology.

Importance Rating _____ Performance Rating _____

Seven Point Scale for 1990 Importance Rating
Least Important 1 2 3 4 5 6 7 Extremely Important

Seven Point Scale for 1990 Performance Rating
Poor 1 2 3 4 5 6 7 Excellent

15. Product Improvement/Refinement: The ability to further develop and refine existing products.

Importance Rating _____ Performance Rating _____

16. New Product Development: The ability to develop new products for existing markets.

Importance Rating _____ Performance Rating _____

17. Original Product Development: The ability to develop original (i.e. "new-to-the-world") products that create entirely new markets.

Importance Rating _____ Performance Rating _____

18. Brand Image: The ability to create a positive or favorable image in the customer's mind when he/she hears the product's brand name

Importance Rating _____ Performance Rating _____

19. Competitive Pricing: The ability to offer a lower product price than direct competitors.

Importance Rating _____ Performance Rating _____

20. Low Price: The ability to offer one of the lowest or the lowest available product price.

Importance Rating _____ Performance Rating _____

21. Advertising and Promotion: The ability to create effective advertising and/or promotional campaigns.

Importance Rating _____ Performance Rating _____

22. Target Market(s) Identification and Selection: The ability to identify promising target markets and select the best ones for consideration.

Importance Rating _____ Performance Rating _____

23. Responsiveness to Target Market(s): The ability to respond to the needs and wants of the firm's target market(s).

Importance Rating _____ Performance Rating _____

24. Pre-Sale Customer Service: The ability to service the customer during the purchase decision process (i.e. before the customer buys the product).

Importance Rating _____ Performance Rating _____

Seven Point Scale for 1990 Importance Rating
Least Important 1 2 3 4 5 6 7 Extremely Important

Seven Point Scale for 1990 Performance Rating
Poor 1 2 3 4 5 6 7 Excellent

25. Post-Sale Customer Service: The ability to service the customer after the sale of the product to ensure continuing customer satisfaction.

Importance Rating _____ Performance Rating _____

26. Broad Product Line: The ability to provide a comprehensive set of related items within a given product line offering.

Importance Rating _____ Performance Rating _____

27. Widespread Distribution Coverage: The ability to effectively provide widespread and/or intensive distribution coverage.

Importance Rating _____ Performance Rating _____

28. Low Cost Distribution: The ability to minimize the total cost of distribution.

Importance Rating _____ Performance Rating _____

29. Selective Distribution Coverage: The ability to effectively target selective or exclusive distribution outlets.

Importance Rating _____ Performance Rating _____

30. Personal Selling Proficiency: The ability to successfully move products through personal selling activities.

Importance Rating _____ Performance Rating _____

31. Company Reputation: The ability to create a positive or favorable image in the customer's mind when he/she hears the company's name.

Importance Rating _____ Performance Rating _____

PART II. MANUFACTURING TECHNIQUES AND PROGRAMS

Part II is directed at determining which manufacturing techniques and programs are being used in your firm to achieve the competencies selected in Part I. In this section, we ask that you assess each of the techniques and programs in the table presented on the following pages individually. If you are unfamiliar with the technique, or unclear of the meaning of the name of a technique, a GLOSSARY has been provided IN YOUR PACKET. Please use the glossary if you have any hesitation about the meaning of a technique. The glossary is in alphabetical order. Please evaluate each technique or program with regard to the following items:

a) EXTENT OF USE OF TECHNIQUE: Refers to the degree to which the technique or program was utilized in your firm in 1990.

b) NUMBER OF MONTHS IN USE: Refers to the overall duration of use of the technique.

c) CONTRIBUTION TO QUALITY GOALS: Refers to the contribution of the technique or program to the achievement of 1990 quality goals such as fewer defects, lower cost of quality, fewer customer complaints, higher incoming quality, etc.

d) CONTRIBUTION TO COST GOALS: Refers to the contribution of the technique or program to the achievement of 1990 cost goals such as lower per unit costs, lower overhead, reduced inventory costs, lower purchase price, etc.

e) CONTRIBUTION TO FLEXIBILITY GOALS: Refers to the contribution of the technique or program to the achievement of 1990 flexibility goals. Flexibility refers to items such as the ability to alter production volumes, the ability to produce multiple products, the ability to adapt to changing conditions, the ability to provide increased product customization, the ability to increase worker flexibility, etc.

f) CONTRIBUTION TO TIME-BASED GOALS: Refers to the contribution of the technique or program to the achievement of time-based goals such as time to market for new products, rate of new product introduction, lead time reduction, setup time reduction, increased inventory turns, faster response time to customer complaints, etc.

For all of the items listed above, except for NUMBER OF MONTHS IN USE, please assess each technique or program using the seven point scales provided below. Please evaluate the techniques for the year 1990. For NUMBER OF MONTHS IN USE, please write in the total number of months that this technique or program has been in use at your firm.

EXTENT OF USE IN 1990:

	1	2	3	4	5	6	7	
Extremely LOW use of the technique								Extremely HIGH use of the technique

CONTRIBUTION TO GOALS IN 1990:

	1	2	3	4	5	6	7	
Extremely LOW contribution to goals								Extremely HIGH contribution to goals

NOTE: If your firm is not currently using a technique or program, please respond by placing a 0 in the blank for EXTENT OF USE and proceed directly to the next technique or program.

LOW 1 2 3 4 5 6 7 HIGH						
Technique or Program	Extent of Use in 1990	Number Of Months In Use	CONTRIBUTION TO 1990 ...			
			Quality Goals	Cost Goals	Time-based Goals	Flexibility Goals
MATERIAL REQUIREMENTS PLANNING (MRP)						
MANUFACTURING RESOURCE PLANNING (MRPII)						
CAPACITY REQUIREMENTS PLANNING						
JUST-IN-TIME (JIT)						
AUTOMATION						
TOTAL QUALITY CONTROL (TQC)						
TRAINING FOR EXECUTIVES AND MANAGERS						
TRAINING FOR WORKERS						
ZERO DEFECTS						
DESIGN FOR MANUFACTURABILITY						
GROUP TECHNOLOGY						
CELLULAR MANUFACTURING						
BACKWARD INTEGRATION						
FORWARD INTEGRATION						
CAPITAL INVESTMENT						
COMPUTER INTEGRATED MANUFACTURING						
FUNCTIONAL INTEGRATION						
GOALSETTING						
ABC ANALYSIS						
WORKER MOTIVATION						
GAINSHARING						
QUALITY OF WORK-LIFE INITIATIVES						
PRODUCT-FOCUSED FACTORY						
PROCESS-FOCUSED FACTORY						
VARIETY REDUCTION						
REDUCE ENGINEERING CHANGE ORDERS						

LOW 1 2 3 4 5 6 7 HIGH						
Technique or Program	Extent of Use in 1990	Number Of Months In Use	CONTRIBUTION TO 1990 ...			
			Quality Goals	Cost Goals	Time-based Goals	Flexibi-lity Goals
SIMPLIFIED MATERIAL FLOW						
PRODUCT SIMPLIFICATION						
COMPUTER-AIDED DESIGN (CAD)						
SYNCHRONOUS MANUFACTURING						
GENERAL PURPOSE EQUIPMENT						
DEDICATED EQUIPMENT						
LARGE BATCH PRODUCTION						
CROSS-TRAINING WORKERS						
EMPLOYEE SUGGESTIONS						
REDUCTION IN THROUGHPUT TIMES						
QUALITY CIRCLES						
PRODUCT STANDARDIZATION						
VERTICAL JOB ENLARGEMENT						
REDUCTION IN RAW MATERIALS INVENTORY						
REDUCTION IN WIP INVENTORY						
REDUCTION IN FINISHED GOODS INVENTORY						
PURCHASE IN LARGE QUANTITIES						
SUPPLIER SELECTION BASED ON QUALITY						
SUPPLIER SELECTION BASED ON PRICE						
ADVANCED FORECASTING						
WORK MEASUREMENT						
VALUE ANALYSIS						
REDUCING SETUP TIMES						
PREVENTIVE MAINTENANCE						
FAILSAFING OR FOOLPROOFING						
LOT SPLITTING						

LOW 1 2 3 4 5 6 7 HIGH						
Technique or Program	Extent of Use in 1990	Number Of Months In Use	CONTRIBUTION TO 1990 ...			
			Quality Goals	Cost Goals	Time-based Goals	Flexibi-lity Goals
ELECTRONIC DATA INTERCHANGE (EDI)						
WORKER SPECIALIZATION						
QUALITY FUNCTION DEPLOYMENT (QFD)						
TOTAL PRODUCTIVE MAINTENANCE						
MEAN AND RANGE CONTROL CHARTS						
ADVANCED STATISTICAL TECHNIQUES						
USE OF THE SEVEN BASIC STATISTICAL TOOLS						
INSPECTION OF INCOMING MATERIALS						
INSPECTION OF IN-PROCESS WORK						
INSPECTION OF FINISHED GOODS						
100% INSPECTION						
ACCEPTANCE SAMPLING						
WORKPLACE ORDERLINESS						
QUALITY AUDIT						
PRODUCT RELIABILITY TESTING						
MEASURING PRODUCT RELIABILITY						
AVAILABILITY OF QUALITY RELATED DATA TO MANAGERS						
AVAILABILITY OF COST OF QUALITY DATA TO MANAGERS						
AVAILABILITY OF QUALITY RELATED DATA TO WORKERS						
BENCHMARKING						
EMPLOYEE INVOLVEMENT						
EMPLOYEES HELD RESPONSIBLE FOR OUTPUT QUALITY						
TIMELY FEEDBACK OF QUALITY DATA						
EMPLOYEE RECOGNITION						
VISIBLE PERFORMANCE CHARTS						

LOW 1 2 3 4 5 6 7 HIGH						
Technique or Program	Extent of Use in 1990	Number Of Months In Use	CONTRIBUTION TO 1990 ...			
			Quality Goals	Cost Goals	Time-based Goals	Flexibility Goals
ADOPTION OF QUALITY STANDARDS						
EMPHASIS ON "DOING IT RIGHT THE FIRST TIME"						
COORDINATION AMONG DEPARTMENTS IN PRODUCT DESIGN						
SUPPLIER CERTIFICATION						
TRAINING PROVIDED TO SUPPLIERS						
RELIANCE ON FEWER SUPPLIERS						
INVOLVE SUPPLIERS IN PRODUCT DESIGN						
SEPARATE MANUFACTURING LEAD TIME INTO COMPONENTS						
COMMON MANUFACTURING DATABASE						
CONCURRENT ENGINEERING						
ADVANCED MANUFACTURING TECHNOLOGY						
MIXED-MODEL PRODUCTION SCHEDULING						
LINE BALANCING						
AUTOMATED MONITORING DEVICES						
MAINTAIN EXCESS EQUIPMENT CAPACITY						
REDUCING SIZE OF WORK FORCE						
SELF-DIRECTED WORK TEAMS						
SUBCONTRACTING						
PROGRAMMABLE TECHNOLOGY						
FLEXIBLE MANUFACTURING SYSTEM						
CROSS-FUNCTIONAL TEAMS						
WORKER SAFETY						
PRODUCT TEAMS						
PROPRIETARY TECHNOLOGY						

LOW 1 2 3 4 5 6 7 HIGH						
Technique or Program	Extent of Use in 1990	Number Of Months In Use	CONTRIBUTION TO 1990 ...			
			Quality Goals	Cost Goals	Time-based Goals	Flexibility Goals
ALWAYS PRODUCE SAME PART ON SAME MACHINE						
COLOR CODING OF PARTS AND MACHINES						
OTHER - Please Write In						

Part III. MANUFACTURING PERFORMANCE MEASURES

In this section, we ask that you please provide objective performance data for the areas listed below. Please use 1990 as the year of reference. If your firm does not collect information in the area, please respond with a N/A (not applicable).

A. QUALITY RELATED PERFORMANCE MEASURES:

1. PERCENTAGE OF ...

   Parts Scrapped _____%
   Parts Reworked _____%
   Products Returned _____%
   Processes in statistical control _____%
   Your time spent on quality improvement _____%

2. DOLLAR COSTS OF ...

   Scrap $_______
   Rework $_______
   Inspection and testing $_______
   Education and training $_______
   Supplier certification $_______
   Supplier Development $_______

3. NUMBER OF ...

   Customer of complaints per month ______
   Warranty claims per month ______
   Quality audits per year ______
   Suppliers ______
   Certified suppliers ______
   Visits to suppliers per year ______

4. OTHER (Average across all products and processes)

   Incoming quality level _____%
   Mean time to product failure (MTTF) ______
   Mean time between failure (MTBF) ______
   Mean time to first failure (MTFF) ______
   Process capability (Cp) ______
   Process capability index (Cpk) ______
   Does your firm have a "quality manual" containing written procedures and policies? ______

B. TIME-BASED PERFORMANCE MEASURES

1. NEW PRODUCT DEVELOPMENT

Average time from product idea to market (months) ______
Rate of new product introduction (#/year) ______
Percent of new products released on schedule _____%
Percent of products first to market _____%

2. PROCESSING AND PRODUCTION

Value added time as a percent of total elapsed manufacturing lead time _____%
Inventory turns (per year) ______
Cycle time (days) ______
Average age of equipment (years) ______
Production throughput time (weeks) ______
Average production batch size ______
Average number of setups per week ______
How would you classify your operation (check one)?
Make-to-order (MTO) ___ Make-to-stock (MTS) ___ Assemble-to-order (ATO) ___

3. CUSTOMER SERVICE

Order response time (weeks) ______
Average quoted lead time (weeks) ______
Percentage of deliveries on time _____%
Average response time to customer feedback (days) ______
Number of stockouts per month ______
Percentage of orders requiring a second call by customers _____%
Percentage of orders shipped on time _____%
Percentage of orders past due _____%
Percentage of orders shipped incomplete _____%

C. FLEXIBILITY PERFORMANCE MEASURES

1. PRODUCTS

Number of products offered ______
Number of part numbers ______
Number of new products offered per year ______
Number of products retired per year ______

2. MACHINERY

Number of manufacturing plants ______
Number of different manufacturing processes ______
Number of programmable machines (please check one)

0 ____, 1-5 ____, 6-10 ____, 11-25 ____, > 25 ____

3. WORKFORCE

Average number of machines each worker can operate ______
Percentage of employee suggestions implemented _____%

D. COST-BASED PERFORMANCE MEASURES

1. Please estimate the Cost of Goods Sold for your average product _____%

2. Please estimate the cost breakdown for your average product (as a percentage).

Raw materials _____% Labor _____%
Energy _____% Overhead _____%

3. What is the average machine utilization rate for your equipment? _____%

4. What is the average capacity utilization rate for your facilities? _____%

5. What is the average number of days of RAW MATERIALS inventory held? _____%

6. What is the average number of days of WORK-IN-PROCESS inventory held? _____%

7. What is the average number of days of FINISHED GOODS inventory held? _____%

8. How many inventory turns did you have in 1990? _____%

9. What is your Direct Labor productivity? _____%

10. What is your average production lot size? _____%

11. Please rate the level of orderliness and cleanliness of your manufacturing shops, as compared to your competitors. Circle the appropriate value using the scale below.

Significantly less orderly	1	2	3	4	5	6	7	Significantly more orderly
				About the same				

12. Please place a check next to the cost accounting method utilized by your firm.

Activity-based costing ___ Direct costing ___
Indirect costing ___ Life-cycle costing ___
Other ___, please list method ___________

Part IV. STRATEGIC INTEGRATION

In this section, please indicate the degree of integration between functional managers in strategy formulation. Use the scale below for your responses.

NO Integration	1	2	3	4	5	6	7	MUCH Integration

1. What is the level of integration between Manufacturing managers and Marketing managers in strategic planning?

   Level of Integration ____

2. What is the level of integration between Manufacturing managers and Product Design managers in strategic planning?

   Level of Integration ____

3. What is the level of integration between Product Design managers and Marketing managers in strategic planning?

   Level of Integration ____

4. What is the level of integration between Product Design personnel and Manufacturing personnel in the product design phase?

   Level of Integration ____

5. What is the level of integration between Marketing personnel and Manufacturing personnel in the product design phase?

   Level of Integration ____

THANK YOU AGAIN FOR YOUR PARTICIPATION! PLEASE RETURN THE COMPLETED QUESTIONNAIRE IN ENVELOPE PROVIDED. THERE IS NO NEED TO RETURN THE GLOSSARY.

MANUFACTURING TECHNIQUES GLOSSARY

100% INSPECTION: Ensuring quality and process control through inspection of ALL parts as they are produced by a given process.

ABC ANALYSIS: A materials classification system in which all stocked items are classified by annual dollar volume.

ACCEPTANCE SAMPLING: Inspection in which decisions are made to accept or not accept a product or service based on a random sample, as opposed to an entire lot (Attribute or Variables).

ACTIVITY-BASED COSTING: A method of costing whereby a job, product or service is assigned overhead costs only if overhead activity is actually expended in support of it.

ADOPTION OF QUALITY STANDARDS: Adopting and using national and international standards to establish quality goals within the organization, to measure progress on quality improvement programs, marketing the organization, and developing suppliers.

ADVANCED MANUFACTURING TECHNOLOGY: Involving new technologies such as Artificial Intelligence, CNC-machines, Decision Support Systems (DSS), CAD/CAM, Flexible Manufacturing Systems (FMS) in production processes.

ADVANCED STATISTICAL TECHNIQUES: Those techniques used to help analyze the interaction of factors in design and production to reduce the variability inherent in the manufacturing process. Included are ANOVA, correlation/regression, multivariate analysis, DOE, and Taguchi methods.

AUTOMATED MONITORING DEVICES: Using devices which can automatically detect defects during machining/production.

AUTOMATION: A system, process, or piece of equipment that is self-acting or self-regulating, substituting mechanical or electronic devices for human observation, effort and decision making.

AVAILABILITY OF COST OF QUALITY DATA TO MANAGERS: Collecting data regarding the "Cost of Quality" and made available to unit managers.

AVAILABILITY OF QUALITY RELATED DATA TO MANAGERS: The degree to which managers have access to quality data to aid in learning, decision making, and monitoring.

AVAILABILITY OF QUALITY RELATED DATA TO WORKERS: The degree to which hourly workers have access to quality data to assist in learning, quality improvement and provide a sense of ownership.

BACKWARD INTEGRATION: The degree to which your firm controls and/or operates the supply chain from raw material to your finished product.

BENCHMARKING: The continuous process of measuring products, services, and practices against the toughest competitors or those companies recognized as industry leaders.

CAPACITY REQUIREMENTS PLANNING (CRP): A computer-based method of determining current and future work-center loads and determining the labor and machine resources needed to achieve planned outputs.

CAPITAL INVESTMENT: An emphasis on increasing outlays for manufacturing facility upgrades, dedicated production equipment, or new process technology to reduce overall manufacturing costs.

CELLULAR MANUFACTURING: A layout in which workstations and machines are arranged into manufacturing cells that provide families of parts with similar flow paths.

COLOR CODING FOR PARTS AND MACHINES: A foolproofing system which ensures that parts get machined on the proper machine.

COMMON MANUFACTURING DATABASE: Database of manufacturing information accessible by several different functional areas.

COMPUTER INTEGRATED MANUFACTURING (CIM): The total integration of product design, engineering, process planning, and manufacturing through computer systems.

COMPUTER-AIDED DESIGN (CAD): Designing products using a computer and a data-base of part numbers allowing for speed and simplification through increased standardization.

CONCURRENT/SIMULTANEOUS ENGINEERING: Reducing lead times in projects by doing design and production of later stages at the same time and coordinated with earlier activities; inclusion of suppliers, process and manufacturing engineers, and marketing personnel early in product design.

COORDINATION AMONG DEPARTMENTS IN PRODUCT DESIGN: Including representatives from various functional areas, such as manufacturing, marketing, and purchasing in product design.

CROSS-FUNCTIONAL TEAMS: The formation of teams whose members come from different functional areas.

CROSS-TRAINING WORKERS: Training workers to have the ability to perform multiple tasks or operate multiple machines.

DESIGN FOR MANUFACTURABILITY (DFM): An approach which characterized by the simultaneous involvement of various departments within the firm (e.g. manufacturing, marketing, purchasing, etc.) and/or suppliers along with product design and development personnel in the design process to reduce the cost and time involved in designing, developing and producing a product.

ELECTRONIC DATA INTERCHANGE (EDI): Electronic connection with customers and suppliers using computers to quickly place and receive orders.

EMPHASIS ON "DOING THINGS RIGHT THE FIRST TIME": Reducing cost of quality (scrap and rework, and external failures such as warranty expense, failure detection/inspection, and failure prevention) by focusing efforts on quality products produced on the first run.

EMPHASIS ON QUALITY BY UPPER MANAGEMENT: Upper management's involvement and support of quality programs.

EMPLOYEE INVOLVEMENT: Allowing and encouraging employee decision making, implementation of ideas, free up time to create ideas, communicate what is expected of employees, etc.

EMPLOYEE RECOGNITION: Individual employees or teams are formally recognized through awards, gifts, time off, merit pay increases, bonuses, parking privileges, etc.

EMPLOYEE SUGGESTIONS: A formal system for eliciting employee suggestions for methods of improving operations and for rewarding workers whose suggestions are implemented.

EMPLOYEES HELD RESPONSIBLE FOR OUTPUT QUALITY: Holding employees responsible for quality at their operations by using techniques such as communicating to employees that they are not to pass on defective material, tying pay to quality performance, etc.

EXCESS EQUIPMENT CAPACITY MAINTAINED: Excess capacity is maintained to accommodate demand fluctuations.

FAILSAFING OR FOOLPROOFING (POKA-YOKE): Building into operations methods that either prevent mistakes or defects from occurring or being passed on, or instantly detect mistakes or defects.

FLEXIBLE MANUFACTURING SYSTEMS (FMS): Using an FMS in production of your products.

FORWARD INTEGRATION: The degree to which your firm controls and/or operates the distribution chain and markets for its products.

FUNCTIONAL INTEGRATION: Increasing formal and informal communication across functional lines (e.g. manufacturing and marketing, design and marketing) within the firm.

GAINSHARING: An incentive pay system in which everyone receives a share of the value of cost decreases or productivity increases.

GROUP TECHNOLOGY: A technique by which products or parts with similar characteristics are grouped into distinct families and machines are arranged to specifically produce a family of parts.

IMPROVED FORECASTING: Reducing inventory costs through more accurate forecasting.

INSPECTION OF FINISHED GOODS: Materials are inspected before they are shipped to customers.

INSPECTION OF IN-PROCESS WORK: Materials are inspected at points in the production process.

INSPECTION OF INCOMING MATERIALS: Materials are inspected upon arrival from suppliers.

INVOLVE SUPPLIERS IN PRODUCT DESIGN: Using suppliers' technical abilities and product knowledge in the design stage of your products.

JUST-IN TIME (JIT): Production and inventory control system designed to produce small lots, minimize waste and reduce WIP inventory.

LARGE BATCH PRODUCTION: Reducing unit costs through producing in larger lots.

LEVEL WORK RELEASES: Releasing work to the shop floor in a level manner, thereby eliminating bottlenecks.

LINE BALANCING: A procedure for dividing tasks evenly among employees at workstations in a product or cellular layout.

LOT SPLITTING: Splitting a lot quantity into more than one sublot and working on a sublot, rather than waiting for the entire lot to be competed before beginning process on the next stage.

MANUFACTURING RESOURCE PLANNING (MRPII): A comprehensive planning and control system using the Master Production Schedule as a basis for scheduling capacity, shipments, tool changes, design work, and cash flow.

MATERIAL REQUIREMENTS PLANNING (MRP): A computerized information system for tracking inventory and scheduling stock replenishment orders.

MEAN AND RANGE CHARTS: A graphic representation of the variation in the characteristics being produced by a process which shows the amount and nature of that variation by time, indicates statistical control or lack of it, and enables pattern interpretation and detection of changes in quality levels.

MEASURING PRODUCT RELIABILITY: Most interested in total number of failures and total cumulative operating time (in hours, days, cycles, etc.).

MIXED MODEL PRODUCTION SCHEDULING: A production schedule that is repetitive in short cycles and is more conducive to supplying some of each needed model each day closely in line with customer requirements.

OFFER LONGER TERM AGREEMENTS TO SUPPLIERS: Moving away from short term contracts to longer, more stable contacts.

PREVENTIVE MAINTENANCE: Any actions such as adjustments, replacements and basic cleanliness that forestall equipment failures.

PROCESS-FOCUSED FACTORY: An approach which narrows the range of tasks and demands placed on the manufacturing organization by focusing efforts on a limited range of process technologies.

PRODUCT RELIABILITY TESTING: The probability that a product will perform its intended functions under stated conditions for the specified time period. The following are techniques that use these elements to improve reliability.

PRODUCT SIMPLIFICATION: A search for ways to enable a product to perform the same function, but with fewer parts and less processing time required for manufacturing.

PRODUCT STANDARDIZATION: Making products standardized to ease manufacture and increase efficiency.

PRODUCT-FOCUSED FACTORY: An approach which narrows the range of tasks and demands placed on the manufacturing organization by focusing efforts on a limited number of products.

PROGRAMMABLE TECHNOLOGY: A means of production for which the functions are controlled by computers, microprocessors, or programmable controllers, allowing for quick changeover to production of next product.

PROPRIETARY TECHNOLOGY: The development and use of proprietary technology in production that enables the firm to gain an advantage over competitors.

PURCHASE IN LARGE QUANTITIES: Reducing unit prices by realizing quantity discounts, shipping discounts, order processing costs, etc.

QUALITY AUDIT: A documented activity performed in accordance with written procedures or check lists to verify that applicable elements of the quality assurance program have been developed, documented and effectively implemented in accordance with specified requirements.

QUALITY CIRCLES: Small work groups that meet periodically to discuss ways to improve quality, productivity, or the work environment.

QUALITY FUNCTION DEPLOYMENT (QFD): A mechanism used to capture customer desires and wants, and assign functional responsibility throughout the company.

QUALITY OF WORK-LIFE (QWL) INITIATIVES: A program aimed at improving the work environment consisting of one or more of the following: job enrichment, cleanliness, temperature, noise reduction, benefits, meetings, etc.

REDUCE SIZE OF WORKFORCE: Reducing the size of the workforce using layoffs, dismissals and attrition.

REDUCING SETUP TIMES: Those activities aimed at reducing the time required between production runs.

REDUCTION IN ENGINEERING CHANGE ORDERS: Reducing the number of engineering change orders allowed to increase the stability of the production plan/schedule.

REDUCTION IN FINISHED GOODS INVENTORY: Practices which reduce the amount of product in finished goods inventory.

REDUCTION IN RAW MATERIALS INVENTORY: Practices which reduce the amount of raw materials in inventory.

REDUCTION IN THROUGHPUT TIMES: Reducing throughputs to lower costs in areas such as inventories and job lateness, and to improve machine utilization.

REDUCTION IN WORK-IN-PROCESS (WIP) INVENTORIES: Efforts to reduce the size of WIP inventory.

RELIABILITY ASSESSMENT: Flagging reliability problems through measures such as total number of failures, failure rate, warranty costs, factory inspection and test reports, customer returns, field service reports, competitor's relative reliability performance, and customer or dealer complaints.

RELIANCE ON A FEW, DEPENDABLE SUPPLIERS: Awarding business to a limited number of suppliers to foster a cooperative relationship.

REVERSE ENGINEERING: Competitors' products are physically disassembled and inspected to determine what components, design aspects, or inferred manufacturing processes have been used or improved upon.

SELF-DIRECTED WORK TEAMS: Small groups of workers (5-15) rotating through jobs without the presence of supervisors.

SIMPLIFIED MATERIAL FLOW: The re-arrangement of equipment or altering of routing plans to simplify the flow of material.

STATISTICAL PROCESS CONTROL (SPC): A collection of process analysis techniques including flowcharts, Pareto analysis, fishbone chart, and control charts to monitor process quality.

SUBCONTRACTING: Farming out work in heavy demand periods to free up capacity.

SUPPLIER CERTIFICATION: Structured programs that use supplier ratings to award certification based on achievement of stated goals.

SUPPLIER SELECTION BASED ON PRICE: Suppliers are chosen primarily for their ability to deliver a low-cost product.

SUPPLIER SELECTION BASED ON QUALITY: Suppliers are chosen primarily for their ability to deliver a quality product.

SYNCHRONOUS MANUFACTURING: An integrated system of manufacture in which all functions of the firm are involved in the design and production of a product.

TIMELY FEEDBACK OF QUALITY DATA: Providing feedback to workers on quality performance to be used in the identification and correction of quality problems.

TOTAL PRODUCTIVE MAINTENANCE (TPM): A full agenda of procedures that improve the dependability of equipment, with emphasis on maintaining equipment before it breaks down; bestows primary responsibility for Preventive Maintenance on the equipment operator.

TOTAL QUALITY CONTROL (TQC): A comprehensive program to ensure quality throughout the organization; includes planning and design, supplier and manufacturing interface, customer service and 'quality at the source'.

TRAINING FOR EXECUTIVES AND MANAGERS: The use of training programs in quality, cost management, productivity improvement, team building, etc., for executives.

TRAINING FOR WORKERS: The use of training programs in quality, cost control, productivity improvement, etc., for workers.

TRAINING PROVIDED TO SUPPLIERS: Providing assistance in the area of quality improvement techniques to your suppliers.

VALUE ANALYSIS: A thorough examination of existing product design specifications with the aim of lowering cost, typically centered in the purchasing or engineering departments.

VARIETY REDUCTION: A technique which simplifies the production task through narrowing the base of parts required to produce.

VENDOR LEAD-TIME MANAGEMENT: Managing suppliers to ensure timely deliveries and working with suppliers to reduce lead times.

VERTICAL JOB ENLARGEMENT: Expanding job design by allowing workers more involvement in planning activities and supervision.

VISIBLE PERFORMANCE CHARTS: Placing performance charts and quality related data so that all employees are able to view them.

WORK MEASUREMENT: The use of industrial engineering techniques to determine standards and produce parts with high efficiency.

WORKER MOTIVATION: Programs aimed at motivating the workforce using items such as recognition, bonuses, contests, rewards, etc.

WORKER SAFETY: Increasing worker safety in your factories to increase attendance and reduce compensation premiums.

WORKER SPECIALIZATION: Workers holding very specialized skills which allow them to be very efficient at a limited number of tasks.

WORKPLACE ORDERLINESS: Having everything needed for production in place and ready for use so that time is not spent searching for tools or materials.

ZERO DEFECTS: A program aimed at reducing the number of product defects to zero.

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