COMPONENTS OF MANUFACTURING STRATEGY WITHIN LEVELS OF U.S. MANUFACTURING SUPPLY CHAINS

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1. Introduction

Since Skinner's breakthrough article in 1969 [26], the importance of manufacturing management has gained momentum. Manufacturing companies have shifted from financial strategies to manufacturing strategies to derive competitive strategy and profitability. Although financial strategies are still important to a manufacturing company, it is manufacturing strategies that are being used to increase profitability.

Many researchers have identified components of manufacturing strategy (Skinner [27], Porter [22], Hayes & Wheelright [14], Wheelright [31], Garvin [11, 12], Adam & Swamidass [2], Anderson, Cleveland & Schroeder [4], Ward, Leong & Snyder [30], White [32], Manoochehri [18]), while others have tested these components against industry (Richardson, Taylor & Gordon [23], Schroeder, Anderson & Cleveland [25], Swamidass [28], Roth, DeMeyer & Amano [24], Marucheck, Pannesi & Anderson [19], Dsouza, McDougall & Deane [8], Wood, Ritzman & Sharma [33], Flynn, Schroeder & Sakakibara [9, 18], Lee, Everett & Tuan [17]). All of these studies indicate the need for a more thorough and expansive empirically based analysis of manufacturing strategy.

The present study builds on the efforts of past research to provide a comprehensive analysis that culminates in a survey that far exceeds (in mailing size) previous survey research on manufacturing strategy. In addition, our study differs from previous studies of manufacturing strategy because we relate manufacturing strategy to the respondent's company's level in the supply chain. Our study involves a national mailing to 3,375 managers that represent 3,285 different manufacturing companies. Six hundred thirty four of the returned surveys were analyzed to answer the following questions:

- What are the current components of manufacturing strategy that have been identified as competitive strengths?
- What components combine to make coherent manufacturing strategies?
- Do manufacturing strategies differ in importance across five levels of supply chain?

2. Manufacturing Strategy Defined

In 1986, Paul Swamidass stated: „Manufacturing strategy involves the development and deployment of manufacturing capabilities in total alignment with the firm's goals and strategies. When manufacturing strategy is well formulated and implemented, it gives competitive advantage to the manufacturer through the best and conscious use of uniqueness of the manufacturing function such as low cost manufacturing, high quality production, manufacturing flexibility, etc." [28, p. 472]

Although Swamidass calls for a well formulated strategy, Schroeder et al.[25] determined in their study that „The term ‚manufacturing strategy' is not well understood..." [25, p. 405]. Given the ambiguity over what constitutes a manufacturing strategy, Swamidass [28], Schroeder et al.[25], Anderson et al.[4] and Wood et al.[33] suggest that strategic components first be defined and identified. One of the purposes of the present study is to uncover those components through the use of a survey of U.S. manufacturing firms. The next step, as Wood et al.[33] and White [32] outline, is to form these components into coherent manufacturing strategies. We use factor analysis of manufacturing components to develop meaningful clusters that can be interpreted readily into manufacturing strategies. Further, managers in different levels of the supply chain may view different strategies as important and this is examined as well.

3. Literature Review

Because this research involves manufacturing strategy with respect to level in the supply chain, we examined the literature on both components of manufacturing strategy and supply chains.

3.1 Components of Manufacturing Strategy

Many researchers who have identified components of manufacturing strategy have used different terms such as competitive priorities, competitive abilities, corporate strategies and competitive advantages. For the purpose of clarity we use the term components of manufacturing strategy. In addition, we present the literature in chronological fashion. We discuss the concepts developed by each author and, if appropriate, list the strategic components identified in Table 1. The appropriateness of including a component of manufacturing strategy in the table is dependent upon further conceptual development. If a later researcher expanded upon and refined an earlier strategy, we use the later development. For example, Hayes and Wheelright [14] identified technology as a component of manufacturing strategy. To them, technology included equipment, automation and connectedness. Adam and Swamidass [2] used the term technology-process to describe manufacturing process and manufacturing technology. We are interpreting these definitions to be interchangeable and use the term technology-process because it is more current.

Skinner [26] was the first to write about manufacturing‘s potential to increase a company‘s competitive ability. He suggested „top-down“ manufacturing that „starts with the company and its competitive strategy; its goal is to define manufacturing policy.“ [26, p. 145] Skinner provided anecdotal evidence of anonymous companies that failed to identify their competitive strategies because they had been managed from the bottom-up. Skinner then details a top-down management process that links up manufacturing strategy with corporate strategy. Although insightful, Skinner offered no empirical data to substantiate his theory. In 1974, Skinner [27] wrote of the need for a factory to be focused on manufacturing a narrow product mix. Skinner based his conclusions on 50 plants in six industries. Focusing on a narrow product mix is labeled „focus“ in Table 1. Table 1, shown below, will be further explained throughout this section.

Porter [22] identified market focus, low-cost producer and product differentiation as components of manufacturing strategy. In Table 1, we identify „focus“ and „low cost“ as two components, but allow Wheelright [31] to expand on Porter‘s generic definition of product differentiation. Wheelright [31] listed quality, dependability, flexibility and low cost as categories of manufacturing strategy. Wheelright broke down the term quality into higher quality, product features and performance capabilities as bases of competitive advantage (The terms „quality“, „features“ and „performance“ are used to identify these in Table 1). He further interpreted quality by defining perceived quality as well as quality defined by the absence of defects. In Table 1, we define perceived quality as „perceived quality“ and absence of defects as „defect free quality“. We are not going to include dependability because Wheelright used it as a catchall term and provided examples that included doing work as specified, delivering on time and serviceability. Subsequent researchers provided better delineation of dependability. Wheelright continued by defining flexibility as product flexibility and volume flexibility. We provide these as „flexibility-product“ and „flexibility-volume“ in Table 1.

Hayes and Wheelwright [14] offered eight categories for composing a manufacturing strategy. Because each of the eight is strategic in nature, we consider each of them a component of manufacturing strategy. These categories are capacity, facilities, technology, vertical integration, workforce, quality, production planning/materials control, and organization. In Table 1, we identify Hayes and Wheelright‘s capacity as „capacity“, facilities as „facilities size“, technology as „technology-process“, vertical integration as „vertical integration“ and production planning/materials control as „materials control“. Workforce will be elaborated through later research as described by Swamidass [28].

Richardson et al.[23] provide qualitative measures of corporate mission and manufacturing tasks by having executives from 64 Canadian firms rank their importance. They listed eight „factors“ (volume of output, cost per unit, quality, on-time delivery, labor productivity, ability to introduce

new products, flexibility to product specification changes and flexibility to volume changes) that can be interpreted as components of manufacturing strategy. New components provided through these researchers are „delivery“, „labor productivity“, and „development time“, shown in Table 1.

Schroeder et al. [25] assessed manufacturing managers and their understanding of manufacturing strategy. Thirty-nine manufacturing managers, while enrolled in an executive course on manufacturing strategy, were surveyed. The study revealed, in rank order, the following eight manufacturing objectives: quality, delivery performance, unit cost, flexibility to change volume, flexibility to change product, employee relations, inventory turnover, and equipment utilization. It is not clear if respondents felt that these objectives were manufacturing strategies for the success of their companies. In Table 1, the strategy components „employee relations“, „equipment utilization“ and „inventory turnover“ are added.

Swamidass [28] assessed 35 small-batch manufacturers, located almost entirely in the Pacific Northwest, with five open-ended questions and a 64-item survey. Three of the five open ended questions involved issues relating strategy to a firm‘s competitiveness. CEO responses indicated that quality, reliability, and performance of their products along with state-of-the-art design, technology, and engineering were the two most frequent elements of their manufacturing and technology vital to their firm‘s competitiveness. Using a 64 item questionnaire, components that were determined most frequently as manufacturing strengths (a term highly related to manufacturing strategy) were quality, reliability, performance of their products, design, technology, engineering, cost, manufacturing, flexibility, responsiveness to customers, experience (know-how), and service. Other components were diverse and integrated products, timeliness, and location near market. Thus, new strategies put forth by Swamidass in Table 1 are „location near market“, „product design/engineering“, „reliability“, „service“, „technology-process“, „experience-hourly“ and „experience-salary.“

Garvin [12] discussed how a firm could compete within a narrow quality niche by choosing one quality dimension upon which to compete. Garvin further developed his idea by choosing eight dimensions (performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality) of product quality as a framework for strategic analysis. Garvin‘s theoretical approach to defining quality and categorizing the dimensions of quality was meant to be a method for managers to realize untapped quality niches and focus manufacturing efforts. Garvin also believed that a company would have to charge unreasonably high prices if it pursued all eight dimensions of quality simultaneously. From Garvin‘s research study, we can add „aesthetics“, „conformance“, „distribution“ and „durability“ to Table 1.

Adam and Swamidass [2] performed a literature search on sixteen content variables of operations strategy (i.e., capacity, cost/price productivity, delivery, product design and engineering, distribution, employee relations, facilities, flexibility, focus, infrastructure, quality, return on investment, service, standardization, technology-process, and vertical integration). In our list in Table 1, Adam and Swamidass are credited with introducing the strategy „infrastructure“.

Wood et al.[33] used factor analysis with variables representing intended and achieved performance in 144 different manufacturing plants located in the Midwest and Northeast. The variables represented 11 different competitive priorities. They were able to show that these variables could be grouped under four factors (high performance product competitive priority, delivery or time competitive priority, cost/price competitive priority, and quality consistency side of the competitive priority). No new components of strategy were added to Table 1 but Wood et al.[33] were the first to use factor analysis to group components into strategies.

White [32] grouped examples of performance measures under the competitive priorities cost measures, quality measures, flexibility measures and speed measures. Although the list defines performance measures, many are examples of manufacturing strategies. In addition, White‘s work allows us to add „cycle time“ to Table 1.

In summary, the contributions of Skinner [27], Porter [22], Hayes and Wheelright [14], Wheelright [31], Garvin[12], Adam and Swamidass [2], and White [32] are theoretically insightful, but little empirical research is provided to substantiate their conceptual research. Richardson et al.[23], Schroeder et al.[25], Swamidass [28], and Wood

et al.[33] have performed empirical studies on manufacturing strategies. However, these authors based their findings on relatively small sample sizes of 64, 39, 35 and 144 subjects, respectively. In Table 1, we have initially identified 33 components of manufacturing strategies based on the cited work.

3.2 Supply Chain Literature

The work reviewed in the previous section focused on defining components of strategy in individual organizations. In the work cited in this section, strategy was studied with respect to the entire supply chain.

Choi and Hartley [6] studied supplier selection practices in the auto industry by surveying 156 companies to compare three levels of a supply chain on 26 variables. These variables were: quality philosophy, capability for incremental improvements, consistent conformance to specifications, after-sales support, ability to change production volumes rapidly, and ability to set up for new products at short notice. Other variables included consistent meeting of delivery deadlines, design capability, communication openness, willingness to resolve conflict, closeness of past relationship, likelihood of long-term relationship, performance awards received by the supplier, profitability of the supplier, and supplier representative's competence. Choi and Hartley found that supplier selection practices were more similar than dissimilar within three levels of supply chain.

Narasimhan and Jayaram [20] investigated causal linkages in supply chain management within 127 North American firms by using structural equation modeling techniques. They measured eight variables on the effectiveness of supply chain management. These were quality, dependability, cost, flexibility, customer responsiveness, strategic outsourcing, and supplier capability. The results showed that an integrated supply chain involves aligning sourcing decisions to achieve manufacturing goals that are set to respond favorably to the needs of the customers.

In conclusion, limited empirical research has been conducted on supplier selection practices and management in a supply chain. We extend this research by determining what strategies are most important to a national sample of manufacturing companies and relate them to level in supply chain.

In total, the two literature reviews revealed 33 components of manufacturing strategy. These components are identified in Table 1, „Components of Manufacturing Strategies Derived from Literature and Empirical Analysis." The last column in Table 1 will be explained later in the Methodology section.

4. Methodology

The methodological steps taken for this study are: literature review (previously discussed), multiple case studies using interviews, development and analysis of pre-survey responses, development and analysis of pilot survey, and development and analysis of national survey.

4.1 Multiple Case Studies Using Interviews

A multiple-case study was done to develop a better understanding of the components of manufacturing strategy identified through the literature review. On-site interviews (personal) and telephone interviews with management personnel who are directly involved with manufacturing organizations were conducted.

Although the discussions were open-ended, they were based upon the concept of structured questions (Yin [34]). The detailed list of topics that were discussed during the structured interviews can be grouped under six major topic areas: organizational information; measuring performance and criteria; development of criteria; role of customers in developing and measuring performance; role of suppliers in developing and measuring performance; and results. Seven different organizations were represented in the interview process. Five of these organizations were manufacturing organizations while two others were corporate (parent) divisions of mainly manufacturing companies.

The technique of personal interviewing (Alreck & Settle, [3]) was used to elicit candid discussions. A total of twenty structured interviews were conducted. Of the twenty interviews, ten were „face to face" and ten were via telephone. The ten personal interviews were conducted on-site and each personal interview ranged in length from one to two hours. The positions of the individuals interviewed included plant manager, executive vice president, director of operations, director

of technical support, product manager, quality assurance manager and technician, materials leader, and supply quality engineer. All personal interviews were recorded and field notes were taken to prepare the case studies. Transcriptions of each interview were made and are available as qualitative data. Follow-up phone calls were made to clarify certain points during the case write-up process.

The ten telephone interviews ranged in length from 10 to 30 minutes. The positions of the individuals interviewed included public relations manager, product support manager, field quality manager, staff quality engineer, director of financial planning and control, sales director, associate buyer, general manager, quality control manager, and inside sales representative. Notes were taken and follow-up phone calls were made to clarify certain points during the case write-up process.

The interviews (multiple case study analysis) focused on the definition, communication and modification of product quality information in a connected manufacturing supply chain. The interviews provided a rich source of information that substantiated 20 of the components identified in Table 1. The components that were identified through these interviews were aesthetics, conformance, cycle time, delivery, development time, durability, employee relations, features, product flexibility, inventory turnover, low cost, product design/engineering, perceived quality, performance, quality, reliability, return on investment, service, technology-process, and vertical integration. No new components of manufacturing strategy were identified through these interviews.

4.2 Development and Analysis of Pre-Survey Responses

Using the information gained through the literature review and multiple case study analysis, a preliminary questionnaire was developed. Twenty-four members of 15 different manufacturing organizations were asked for their candid opinions regarding pre-survey content and clarity. Sixteen members reviewed and mailed their responses back while five additional members allowed on-site evaluations. These on-site evaluations helped determine if some of the questions were confusing, irrelevant or misleading. Mailed back responses and evaluations indicated that 25 of the original 33 components of manufacturing strategy should be retained.

In addition, pre-survey participants indicated three new components of manufacturing strategy that were not identified through our literature review. These components are identified in Table 1 as „innovativeness-marketing," „relations with suppliers" and „value-added services" and are indicated with an asterisk.

At this stage, we added information technology as a potentially important component of manufacturing strategy upon the reading of two articles that discussed the use of the internet in business (Anonymous [1]; Port [21]). From these articles, seven components were selected for use in the survey instrument. These components are identified as „regular e-mail use," „E-commerce in present," „E-commerce in future," „cost reductions with web," „marketing information via web," „generating revenue with web," and „integration via website."

Four respondents, different from those that suggested new components of manufacturing strategy, were interviewed on the ten newly identified components of manufacturing strategy (three from the survey participants and seven involving information technology). The respondents were asked whether the suggestions were applicable as components for their organizations (yes or no answer). A minimum of three out of four similar responses indicated whether the suggestions should be included in the questionnaire. All ten suggestions were considered applicable as components of manufacturing strategies. Given the 43 components of manufacturing strategy in Table 1 (33 from the literature and 10 approved by the managers), a check mark in the column labeled „Component Used?" indicates whether the component was accepted for inclusion in the pilot survey, while an „X" indicates whether the component was excluded. The pre-survey process resulted in a total of 35 components of manufacturing strategy that were included in the pilot survey.

4.3 Development and Analysis of Pilot Survey

A pilot survey was administered to managers in one manufacturing company and its Tier 1

(i.e., direct suppliers to the focal manufacturing company) and Tier 2 suppliers (i.e., suppliers to Tier 1) to properly test the survey content prior to conducting a national study. In total, 104 individuals from 70 different manufacturing organizations were mailed pilot surveys. Respondents in the pilot study were from companies that manufactured metal products, commercial machinery, electrical equipment, transportation equipment, or measurement equipment, and all had managerial or executive titles.

Forty-five managers from the focal company, 34 Tier 1 suppliers and 25 Tier 2 suppliers were asked to participate in the pilot survey. Respondents were asked to respond to: „Please rate each of the following characteristics on their importance to your company competing effectively." Using seven-point Likert scales, with 1 being not important, 4 being moderately important, and 7 being extremely important were used. Respondents indicated their answers on the same page as the survey questions, and mailed back the original survey with their responses in a pre-addressed, first class stamped envelope. In an effort to encourage non-respondents to participate, reminder phone calls were made to participants who had not returned their surveys within three weeks. Fifty-eight surveys (55.8% response rate) were returned and all were considered useful for analysis.

Our goals for using the pilot survey included testing the survey design/scanning software TeleForms package, testing the survey content for reliability and validity, and to delete survey items that were found irrelevant or redundant. Actual (paper) survey responses were checked against the data file that was recorded when surveys were scanned in and no errors were detected. The TeleForms software package was reliable and no problems were encountered.

A correlation analysis was performed to assess the degree of multicollinearity (i.e., the degree to which an item's effect can be predicted or accounted for by other items in the analysis) amongst the items in the scale (i.e., components of manufacturing strategy). Using a threshold of 0.90 (Tabachnick & Fidell [29]), no items were found to be multicollinear.

Cronbach's alpha was used as a form of reliability analysis to assess the internal consistency of the scale items measuring components of manufacturing strategy. Cronbach's alpha for the 35 items was 0.9216. An alpha value of 0.70 is considered acceptable (Hair, Anderson, Tatham, & Black [13]).

Exploratory factor analysis was used to determine which of the 35 items in the scale loaded on common factors, which items had low factor loadings and which items had complex loadings. Principal component analysis was used with varimax rotation and four factors were extracted.

Therefore, all items were evaluated for their impact on high item intercorrelations, low scale reliability, and low factor loadings. Along with these statistical measurements of reliability and relevance, items were evaluated for practical significance. Items that were considered important to our study were retained, even if the statistical measurements indicated that the item might be weak. Our effort for model parsimony led us to the conclusion that seven components could be eliminated from this scale prior to its national administration: cycle time, flexibility-product, flexibility-volume, focus, innovativeness-marketing, inventory turnover and regular e-mail use. Cronbach's alpha for the remaining 28 items decreased to 0.8957, still far above the 0.70 criterion for acceptability. Appendix 1 contains the final 28 survey items that were selected for use in the national survey.

4.4 Development and Analysis of National Survey

Participants

The main purpose of the national survey was to research quality in manufacturing. Because this survey was partially funded by the American Society for Quality (ASQ), members of this organization were targeted. The population for this study was derived from a list of ASQ members who are employed by U.S. and foreign owned manufacturing firms in the U.S. The mailing list for the survey includes ASQ members within selected SIC codes, positions, job functions, or divisions as described below:

Participants were chosen from manufacturing organizations in five SIC codes (34 -Fabricated Metal Products; 35 - Industrial & Commercial Machinery & Computer Equipment; 36 - Electronics & Other Electrical Equipment; 37 - Transportation Equipment; and 38 - Measure, Analyze & Con-

struction Industries) and had job titles that were representative of higher level management (i.e., Director, Manager, President, Vice President and General Manager). Additionally, we selected participants who came from the job functions of Inspection, Product Assurance, Quality Assurance, Quality Control, Quality and Supplier Quality, and from Quality Audit, Quality Management and Reliability divisions in their organizations. The total number of individuals that fit the above stated criteria in the database was 3,375. These 3,375 individuals represented 3,285 different companies.

All 3,375 individuals received the survey via first class postage. Two sets of reminder, or follow-up, post cards were sent out. One set of reminder post cards was mailed out one week after the survey distribution while the second set was sent out two weeks after survey distribution. All reminder post cards were sent out via first class postage. Answers were indicated on the same page as the survey questions (using scanable forms) and mailed back in a pre-addressed, first-class stamped envelope.

Measures

For the purposes of the current study, the following variables were measured.

Components of manufacturing. The 28 items developed and refined as a result of the literature review, multiple case study, pre-survey and pilot survey were used to measure the respondents' perceptions of the importance of various components of manufacturing strategy in their company competing effectively. Items were rated on seven-point Likert scales (1= Not Important, 4 = Moderately Important, and 7 = Extremely Important).

Level in supply chain. One item was used to determine the level in the supply chain that best represented each respondent's company. The question asked: „What best describes your company's position in your manufacturing supply chain? Arrows indicate product flow direction." Respondents had five choices: base level supplier, sub-component supplier, component supplier, major component supplier, and end product producer. The arrow went from left to right and base level supplier was on the far left. In other words, product flows from the base level supplier to the sub-component supplier. The sub-component supplier then supplies, or flows, the product to the component supplier, etc. The self reported description of each respondent's level in the supply chain could not be verified by any other sources.

Organizational and respondent information. General questions about company size, annual sales, number of suppliers, hours of quality training, manufactured products (based on the five SIC codes described above), and job titles were asked for descriptive purposes.

5. Results

The purposes of this study was to answer three questions:

- What are the current components of manufacturing strategy that have been identified as competitive strengths?
- What components combine to make coherent manufacturing strategies?
- Do manufacturing strategies differ in importance across five levels of supply chain?

The analyses and results are organized as follows: first, we present descriptive statistics on the sample; second, we examine the psychometric properties of the 28 items used to measure the importance of manufacturing strategy components (i.e., means and inter-correlations among the items); thirdly, we present the results of a principle components analysis to determine if the 28 components group into coherent manufacturing strategies; and lastly, we present the results of an analysis of variance (ANOVA) of the importance of manufacturing strategies across levels of supply chain.

5.1 Descriptive Statistics of the Sample

A total of 637 of the 3,375 surveys mailed to respondents were returned and 634 were determined to be useful for analysis. This represented a response rate of 18.8%. Performing a power analysis (Keller & Warrack [15]), we determined that our minimum sample size should be 356 (95% confidence level, error bound of 10%, and average standard deviation of .963). If the error bound is decreased to 7.5%, a sample of 633 respondents is needed. According to industry standards reported by Keppel [16], if power equals 0.9, a sample size of 478 is required to

have an (=0.01 and small effect size=0.01. Dillon, Madden, and Firtle [7] suggests a minimum sample size of 200, but they further state that a typical size of 400-500 is suggested for strategic studies. We conclude that our sample size of 634 respondents is sufficient to detect significant differences, if they exist, in the population.

Tables 2 and 3 provide characteristics of the population and the sample respondents. Thirty-three respondents failed to identify their company with one of the five industry descriptions. Although all SIC codes were represented in the survey responses, the sample ratios were not proportional to the population ratios. Specifically, SIC codes 34 and 36 were over-represented in the sample as compared to the population while SIC codes 35 and 38 were underrepresented in the sample as compared to the population. Sample ratios for job title more closely represented population ratios except for the title „Director". In our mailing list population, no „Directors" were identified while our sample self-identified 66 „Directors".

One item in the survey was used to determine the level in the supply chain that represented each of the respondents. A total of 615 respondents indicated their position in their supply chain while 19 respondents did not. These 19 respondents were included in the total analysis but were not included in the analyses involving differences among supply chain levels. Tables 4 and 5 provide selected characteristics of the respondents' companies in the total sample and within individual levels in supply chain.

Companies with various levels of sales were evenly distributed throughout the sample whereas number of employees in company was not. About 54 % of our sample represented companies that had less than 250 employees.

5.2 Components of Manufacturing Strategy

The average value for each item in the survey and its standard deviation is shown for the total sample in Table 6.

A correlation analysis was performed and only four pairs of items were found to have correlation higher than 0.7. Specifically, innovativeness of the design team and speed of the design phase (r = .76); ability to communicate goals to employees and ability to communicate goals to suppliers (r = .78); experience of hourly employees and experience of salary employees (r = .73); and e-commerce is an important part of present company strategy and e-commerce is an important part of future company strategy (r = .79) were somewhat highly related, but none are considered to be redundant (i.e., greater than 0.9).

Cronbach's alpha was calculated to be 0.9034 for the 28 items in the manufacturing components scale. This strong measure of internal consistency tells us that our scale is a reliable indicator of these components of manufacturing strategy. With regard to our first research question, these results indicate that we can identify current components of manufacturing strategy in a reliable way.

5.3 Development of Manufacturing Strategy Factors

Our second research question asked what components combine to make coherent strategies. We conducted a factor analysis to find which strategic components load (grouped together) to form common factors. The number of components to analyze is minimized and this reduction aids in analysis. In order to derive meaningful results, these factors would have to be present in all five levels of the supply chain. It would not be possible to distinguish the importance of each factor at each level if structural invariance (i.e., the same factors, and only these factors, exist in each level) was not established. Accordingly, exploratory factor analysis using principle component analysis with varimax rotation was performed on all 28 items for each level of the supply chain. Level 1 (base level supplier) with only 17 subjects and Level 2 (sub-component supplier) with 49 subjects were too small to have meaningful results (Tabachnick & Fidell [29]). Although factor analysis was performed on these two levels, the analysis focused on Levels 3, 4 and 5 to determine structural invariance.

To determine common strategies across levels, the following steps were taken:

1) The 28 items were factor analyzed within each individual supply level.
2) Components with factor loadings greater than 0.4 were retained while factor loadings less than 0.4 were dropped from further analyses.

3) If an item was identified as being complex in two or more of the three largest levels (i.e., had two or more factor loadings greater than 0.4), it was dropped from further analyses.
4) After steps 2 and 3, another factor analysis was performed. Items with factor loadings of less than 0.4 on any factor or items with complex loadings as described above were dropped from further analyses.
5) The process of principle component analysis was continued until only factors with items loading over 0.4 and items with no complex loadings were obtained.

Through our iterative analysis of the manufacturing components and examination of scree plots, 13 of the original 28 items were retained to derive four factors that were invariant across all five levels of the supply chain. Using these 13 items, a final factor analysis was run using the complete sample. The results, indicating factor loadings, are shown in Table 7. Note that only item 9 loads on Factor 4 (i.e., the location of our product's manufacturing facility), but it was strong and consistent enough across supply chain levels to retain in the analysis. The final four factors extracted accounted for 69.6 % of the variance in the items (see Appendix 1 for the components to which each item refers). Reliability analyses on the first three factors were performed using Cronbach's alpha, yielding 0.88 for Factor 1, 0.78 for Factor 2, 0.74 for Factor 3. These values exceed the 0.70 value of acceptability. All of these indicators provide support for four separate manufacturing strategies across all five levels of the supply chain.

Factor 1, made up of items 23-28, represents an „Internet Based Technology" strategy. Factor 2 consists of items 2, 14 and 15. They group to form an „Effectiveness of Design" strategy. Factor 3, made up of items 10, 18 and 19, groups employee experience with on time delivery. This strategy is described as „Employee Experience/ Delivery". Factor 4, technically not a factor because it is composed of only item 9, location of product's manufacturing facility, is called „Facility Location". We performed a correlational analysis to determine if the strategies were highly related to each other within each supply chain level. Overall, the results indicate that some strategies are statistically correlated with one another but none of them are highly correlated (i.e., 0.6 or greater). These results indicate that at each level in the supply chain there are four strategies that are individually distinct, but may be related to other strategies. With regard to our second research question, the results of the factor analyses and subsequent reliability and correlational analyses indicate that we can group manufacturing components derived from past conceptual and empirical studies into four coherent manufacturing strategies.

5.4 Manufacturing Strategy Importance Across Supply Chain Levels

To answer our third research question, we need to determine if the four manufacturing strategies differ in importance across the five levels of the supply chain. This can be determined through an analysis of variance (ANOVA) of the four strategies across the five levels of the supply chain. The results of the ANOVAs are presented in Table 8, along with the standardized mean scores for each strategy within each level of the supply chain. Follow-up Tukey tests indicate whether significant mean differences in strategy importance across the five levels exist.

The results of each of the ANOVAs indicate there are significant differences in the importance of the four strategies across the different levels in the supply chain (see F-tests in Table 8). For Strategy 1 (Internet Based Technology), end--product producers rate this strategy significantly more important than do sub-component suppliers. For Strategy 2 (Effectiveness of Design), major component suppliers and end product producers rate this strategy significantly more important than do sub-component suppliers. In addition, end product producers rate this strategy significantly more important than do component suppliers. With regard to Strategy 3 (Employee Experience/Delivery), sub-component suppliers rate this strategy significantly more important than component, major component, and end product producers. However, major component suppliers rate this strategy as significantly more important than do end product producers. Lastly, with regard to Strategy 4 (Facility Location), end product producers rate this strategy as significantly less important than do the other levels in the supply chain.

Within each supply chain level, we can determine which strategies appear to be more important through examination of the absolute ranking of mean scores. It appears that for all levels, the most important strategy is Strategy 3, „Employee Experience/Delivery". Respondents felt that employee experience (both hourly and salary) coupled with on time delivery is the most important strategy to their company competing effectively. The second most important strategy, again across all levels, is Strategy 2, „Effectiveness of Design". Base level and major component suppliers consider Strategy 4, „Facility Location" their third most important strategy, while Strategy 1, „Internet Based Technology" is considered their fourth most important strategy. End product producers consider „Internet Based Technology" to be their third most important strategy while „Facility Location" is considered their fourth most important strategy.

6. Discussion and Conclusion

In the present study, components of manufacturing strategy were determined from previous research, in depth interviews, multiple case study analysis, and an empirically based survey. Twenty--eight components were identified and a national survey was conducted in which 634 surveys were returned and analyzed. Through factor analysis, four coherent strategies that were consistent across the five levels of supply chain were derived from the data. Significant differences across several levels in the supply chain in the importance of each strategy for manufacturing competitiveness were found.

In order to create coherent factors across five levels of the supply chain, 15 of the original 28 items derived from the literature review, case studies, and interviews with manufacturing managers were dropped from later stages of the analysis. Some of the excluded items were 1, 3, 4, 5, 7, and 8 (i.e., performance, reliability, conformance, durability, aesthetics and perceived quality, respectively). Garvin [12] described these components, along with „features" (item 2) and „service" (item 6), as dimensions of quality used as individual strategies. He further stated: „A company need not pursue all eight dimensions simultaneously. In fact, that is seldom possible unless it intends to charge unreasonably high prices." [12, p. 108]

Our study shows that managers in companies in different levels of the supply chain did not consider these eight strategic components to form coherent strategies used to gain a competitive advantage. However, it may be that these components were viewed by the respondents as important components of multiple strategies. That is, these components do not individually provide a competitive advantage; however, they are essential requirements of doing business as a manufacturer. Regardless of the firm's strategic posture, the company must provide high levels of these quality components. Fifteen or twenty years ago these quality components, if successfully individually executed, might have provided a competitive advantage through a market niche. Given the widespread adoption of these quality components throughout the industry, it may be that they are now merely requirements for staying in business.

Two other manufacturing components uncovered in our research (i.e., items 11 and 12, low cost and quality, respectively) have long been described as strategies used to develop competitive advantage (Wheelright [31], Swamidass [28], Schroeder et al.[25], Wood et al.[33], White [32]). Our qualitative research indicates these components are important to overall success, but again they may not be used as coherent, integrated strategies. As with Garvin's quality components, they may now be basic business requirements. Similarly, employee relations (item 16), relations with suppliers (item 17), return on investment (item 20) and technology process (item 21) may be important parts of multiple strategies.

We found empirical support to answer our third research question, „Do manufacturing strategies differ in importance across five levels of supply chain?" Some strategies were more important to companies in different levels of the supply chain than others. It is interesting that end product producers report the internet based technology strategy to be significantly more important than do the other levels in the supply chain. Since these companies are generally larger in terms of both employees and annual sales than the companies in other supply levels, they might have more resources to allocate to newer manufacturing technologies that are internet-based. In addition, perhaps these companies more often than the other

suppliers deal directly with end customers who are becoming more accustomed to interacting with companies using this technology. Customer demands might be increasing the importance of this strategy in competing effectively.

Surprisingly, although internet based technology strategies were more important to end product producers than to the other companies in the sample, it was not their most important strategy as determined by the absolute rankings of the mean strategy scores for this level (i.e., it was third in importance after facilities location and employee experience/delivery). In fact, this particular strategy was ranked lowest in importance within all five levels. To date, internet based strategies might not be developed and utilized fully in manufacturing organizations. A survey by the National Association of Manufacturers seems to confirm this view in that over two-thirds of the companies surveyed did not use the internet for business to business commerce (Cairncross [5]). As these technologies are perfected and diffused throughout the industry, it is likely that the number of manufacturing companies using them will grow and the importance of internet based strategies for competitive advantage will increase.

Similar to internet based strategies, customer demands may be driving the importance of the second strategy of design effectiveness. The results show that this strategy is more important to major component suppliers and end product producers than to the lower levels in the supply chain. Product innovation, features, and speed of design might be more critical for those suppliers who are closer to the end customer in the supply chain. The absolute rankings of strategies within each level indicate that this is indeed an important strategy for all levels in the supply chain.

Strategy 3, employee experience and delivery and strategy 4, facilities location, generally appear to be more important for suppliers in the lower levels of the supply chain than for those in the higher levels. It might be argued that companies that process raw materials or produce small components that make up larger components of products are highly dependent on experienced workers, close location to raw materials and skilled labor markets, and on-time delivery of their parts to maintain their competitiveness in supplier markets. Major component suppliers and end product producers (as customers of these lower level suppliers) may demand these qualities of their suppliers and if not obtained, may source their components elsewhere. The absolute rankings of the strategies within the five levels indicate that employee experience/delivery currently is a critically important strategy for manufacturing companies in general.

There are several limitations of this study. First, a sample size of 634 was derived from a population of 3,375. Industry characteristics of the sample did not closely represent those of the population, and job titles did not closely match those of the population, although some were similar. Supply chain levels 1 and 2 (base level and sub-component level suppliers) were represented by 27 and 49 respondents, respectively. Results must be interpreted cautiously for these two levels. To properly analyze each of these levels, a minimum sample size of 140 subjects each is suggested. As within any survey, answers to all questions are subjective. Level in supply chain could have been innocently misrepresented by the respondent. In some cases, respondents' companies might operate at multiple levels in the supply chain and the most representative level was chosen. By having only one respondent per company, the researcher is depending upon his/her viewpoint. Obtaining several surveys from the same company and collectively analyzing them is one method to alleviate that problem.

In this paper we have answered the initial research questions. First we identified 28 current components of manufacturing strategy through a literature review, in depth interviews, multiple case study analysis and a survey of U.S. manufacturing companies. An analysis of the national survey responses addressed the second research question. We identified components that group cleanly together to form four coherent manufacturing strategies throughout the individual levels of supply chain. These strategies were labeled: Internet Based Technology, Effectiveness of Design, Employee Experience/Delivery, and Facility Location. Our third research question was addressed by determining where significant differences existed across the five levels of the supply chain. An interesting result of our research was that we identified many components of manufacturing strategy that might now be considered prerequisites for doing business, but which might not lead to competitive advantage.

Our study is important because it expanded on other research efforts and determined what components of manufacturing strategy are current. This research is also important to the manufacturing community because it empirically demonstrates the current components of manufacturing strategy and shows which strategies seem most likely to enhance competitive advantage based on level in the supply chain. It is hoped that knowledge derived from this study will provide a basis from which researchers and practitioners can derive the status of present day manufacturing.

Tab. 1: Components of Manufacturing Strategies Derived From Literature and Empirical Analysis Inserted Here

Appendix 1

28 Items Used in Survey on Components of Manufacturing Strategy

Please rate each of the following characteristics on their importance to your company competing effectively.

Not Important			Moderately Important			Extremely Important
1	2	3	4	5	6	7

1.	Our product's performance (operating characteristics)	____
2.	Our product's features	____
3.	Our product's reliability	____
4.	Our product's conformance (ability to meet factory and customer established standards with our product's design and operating characteristics)	____
5.	Our product's durability (product life)	____
6.	Our product's serviceability (speed, courtesy, competence and ease of repair)	____
7.	Our product's aesthetics (how a product looks, feels, sounds, etc.)	____
8.	Our product's perceived quality (our reputation)	____
9.	The location of our product's manufacturing facility	____
10.	The ability to deliver our product on time	____
11.	Our product's low cost	____
12.	Our product's quality	____
13.	Our value added services	____
14.	The innovativeness of our design team	____
15.	The speed of our design phase/stage	____
16.	Our ability to communicate our goals to our employees	____
17.	Our ability to communicate our goals to our suppliers	____
18.	The experience of our salaried employees	____
19.	Our return on investment	____
20.	Our technology-process	____
21.	Our amount of vertical integration	____
22.	E-commerce (using the web to do business) is an important part of our company's present strategy	____
23.	E-commerce is an important part of our company's future strategy	____
24.	Web based business has allowed us to cut our costs	____
25.	Our company uses the web to provide marketing information	____
26.	Our company uses the web as an important source for generating revenue	____
27.	Our customers and suppliers are integrated through our website	____

Tab. 2: Industry Characteristics of Population and Sample (Response)

	Population		Sample	
Industry Description	**n**	**Ratio (%)**	**n**	**Ratio (%)**
Fabricated Metal Products (SIC Code 34)	627	18.6	233	36.8
Industrial & Commercial Machinery & Computer Equipment (SIC Code 35)	755	22.4	84	13.2
Electronic & Electrical Equipment (SIC Code 36)	730	21.6	188	29.7
Transportation Equipment (SIC Code 37)	370	11.0	71	11.2
Measure Analyze, & Construction (SIC Code 38)	622	18.4	25	3.9
Other	271	8.0	33	5.2
Total Population	**3375**	**100.0**	**634**	**100.0**

Own source

Tab. 3: Job Title Characteristics of Population and Sample (Response)

	Population		Sample	
Job Title Description	**n**	**Ratio (%)**	**n**	**Ratio (%)**
Director	0	0.0	66	10.4
Manager	2943	87.2	504	79.5
President	42	1.2	4	0.6
Vice President	211	6.3	38	6.0
General Manager	16	0.5	15	2.4
Other	163	4.8	7	1.1
Total Population	**3375**	**100.0**	**634**	**100.0**

Source: own

Tab. 4: Sales of Respondents' Companies

Position in supply chain	Total	Base Level	Sub-Component	Component	Major Component	End Product
	634	27	49	121	139	279
Company Sales ($ million)	(%)	(%)	(%)	(%)	(%)	(%)
0 – 3	4.7	0.0	16.3	5.0	2.9	4.3
4 – 10	14.8	29.6	30.6	20.7	13.7	9.0
11 – 20	17.0	33.3	32.7	25.6	15.1	10.0
21 – 50	16.6	0.0	14.3	19.0	21.6	14.7
51 – 100	12.8	7.4	4.1	16.5	12.2	14.0
101 – 500	17.2	11.1	0.0	6.6	17.3	24.7
Over 500	13.2	11.1	2.0	5.0	14.4	18.6
Missing	3.6	7.4	0.0	1.7	2.9	4.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: own

Tab. 5: Number of Employees in Respondents' Companies

Position in supply chain	Total	Base Level	Sub-Component	Component	Major Component	End Product
	634	27	49	121	139	279
Number of employees	(%)	(%)	(%)	(%)	(%)	(%)
1 - 100	28.7	44.4	61.2	41.3	24.5	18.3
101 - 250	25.6	29.6	34.7	28.1	27.3	21.5
251 – 500	15.8	7.4	2.0	17.4	12.9	20.1
501 – 1000	12.1	7.4	0.0	5.8	14.4	16.8
1001 – 2500	6.8	3.7	0.0	4.1	8.6	8.2
2501 – 5000	3.6	0.0	0.0	0.8	2.9	6.5
Over 5000	7.1	7.4	2.0	2.5	9.4	8.6
Missing (%)	0.3	0.0	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: own

Tab. 6: Means and Standard Deviations of Components of Strategy in Total Sample

Item Number	Description	Mean Sample Value	Standard Deviation
1*	Performance	6.24	1.01
2	Features	5.54	1.30
3	Reliability	6.15	1.15
4	Conformance	6.12	0.98
5	Durability	5.56	1.36
6	Service	4.76	1.79
7	Aesthetics	4.64	1.74
8*	Perceived quality	6.26	0.94
9	Location near market	3.37	1.76
10	Delivery	6.16	1.03
11	Low cost	4.84	1.59
12*	Quality	6.23	0.94
13	Value added services	5.00	1.55
14	Product design/engineering	4.55	1.79
15	Development time	4.43	1.81
16	Employee relations	4.77	1.60
17	Relations with suppliers	4.67	1.61
18	Experience-hourly	5.11	1.35
19	Experience-salary	5.37	1.25
20	Return on investment	5.55	1.32
21	Technology-process	5.23	1.40
22	Vertical integration	4.03	1.63
23	E-commerce in present	3.38	1.70
24	E-commerce in future	4.12	1.82
25	Cost reductions with web	2.49	1.53
26	Marketing info via web	4.03	1.81
27	Generating revenue w/ web	2.54	1.46
28	Integration via website	2.47	1.58

* Item used to determine average σ for power analysis.

Source: own

Tab. 7: Strategies in Manufacturing Supply Chains for Total Sample

Item	Factor 1	Factor 2	Factor 3	Factor 4
27 23 25 24 26 28	.839 .835 .802 .771 .738 .703			
15 14 2		.856 .853 .693		
18 19 10			.894 .889 .572	
9				.913
% of Variance Explained	29.18	16.45	15.65	8.31
Chronbach's Alpha	.88	.78	.74	-

Source: own

Tab. 8: Comparison of Mean Strategy Scores

	Base Level Supplier	Sub-Component Supplier	Component Supplier	Major Component Supplier	End Product Producer
Strategy 1	3.1795	2.7083*5	3.0702	2.9937	3.3544*2
Strategy 2	4.5769	4.2245*4, 5	4.4266*5	4.8856*2	5.1107*2, 3
Strategy 3	5.6049	6.1701*3, 4, 5	5.5462*2	5.7026*2, 5	5.3640*2, 4
Strategy 4	3.5556	4.1224*5	3.5083*5	3.7194*5	2.9455*2, 3, 4

Source: own

Strategy 1 - $\underline{F}(4, 584) = 3.636$, $p = 0.006$
Strategy 2 - $\underline{F}(4, 596) = 8.352$, $p = 0.000$
Strategy 3 - $\underline{F}(4, 601) = 8.367$, $p = 0.000$
Strategy 4 - $\underline{F}(4, 605) = 8.318$, $p = 0.000$

Notes explain where Tukey tests determined significant (at 0.05 level) mean differences between levels occur:

*2 Significant mean difference (at the 0.05 level) with the sub-component supplier level
*3 Significant mean difference (at the 0.05 level) with the component supplier level
*4 Significant mean difference (at the 0.05 level) with the major component supplier level
*5 Significant mean difference (at the 0.05 level) with the end product producer level

Tab. 1 - Components of Manufacturing Strategies Derived From Literature and Empirical Analysis

Strategies	Skinner 1974	Porter 1980	Hayes & Wheelright 1983	Wheelright 1984	Richardson, Taylor & Gordon 1985	Swamdiss 1986	Schroeder, Anderson & Cleveland 1986	Garvin 1987	Adam & Swamdiss 1989	Wood, Ritzman & Sharma 1990	White 1996	Component Used?
Aesthetics								√				√
Capacity			√		√				√			X
Conformance								√	√			√
Cost reductions with web												√
Cycle time											√	√
Defect free quality				√								X
Delivery					√	√	√		√	√		√
Development time					√	√				√	√	√
Distribution									√			X
Durability								√		√		√
E-commerce in future												√
E-commerce in present												√
Employee relations							√		√			√
Equipment utilization							√					X
Experience-hourly			√			√						√
Experience-salary			√			√						√
Facilities size			√						√			X
Features				√				√		√		√
Flexibility-product				√	√	√	√				√	√
Flexibility-volume				√	√	√	√		√		√	√
Focus	√	√							√			√
Generating revenue w/ web												√
Infrastructure									√			X
Innovativeness-marketing*												√
Integration via website												√
Inventory turnover							√				√	√
Labor Productivity					√							X
Location near market						√					√	√
Low cost		√		√	√	√	√		√	√	√	√
Marketing info via web												√
Materials control			√									X
Perceived quality				√				√		√		√
Performance				√		√		√		√		√
Product design/engineering						√			√		√	√
Quality			√	√	√	√	√		√	√	√	√
Regular e-mail use												√
Relations with suppliers*												√
Reliability						√		√		√	√	√
Return on investment									√			√
Service						√		√	√			√
Technology-process			√			√			√			√
Value added services*												√
Vertical integration			√			√			√			√
* Indicates a component of manufacturing strategy that was not defined in literature and was suggested by survey participants												
X Indicates a component of manufacturing strategy that was rejected by pre-survey participants												
√ Indicates a component of manufacturing strategy that was accepted by pre-survey participants												

Source: own

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ABSTRACT

COMPONENTS OF MANUFACTURING STRATEGY WITHIN LEVELS OF U.S. MANUFACTURING SUPPLY CHAINS

Christopher Roethlein, Paul Mangiameli, Laura Beauvais

This study built on past research that has identified manufacturing strategies from which a company derives its competitive advantages and related it to a multi-level analysis of manufacturing supply chains in the United States. Through a combination of literature review, structured interviews, and a questionnaire to a large national sample, 28 components of manufacturing strategy upon which a company uses to compete were identified. Factor analysis was used to group components into four factors that clustered logically into coherent manufacturing strategies (Internet Based Technology, Effectiveness of Design, Employee Experience/delivery, and Facility Location) across the five defined levels of supply chain. Significant differences in the importance of manufacturing strategy among the five levels of supply chain were found. For Strategy 1 (Internet Based Technology), end-product producers rate this strategy significantly more important than do sub-component suppliers. For Strategy 2 (Effectiveness of Design), major component suppliers and end product producers rate this strategy significantly more important than do sub-component suppliers. In addition, end product producers rate this strategy significantly more important than do component suppliers. With regard to Strategy 3 (Employee Experience/Delivery), sub-component suppliers rate this strategy significantly more important than component, major component, and end product producers. However, major component suppliers rate this strategy as significantly more important as end product producers do. Lastly, with regard to Strategy 4 (Facility Location), end product producers rate this strategy as significantly less important as do the other levels in the supply chain. An interesting result of our research was that we identified many components of manufacturing strategy that might now be considered prerequisites for doing business, but which might not lead to competitive advantage. This research provides a snapshot of the status of how present manufacturing companies view their competitive strengths and will help them understand and define strategies for their futures.

Key Words: *application, factor analysis, manufacturing strategy, supply chain*

JEL Classification: *M11, L62, L64*