Order Number 9108098

Analyzing the competitive priorities of advanced manufacturing technology: An empirical study

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City University of New York, 1990

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ANALYZING THE COMPETITIVE PRIORITIES OF ADVANCED MANUFACTURING TECHNOLOGY AN EMPIRICAL STUDY

by
Sayed Mahmoud Elsayed

A dissertation submitted to the Graduate Faculty
in Business in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
The City University of New York

1990

This manuscript has been read and accepted for the Graduate Faculty in Business in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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ABSTRACT
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OF
ADVANCED MANUFACTURING TECHNOLOGY
AN EMPIRICAL STUDY

by
Sayed Mahmoud Elsayed

Adviser: Professor Michael N. Chanin

This dissertation examines the overall influence of three different levels of advanced manufacturing technology (AMT) on companies ability to achieve the competitive priorities and manufacturing strategy decisions categories.

The three levels of AMT are (1) computer integrated manufacturing; (2) group technology; and (3) flexible manufacturing systems.

Five industries are analyzed: motor vehicle, machine tools and farm equipment, computer and calculating equipment, electronics, and aerospace. The sample was composed of a total of one hundred and twelve companies, distributed as follows: five responses within motor vehicle industry, thirty-one responses within machine tools and farm equipment industry, twenty-three responses within computer and calculating equipment industry, thirty-one responses within electronic industry and twenty-two responses within aerospace industry.

Factor analysis was used to identify the underlying dimensions of the two models: competitive advantages of advanced

manufacturing technology and the impact of AMT on manufacturing strategy decision categories. Three factors were obtained for the competitive advantage model (cost, quality, and flexibility) and four factors for manufacturing strategy decision categories and productivity (production planning/material control and organization structure, capacity and facility, vertical integration, and compatibility between AMT objectives and corporate, business, and functional strategy). Multivariate analysis of variance were used to test the hypotheses.

Although the date were classified by industry, all factors included in the final analysis had high loadings, with scoring coefficients higher than .85 to ensure the reliability and validity.

Regarding companies ability to compete, it was hypothesized that different levels of advanced manufacturing technology users are more likely to gain competitive advantages in terms of cost, quality and flexibility than non-users at different levels of automation. It was further hypothesized that AMT would have an important effect on manufacturing strategy decision categories.

Findings indicate that, there were significant differences between all levels of automation for manufacturing strategy decision categories, productivity, and compatibility among corporate, business and functional strategy. That is, organizations adopted increasingly sophisticated levels of automation, the manufacturing strategy decisions categories changed in the following ways:

There was more effective utilization of manufacturing facilities and capacity. Organizational structure moved from bureaucratic to organic. Vertical integration increased. There was greater compatibility among corporate, business and functional strategy.

Industry analyses were performed to identify priorities for all industry. For each industry in this research high and low priorities regarding manufacturing strategy decisions categories and the competitive advantages of advanced manufacturing systems has been identified.

Recommendations as to the manufacturing implications of the findings of this research were offered.

AKNOWLEDGMENTS

I would first like to thank my advisor, Dr. Michael Chanin, for his guidance, encouragement and providing the idea of this study.

Special appreciation goes to Dr. George Sphicas, who has been supportive and generous in assisting and guiding me, not only through this research, but also during my doctoral studies. It is not possible to sufficiently express my gratitude to you, Dr. Sphicas.

I am delighted to thank Dr. Edward Wolf for guiding me with inspiration, unique knowledge, and expert guidance. I especially feel very fortunate to have been able to work with him. Thanks Dr. Wolf for the valuable research lessons that I have learned from you.

I am very grateful to Dr. Dannenbring who provided invaluable help and assistance toward the completion of this dissertation.

Special thanks are due to Dr. Harris J. Shapiro for his guidance, encouragement and giving me the chance to be a part of Baruch family.

Secondly, I extend my special appreciation to the companies listed below as well as to the other companies that selected to maintain anonymity, and to the individuals within these companies, for reviewing and responding to the questionnaire:

A.O. Smith Automotive Products Co.
Allied Signal
AT & T Technology Systems
Automatix, Inc.
Bethlehem Corp.
Black & Decker Corporation
CYPRESS Corporation
Cooper Industries (Industrial Machinery)
BRK Electronics
General Dynamics
General Instrument (Jerrold Division)
Martin Marietta Electronic Systems
Metco Corporation
National Computer Systems
Storage Technology

I also appreciate the moral support provided by my colleagues at Hofstra University, particularly Dr. Smith, Dr. Sonfield, Dr. Lazarus, and Dr. Wahba.

I also appreciate and thank Mrs. Joanne Paitchell, Mrs. Malvine Karen, and Dr. Vredenburgh of the doctoral office, for their kindness and moral support in all my years at Baruch College.

Special thanks are due to the Special Secretarial Services at Hofstra University, particularly Linda, Raffaela, Barbara, and Fran.

Finally, I would like to express my deepest appreciation and love to my family and friends.

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Chapter One

Introduction

Overview and Significant Prior Research

The literature on Advanced Manufacturing Technology (AMT) has been treated by many authors as an important tool for engineering, design, and manufacturing, but its potential use in gaining a competitive edge by improving manufacturing performance has been largely ignored. To gain some idea of the work done since 1980, I surveyed eleven journals which were devoted exclusively to manufacturing strategy and advance manufacturing technology. Of these eleven journals, seven are refereed. The survey was limited to published papers to ensure that only high quality work was reviewed. Books have been omitted because few include substantive advancements; most relevant books are textbooks, as there is yet no extensive monograph work done in the field. In total, 527 separate categories were checked in the classification of papers. Considering all eleven journals, the categories that received the most citations were: (1) Japanese Management in general, (2) Material Requirement Planning, (3) Flexible Manufacturing Systems, (4) Manufacturing Technology, (5) Manufacturing Strategy, (6) Kanban (Just-IN-time), (7) Computer Aided Design, (8) Computer Aided Manufacturing (9) Computer Integrated Manufacturing, (10) Group Technology, (11) Computer Numerical Control, and (12) Optimized Production Technology. (See table 1.1)

Since the classification was not validated formally, but resulted from extensive literature research and review, the systemization of literature can be reviewed as preliminary classification system. It is interesting to note that statistical testing revealed significant differences in the rankings of the categories between refereed and non-refereed journals. These rankings were obtained by comparing the number of citations in each category. In three areas there are notable differences between the rankings of papers gained from refereed journals and those from non-refereed journals. Refereed journals and the papers published in them emphasize more on technical and rigorous material such as: (1) Material Requirement Planning, (2) Group Technology and (3) Computer Integrated Manufacturing. On the other hand, non-refereed journals emphasize on more general conceptual and qualitative topics such as: (1) Japanese Management, (2) Manufacturing Technology and (3) Manufacturing Strategy.

In the last six years, the volume of articles published in the Flexible Manufacturing Systems, Computer Integrated Manufacturing and Manufacturing Strategy has increased. Based on the work done in compiling Table 1.1, I would conclude that there is considerable change taking place in the manufacturing strategy and advanced manufacturing technology fields and that the change is not just restricted to motion, but is a motion well-directed toward substantive growth of the field.

Table 1.1

Classification of Published Papers (1980-1990)

Topic Areas	HBR	MS*	Interfaces*	PIM*	IE	SMJ*	JBS	AMJ*	OMEGA*	IA	IJPR*	# of papers	Rank of refereed	Rank of Non-refereed	Rank all
1. Manufacturing Strategy	12	2	10	3	4	5	9	5	4	2	4	60	4**	3	5
2. Manufacturing Technology	9	4	4	1	4	1	11	1	11	2	8	56	4**	2	4
3. Japanese Management	15	-	3	11	9	2	19	2	5	10	2	78	4**	1	1
4. Kanban (Just-In-Time)	2	1	2	10	5	-	1	-	2	2	2	27	7	8	7
5. Group Technology	2	1	2	3	3	-	-	-	2	-	9	22	6	12**	8
6. Material Required Planning	-	12	1	73	16	-	-	-	3	4	7	116	1	6	1
7. Computer-Aided Design	1	1	1	1	6	-	3	-	2	2	2	19	8	7	9
8. Computer-Aided Manufacturing	2	1	1	1	3	-	2	-	3	2	2	17	9	9	10
9. Computer Numerical Control	1	-	-	-	1	-	1	-	1	6	3	13	12	10	11
10. Optimized Prod. Technology	-	-	-	6	2	-	-	-	1	3	-	12	10	12**	12
11. Flexible Manufacturing Systems	6	4	1	5	15	-	-	1	5	14	19	70	2	5**	3
12. Computer Integrated Mfg.	3	1	1	2	17	-	1	1	4	2	5	37	11	5**	7
Number of Papers	53	27	26	116	85	8	47	10	43	49	63	527			

HBR = Harvard Business Review
MS = Management Science
PIM = Production and Inventory Management
IE = Industrial Engineering
SMJ = Strategic Management Journal
JBS = Journal of Business Strategy

AMJ = Academy of Management Journal
IA = Iron Age
IJPR = International Journal of Production Research

* denotes a refereed journal
** tied

Significant Prior Research

Rosenthal (1984) undertook three related surveys on factory automation. The intent is to facilitate the exchange of important information about manufacturing. The automation project of Boston University Manufacturing Round-Table viewed as its goal the development of broad managerial views of CAD. Research was not limited to a single technique, but focused rather on several methods of factory automation (Rosenthal, 1986). The problematic results of manufacturers who use Computer Aided Manufacturing Planning (CAMP) in setting up new facilities are examined; specifically at the managerial level. Rosenthal suggests that emphasis should be placed on efforts to attain a formula for factory automation by evaluating the strengths and weaknesses of the new system. The survey of users of factory automation technology claim that they do plan their strategies, although some acknowledge that they are incapable of developing a plan independently related to automated factory. Users are analyzed as to how well they adjust to factory automation, options they may consider, perception of suppliers, coordination with manuals, and the implications of automation on the labor force. When planning has taken place, users report a beneficial impact on their strategies along with quicker responses to changes in product design. Suppliers serve a vast range of customers, from inexperienced to highly sophisticated operations. They have an informed view of the user's stages and activities, as well as an understanding of why the user would prefer not to get involved in automation.

Meyer and Ferdows (1987) focus on the need for the strategic planning of flexible manufacturing systems. To determine this, the reseachers have relied on the European Manufacturing Future Survey. This survey was sent out to approximately 900 of the largest manufacturers in Europe to which 15% responded. The survey found that not particular industry based its production operations on flexible manufacturing systems. The conclusion was drawn that many companies which emphasize flexible manufacturing systems are oriented towards program improvement. These improvements focus on all the major elements of production management: (1) production planning and control, (2) management of workers and shop supervisors, (3) quality management, (4) process technology and the organization of production.

The researchers conclude finally that the idea of the flexible manufacturing systems is being used to force manufacturing functions into new areas of thinking and performance. They relate that a strong emphasis on the FMS signifies the prioritizing of the manufacturing function of a company.

Swamidass and Newell (1987) discuss the environmental uncertainty and performance of manufacturing strategy. Their empirical study based on data gathered from 35 manufacturers found that environmental uncertainty influenced such manufacturing strategy variables as the role of manufacturing managers in strategic decision making and flexibility.

Cleveland (1986) empirically evaluated the relationships between production systems, business strategy and manufacturing competence. The analysis focused on six companies in Minnesota.

Another study by McDougall (1986) analyzed the impact of diversification through the Skinner model using three major corporations with 46 divisions. The study found that the more highly diversified a corporation became, the more efficient its manufacturing strategy was.

The relevant literature in corporate, business and manufacturing strategy will be presented in chapter two.

Design of the Study

Research Objectives and Statement of the Problem

The potential contribution of this study is that the specific items in manufacturing companies adopting Advanced Manufacturing Technologies reflect the current performance in those companies in terms of cost, quality, and flexibility. In this research, Advanced Manufacturing Technology, is defined to included the major five functions in manufacturing organization. These five functions are: (1) planning and control, (2) physical control and tracking, (3) design and engineering, (4) execution and (5) transportation. The major factors in the first analysis include manufacturing cost, flexibility and quality. The final outcome of this analysis compare the competitive advantages of firms adopting different levels of advanced manufacturing technology. For each of these factors a number of items will be examined. For example, flexibility in a specific firm is determined by seven items, cost factor is determined by five items and quality is determined by three items. Figure 1.1 illustrates the major component of Advanced Manufacturing Technology. Figure 1.2 presents the first model in this study. The prior research groups the major components of manufacturing strategy into many different areas supported only by conceptual presentation and theoretical framework. The minimal empirical research that is available in this area is primarily case oriented research and company analysis. The comprehensive analysis used to explore the major factors affecting manufacturing sectors is examined in this research through the use of factor analysis (exploratory factor analysis and confirmatory factor analysis). The exploratory factor analysis includes two hundred items in this study. The first analysis will include nineteen items as an input for confirmatory factor analysis. The data collected are examined first by exploratory factor analysis and the higher loading items are entered and all items with lower loading were deleted.

Figure 1.1

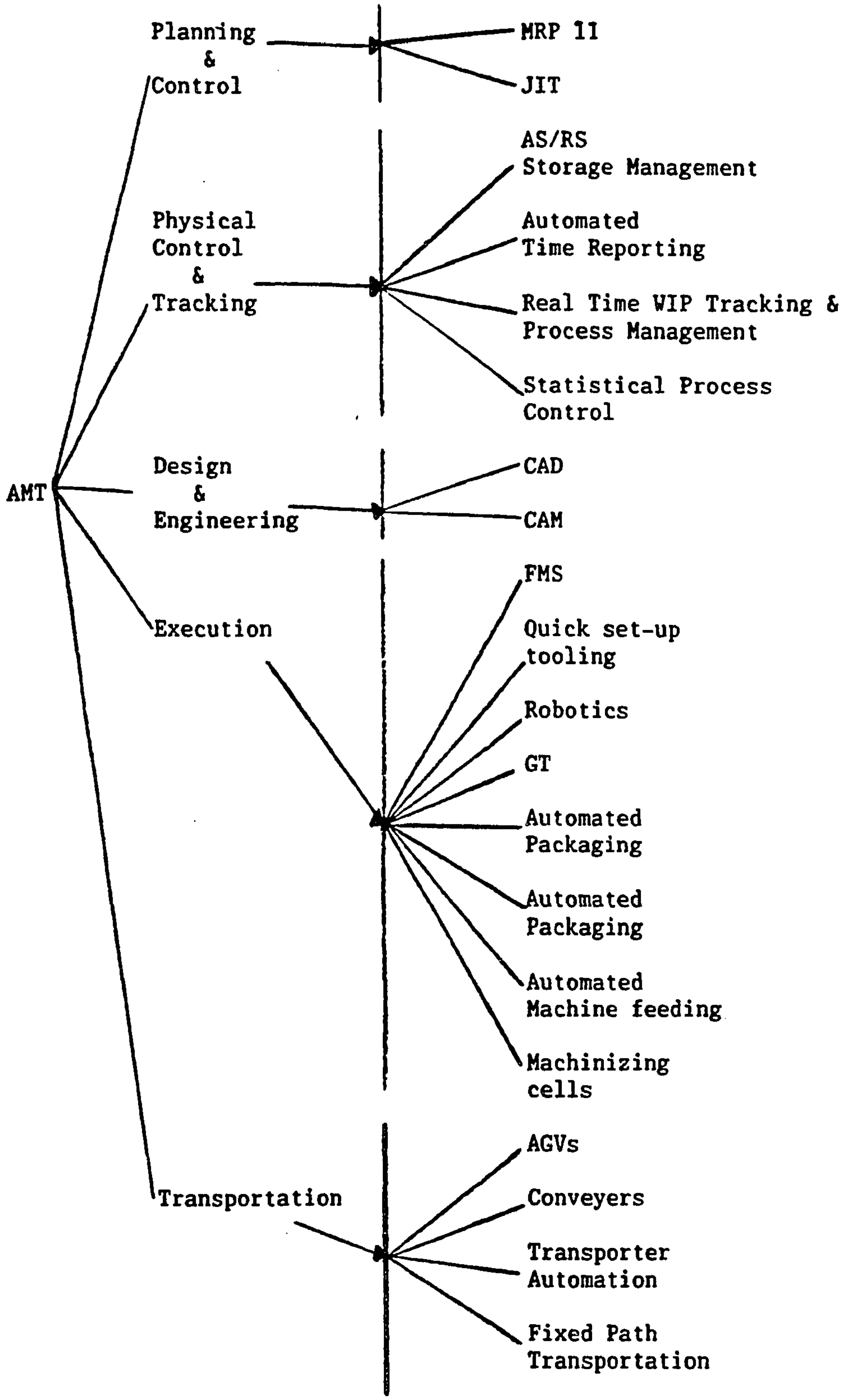
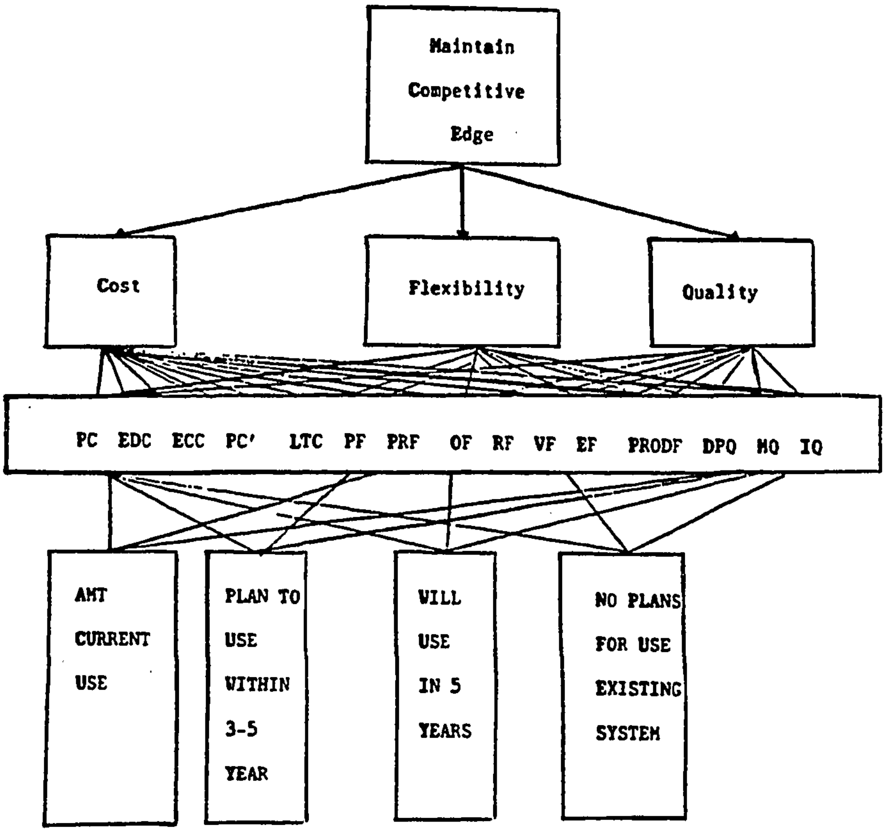

AMT
Planning & Control
MRP II
JIT
Physical Control & Tracking
AS/RS Storage Management
Automated Time Reporting
Real Time WIP Tracking & Process Management
Statistical Process Control
Design & Engineering
CAD
CAM
Execution
FMS
Quick set-up tooling
Robotics
GT
Automated Packaging
Automated Packaging
Automated Machine feeding
Machinizing cells
Transportation
AGVs
Conveyers
Transporter Automation
Fixed Path Transportation

Figure 1.2



Key

PC Product Cost
EDC Engineering Design Cost
ECC Engineering Change Costs
PC Personnel Costs
LTC Lead Time cost
PF Product Flexibility
PRF Process Flexibility
OF Operations Flexibility
RF Rerouting Flexibility
VF Volume Flexibility
EF Expansion Flexibility
PRODF Production Flexibility
DPQ Defect Prevention
MQ Monitoring Quality
IQ Intervention of Defects

The second analysis examines the compatibility of AMT with corporate, business and manufacturing strategy. According to the model, AMT objectives should be central to corporate, business and manufacturing strategy. The second model takes into consideration the manufacturing decision categories presented in the literature. Figure 1.3 illustrates the compatibility that should exist between the strategies of an organization pursuing Advanced Manufacturing Technology.

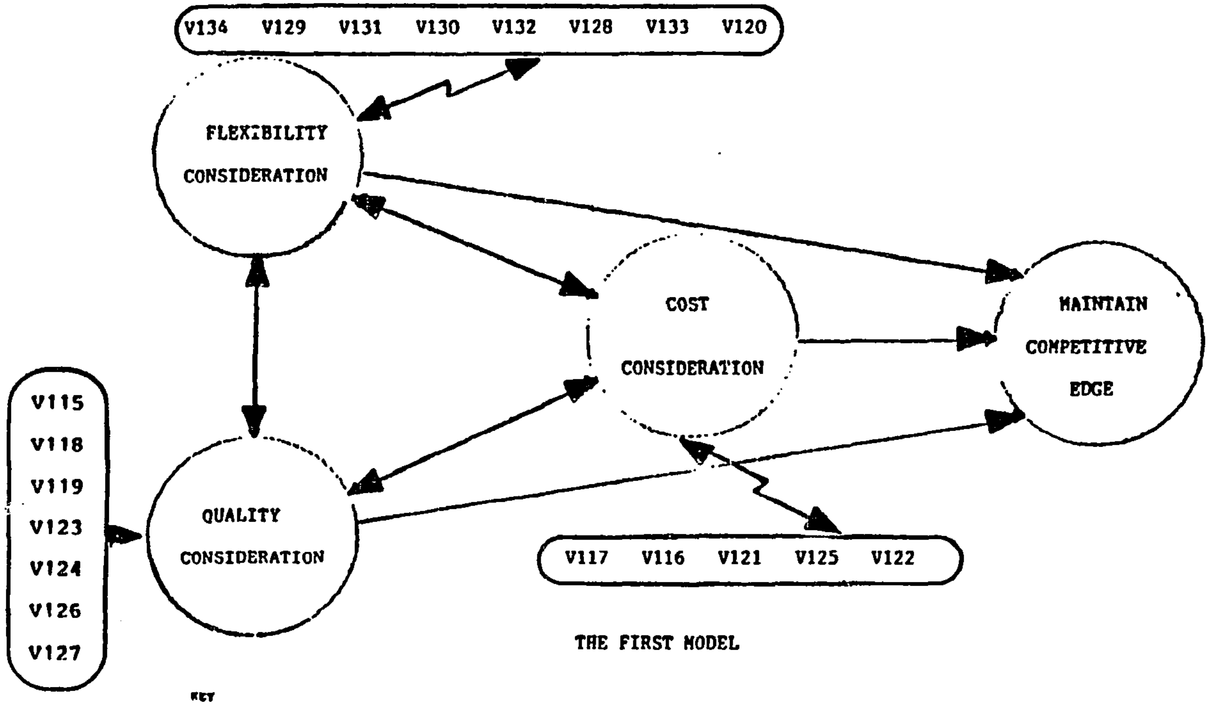
The objective of this model is to examine the following:

- A corporate strategy that is well-defined, communicated, and focused on long term planning.

- A business strategy that is well-defined, communicated, compatible with the corporate strategy, and focused on performance factors.

- A manufacturing strategy that is well-defined, communicated, compatible with the corporate and business strategy, and focused on performance factors.

Figure 1.3

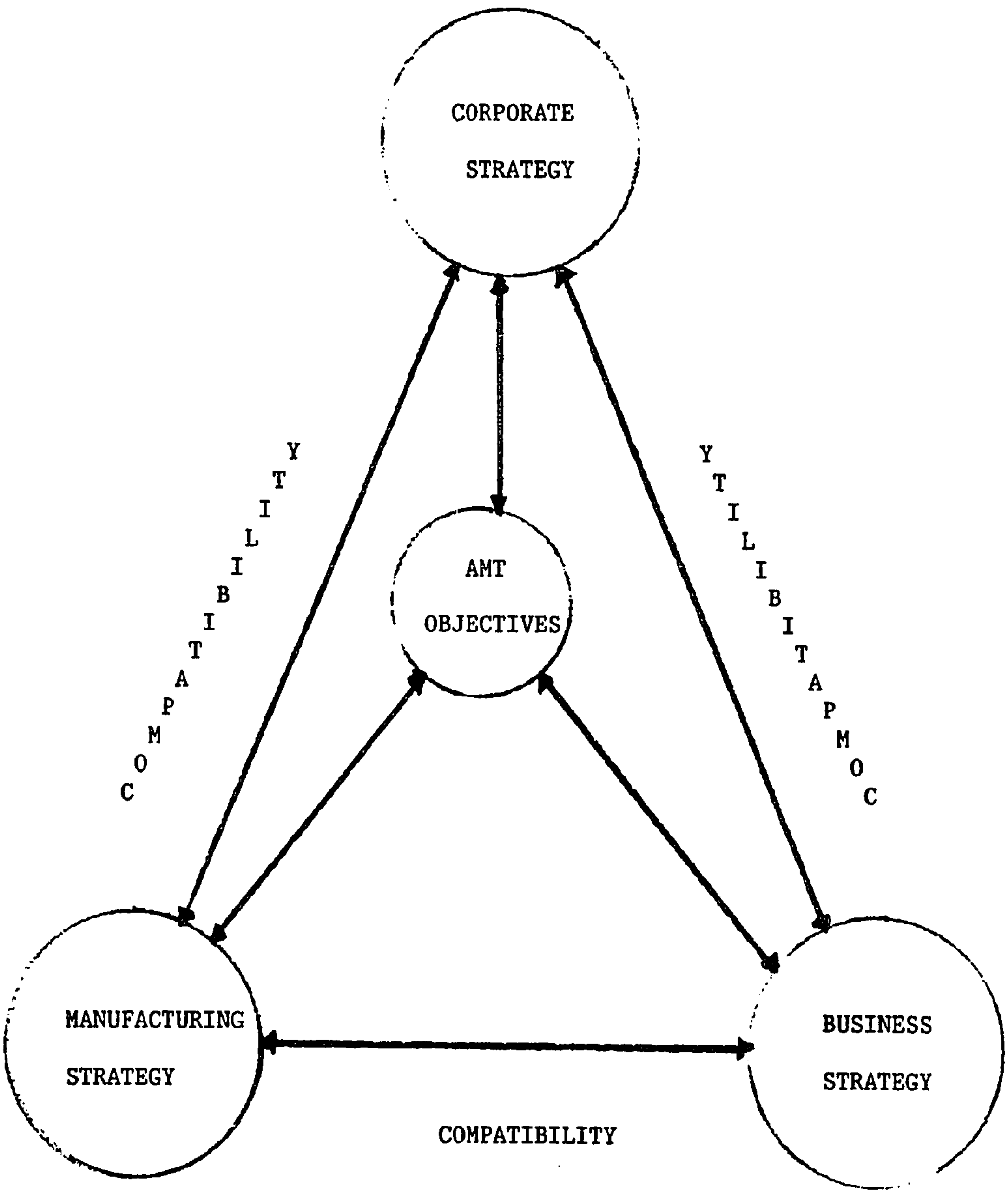


THE FIRST MODEL

KEY

V115 decrease in product cost
V116 increase in control of entire production process
V117 increase in productivity of production operations
V118 increase in utilization of capital equipment
V119 reduction in engineering design cost
V120 increase in capability of engineers
V121 reduction in engineering change costs
V122 increase in product quality
V123 reduction of work-in-process inventory
V124 reduction in materials/supplies costs
V125 reduction of personnel costs
V126 increase in ability to meet delivery dates
V127 increase in order fill rate
V128 decrease in overall lead time
V129 increase in product mix flexibility
V130 increase in component flexibility
V131 increase in modification flexibility
V132 increase in rerouting flexibility
V133 increase in volume flexibility
V134 increase in material flexibility

Figure 1.4


CORPORATE
STRATEGY
AMT
OBJECTIVES
COMPATIBILITY
YTILIBITAPMOC
MANUFACTURING
STRATEGY
BUSINESS
STRATEGY
COMPATIBILITY

- Advanced Manufacturing Technology objectives that are compatible with the corporate, business, and manufacturing strategy.

Compatibility of the objectives of AMT with corporate, business and manufacturing strategy is an important factor in organization performance.

Data Collection Instruments

The instruments combine a questionnaire (closed and open ended investigative questions) with a semi-structured interview schedule. In order to facilitate statistical analysis of the closed-ended questions, a Likert-type scale was used to measure the respondent understanding of certain strategic and operational issues. The questionnaire was based on survey instruments developed by Rosenthal (Factory Automation in the U.S.), Meredith (Justification Survey in the Factory of the Future), and Fossem (Computer Integrated Manufacturing). Certain changes have been made to convert the yes/no questions to the Likert-type scale to allow for the use of statistical analysis, which was not a part of the other studies.

The questionnaire is divided into three segments aimed at the different managerial levels under study. Personal interviews will also be conducted. This combination of closed and open ended investigative questions will provide a relatively broad base of relevant data in considerable detail. It is expected that the general manager and operations manager from each of the selected organizations will be asked to participate. Also, the interview will include a staff specialist (such as a strategist, product engineer, or market analyst), operations specialist (such as a scheduler, engineer, or controller), and/or a line supervisor to obtain sufficient details for subsequent in-depth analysis.

Initial Procedure

1. Set up a research sample by calling or writing a key executive (General Manager or Director of Manufacturing) from randomly pre-selected corporations.
2. Once agreement to participate in the project is obtained from the firm's top management, the respondent will be interviewed in further detail.
3. For each company in the research sample, copies of the following documents will be obtained and reviewed:
   a. Annual Report
   b. Functional Organization Chart
   c. Strategic Planning Document (if available)

The Sample

The sample consists of the major industrial corporations in the United States of America which cover the following industries: Aerospace, Chemicals, Computer and Office Equipment, Electronics, Furniture, Industrial and Farm Equipment, Metal Products. These industries are randomly selected according to their SIC codes from Fortune 500.

Table 1.2 shows the number of companies in each industry according to Fortune 500.

TABLE 1.2

Industry	# of Companies
Aerospace	18
Chemicals	48
Computers	25
Electronics	46
Motor Vehicle	8
Industrial and Farm Equipment	34
Metal Products	19
Total	198

Table 1.3 shows the geographical distribution for major U.S. Corporations, the difference between the total in Table 1.2 and 1.3 refer to the companies which are not covered in Fortune 500, and were obtained from other references such as the Million Dollar Directory.

Table 1.3

Geographical Distribution for Major U.S. Corporations

STATE	# of CORPORATIONS
ALABAMA	3
ARKANSAS	1
CALIFORNIA	23
COLORADO	1
CONNECTICUT	11
FLORIDA	2
GEORGIA	4
ILLINOIS	22
INDIANA	7
IOWA	2
KANSAS	1
KENTUCKY	2
MARYLAND	2
MASSACHUSETTS	5
MICHIGAN	14
MINNESOTA	2
MISSOURI	7
NEBRASKA	2
NEW JERSEY	22
NEW YORK	24
NORTH CAROLINA	2
OHIO	14
OKLAHOMA	2
OREGON	1
PENNSYLVANIA	11
RHODE ISLAND	2
SOUTH CAROLINA	3
TENNESSEE	2
TEXAS	6
VERMONT	6
VIRGINIA	6
WASHINGTON	2
WISCONSIN	12
TOTAL	244

Questionnaires and cover letters will be mailed to over 686 individuals in these corporations.

Structure of the Study

Following the introductory chapter, the study is divided into five chapters. Chapter two covers the pertinent literature on corporate, business and manufacturing strategy. Chapter three presents an overview of advanced manufacturing technology. Chapter four presents research methodology, the preliminary results and the hypotheses of the study. The results of factor analysis to explore the major factors in this study are presented in chapter five, also industry analysis for the factors related to each industry, finally the hypotheses are tested using MANOVA. Chapter six includes a summary of findings and suggestions for future research. The questionnaire and definitions of terms used in this study, along with some statistical results, are provided in the appendices. Figure 1.5 illustrates the detailed steps in designing this study. Figure 1.6 presents a diagnostic framework of the strategic importance of advanced manufacturing technology.

Figure 1.5

Design of the Study

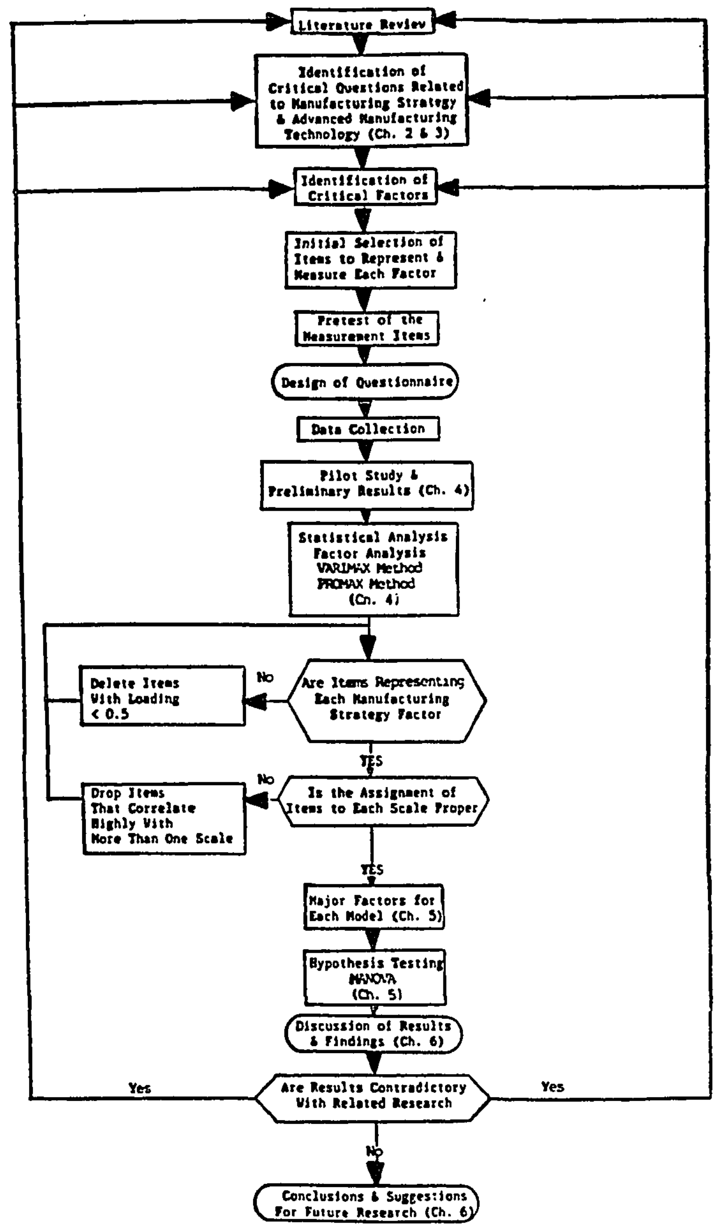
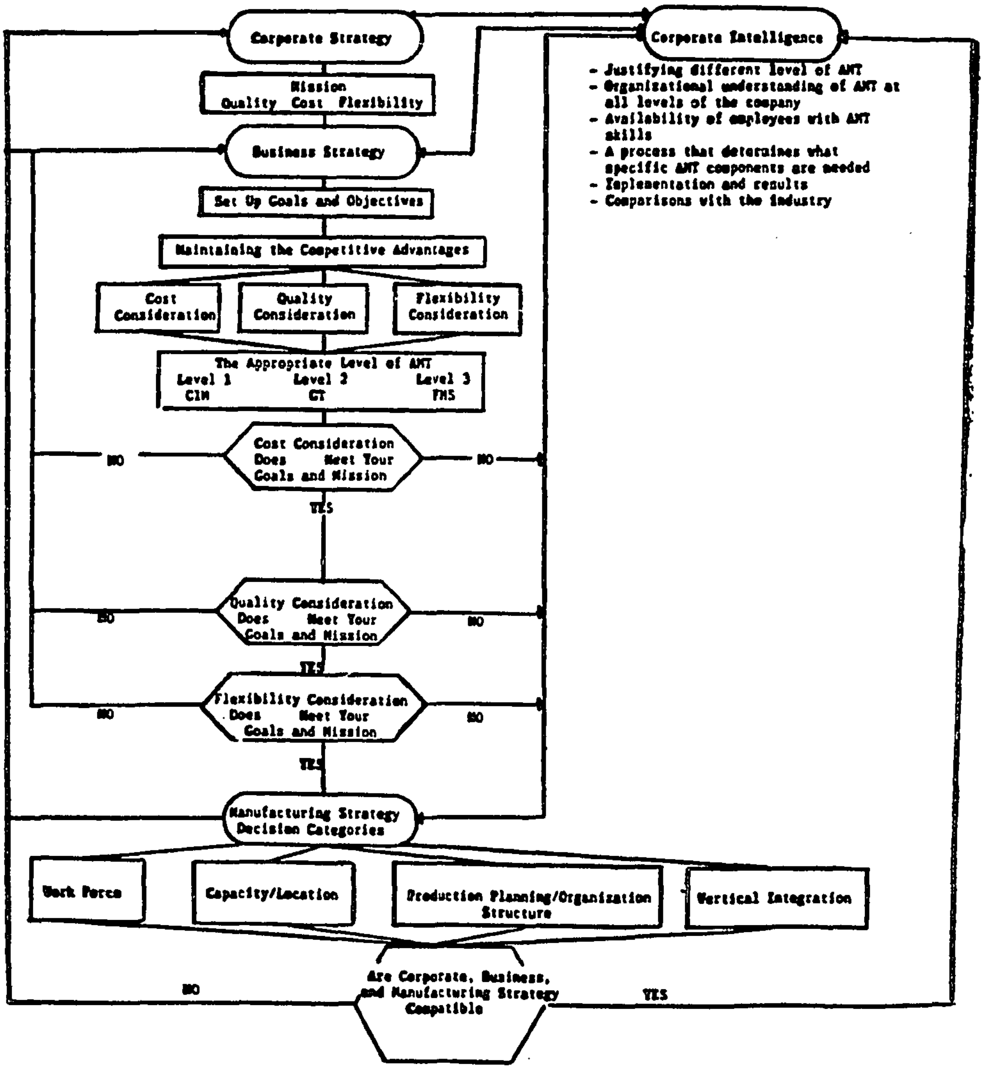


Figure 1.6

Diagnostic Framework of Strategic Importance of AMT



Chapter Two

Strategic Issues in Operations Management

Operations Management is the systematic direction and control of the process that transforms inputs, such as labor, capital, material, and information into outputs, such as goods and services. The main focus of operations management is productivity in both manufacturing and service organizations. This research will focus only on the manufacturing sector in the United States. The increasing importance of operations management results from lagging productivity in the manufacturing sector. U.S. productivity has declined since its cycle peak in 1973 and, in fact, the U.S. has had the lowest productivity growth of the seven major industrialized nations since 1970. As a result, the U.S. has experienced decreasing shares in the world market and foreign competitors, such as Japan, have penetrated U.S. markets. The decline in productivity is variously attributed to governmental regulations, high labor and energy costs, increased competition, reduced net investment in equipment and facilities, education, and delays in decisions to adopt advanced manufacturing technology. These reasons for the major decline in the U.S. manufacturing sector's productivity are explained by the Panel on Advanced Technology Competition and the Industrialized Allies (1987), and The American Productivity Center Report (1988).

Since the pioneering work of Skinner (1969) on the role of manufacturing in corporate strategy has attracted a growing number of researchers now who have made significant contributions in the field of operations management by defining its strategic role. This chapter illustrates the following: (1) definitions of strategy as manifested in corporate strategy, (the mission of the firm, and the external and internal environment), business strategy, and functional strategy, manufacturing strategy decision categories and (3) methodology for the structuring the development of manufacturing strategy.

Definitions and Characteristics of a Strategy

Corporate Strategy (Mission and Environment)

In the last few years, a great deal of attention has been paid to manufacturing function by successfully examining the strategic issues of manufacturing strategy. Surveys conducted on manufacturing in Europe, Japan, and North America proposed questions regarding activities or programs which the business unit is planning to focus on during the next two years to improve operations (Miller, 1984; Ferdows, 1987; Miller and Nakane, 1983). The percentage of responses shown in table 2.1 was recorded against the item defining a manufacturing strategy (Hill, 1989). Manufacturing strategy is a major tool used in many organizations, were 60-70% of an organization's business is achieved by the

Table 2.1 The Percentage of Response in 1983 and 1984 Confirming Plans to define a Manufacturing Strategy in the Next Two Years as a way of Improving Operations

	Percentage of Responses		
Year	Europe	Japan	North America
1983	34	30	42
1984	41	N/A	51

Source: Terry Hill (1989)

operation function (Skinner 1987). Strategic decisions provide companies with guidance and direction. Strategic decisions are guided by a mission statement. A mission statement is a long-term permanent plan by which companies will pursue their goals. A mission statement helps the company locate a specific market and competes with other companies for that market, in order to reach the position the company is striving for. In formulating a strategy, each subunit within a company must take into account the objectives of the other subunits before making a decision that will affect the organization as a whole. To develop a more realistic strategy, upper-level management must evaluate the capabilities and limitations of each subunit within a company. The lower level management in turn must evaluate upper-level management strategy before making any decisions. In other words, compatibility between all managerial levels must be achieved before making any decisions. All managers within a company must develop plans and make decisions which further the direction of the company's goals.

It is important to note that strategic planning is the process of developing a long-term plan which is designed to match the organization's strengths and weaknesses with the threats and opportunities in its environment (Skinner, 1986; Hax, 1985; Buffa, 1984; Hayes and Wheelwright, 1984). In developing strategy, a manager must take into consideration the company's external and internal conditions. In regard to the external conditions which deal with the environment of the market (opportunities and threats), there are some major factors addressed in the literature that may influence a company's strategy. These factors are: economic conditions, political conditions, social conditions, technological conditions and market conditions. Economic conditions include gross national product, employment levels, interest rates, and consumer spending. Political conditions are determined by government regulations and environmental policies. Social conditions are influenced by trends within a given society. Technological conditions must take into account the degree of automation which exists, the availability of equipment and the level of mechanization. Market conditions are dependent on potential customers, products, competitors, volume of sales and production life cycle (Swamidass et al, 1987; Buffa, 1984; Cleveland, 1986; Hayes and Wheelwright, 1984; Hax, 1988).

A company must also evaluate its internal conditions (strengths and weaknesses) in order to determine which strategy will suit its needs and capabilities. The main purpose of evaluating internal conditions is to promote optimal utilization of the company's resources and skills, by which it can maximize opportunities and minimize threats. Some conditions that should be evaluated are understanding of the market, market capabilities in distributing goods and services to the consumers, and its relationship with its customers. A company's external and internal conditions change frequently so it is wise to re-evaluate the company's strategy regularly. For these reasons, external and internal analysis are the corner stone of strategy planning.

Business Strategy

The second major level is associated with a Strategic Business Unit (SBU) or Strategic Planning Unit (SPU), which is usually a subsidiary, division, or product line within the firm. (See figure 2.1) According to Hax (1985), a business strategy specifies:

(1) The scope of that business, in a way that links the strategy of the business to that of the corporation as a whole.

(2) The basis on which that business unit will achieve and maintain a competitive advantage.

Goldhar and Jelinek (1983), state that a major barrier to the use of new manufacturing technology has been the lack of understanding of its impact on business strategy. Lack of understanding of the impact of advanced manufacturing technology on the business strategy can result not only from lack of understanding of the technology but from the absence of well-defined business strategy. Moreover, the business strategy should reflect a long-term focus. Without a long-term focus, the

Figure 2-1

The Formal Corporate Strategic Planning Process

Hierarchal Levels of Plannning	Less Frequent than Annual Review	Annual Review		
	Structural Conditioners	Strategy Formulation	Strategic Programming	Strategic and Operational Budgeting
Corporate	1	2 6	9	12
Business	3	4	7	10
Functional		5	8	11

1. The vision of the firm: corporate philosophy, mission of the firm, and identification of strategies business units (SBUs) and their interactions.
2. Strategic posture and planning guidelines: corporate strategic thrusts, corporate performance objectives, and planning challenges.
3. The mission of the business: business scope, and identification of product-market segments.
4. Formulation of business strategy and broad action programs.
5. Formulation of functional strategy: participation in business planning, concurrence or non-concurrence to business strategy proposals, broad action programs.
6. Consolidation of business and functional strategies.
7. Definition and evaluation of specific action programs at the business level.
8. Definition and evaluation of specific action programs at the functional level.
9. Resource allocation and definition of performance measurements for management control.
10. Budgeting at the business level.
11. Budgeting at the functional level.
12. Budgeting consolidations, and approval of strategic and operational funds.

(Source: Hax and Majluf [1985a, 1984b]

barriers to both justification and effective management of advanced manufacturing technology cannot be addressed adequately.

Gunn (1986) also cites the necessity for business planning. He suggests that the process of creating a planning frame of reference should elicit answers to three questions:

1. Where do we stand today with regard to our manufacturing capability?
2. Where do our world-wide competitors stand today with regard to their manufacturing capability?
3. What are the proven roads (technologies, principles, practices, philosophies) to get us from where we are today to where we'll have to be in the future to maintain competitive advantage in world markets?

Additional support for a well-defined business strategy and plan is provided in the form of key steps for successful implementation of CAD/CAM systems proposed by the U.S. Air Force, and the Integrated Computer Aided Manufacturing (ICAM) program. The success of these programs has been supported by findings of the Manufacturing Studies Board and National Research Council (MSB/NRC) study (1984). For example, the first three steps are: (1) determine how the company is going to run its business in the future, (2) determine the factors that will be keys to the success of this business in the future, and (3) developing a long-range plan which defines product evolution, rate of new product introduction, mission objectives of facilities, and existing and planned capabilities (NSB/NRC, 1987).

Functional Strategies

The third major level identified in Figure 2.1 is comprised of functional strategies. Once a business unit has developed its business strategy, each functional area must develop its plan to support this strategy. According to Hax (1985), each functional strategy must support, through a specific and consistent pattern of decisions, the competitive advantage being sought by the business strategy. Manufacturing strategy has to be designed by the firm at all three levels: corporate, business, and functional. The term "manufacturing strategy" as defined in the literature, is ambiguous and varies from author to author. It is defined by Swamidass (1987) as "the development and deployment of manufacturing capabilities in total alignment with the firm's goals and strategies." Mayer and Moore (1983) define it as "a plan that describes the way to produce and distribute the product. Manufacturing strategies define the choice of process technology, degree of vertical integration, the number and location of facilities, factory focus the manufacturing infrastructure." This definition is very similar to Skinner's (1986). Skinner defines manufacturing strategy as "a description of the competitive leverage required of the production function. It analyzes the entire manufacturing function relative to its ability to provide such leverage, on which tasks it then focuses each element of manufacturing structure. It also allows the structure to be managed, not just the short term, operational details of cost, quality and delivery." Hayes and Wheelwright (1984) described five important characteristics of manufacturing strategy:

1) Time horizon -- any strategy which describes activities that involve an extended time horizon, both with regard to the time it takes to carry out such activities and the time it takes to observe their impact.
2) Impact -- although the consequences of pursuing a given strategy may not become apparent for a long time, their eventual impact will be significant.
3) Concentration of effort -- an effective strategy usually requires concentrating one's activity, effort, or attention on a fairly narrow range of pursuits. Focusing on these chosen activities implicitly reduces the resources available for other activities.
4) Pattern of decisions -- although some companies used to make only a few major decisions in order to implement their chosen strategy, most strategies require that a series of certain types of decisions be made over time. These decisions must be supportive of one another, in that they follow a consistent pattern.

5) Pervasiveness -- a strategy includes a wide variety of activities ranging from resource allocation processes to day-to-day operations. In addition, the need for consistency over time in these activities requires that all levels of an organization act in ways that reinforce the strategy.

Hammer (1981) defined manufacturing strategy as "a set of plans and policies by which a manufacturing firm can gain a competitive edge." The recent book of Terry Hill (1989) groups the factors that define a firm's strategy into order qualifiers (order losers) and order winners. Hill's approach to manufacturing strategy is to link marketing and manufacturing perspectives in order to determine what a company's best strategies might be. Order qualifiers allow a firm to compete in the industry. They represent what a firm must do to be in the market. A firm which does not offer the order qualifier will lose orders. Schroeder et. al (1986) describes operations strategy as "a long-range plan or vision for the operations function. This plan must be integrated with business strategy and implemented throughout operations. It consists of four interrelated elements: mission, objectives, policies, and distinctive competence." Distinctive competence, as defined by Krajewski and Ritzman (1987) includes an available and competent workforce, efficient and well located facilities, the ability to change output levels, to market and distribute a product, and differentiate the organization's products from products offered by competitors.

This research defines manufacturing strategy as a long-term plan or policy for manufacturing organization and should be compatible with corporate, business, and functional strategies in order to achieve the firm's operational performance (quality, price, flexibility) by linking it with advanced manufacturing technology. Operational performance will be achieved by the deployment of manufacturing decision categories identified in the literature: capacity, facilities, technology, vertical integration, workforce, quality, production planning, materials control, and organization structure.

Manufacturing Strategy Decision Categories

There is a general agreement in the literature on the major decisions involved in manufacturing strategy. Skinner (1986) defined them as structural decisions which include the following:

- What to make and what to buy.
- The capacity levels to be provided.
- The number and sizes of plants
- The location of plants
- Choices of equipment and process technology
- The production and inventory control systems
- The quality control system

- The information system
- Workforce management policies
- Organizational structure.

According to Hax (1985), there are nine strategic decision categories providing a comprehensive coverage of the broad set of issues that must be addressed by a manufacturing strategy shown in Figure 2.1. These decision categories have been addressed by Buffa (1984) Hayes and Wheelwright (1984), Hax (1985), Skinner (1986), Hill (1989). Table 2.2 presents a framework specifying eight categories into which manufacturing related decisions can be grouped. On the other hand, Buffa (1984) presents six basic categories of manufacturing strategy shown in Figure 2.2.

According to Buffa (1984), there are two basic manufacturing strategies: the minimum-cost/high-availability strategy and the highest-quality/flexibility strategy. These strategies are very important for implementing the overall company strategy. In his view the company and manufacturing strategies have to be coordinated otherwise the company can not expect to be competitive. Another related manufacturing strategy that is of strategic significance is the decision to manufacture to stock or to order.

As illustrated in Figure 2.2 there are six basic decisions which must be made in determining manufacturing strategy.

1. Capacity/location decisions
2. Product and Process Technology
3. The workforce and job design
4. Suppliers and Vertical Integration
5. Positioning the Production System
6. Strategic implications of operation decisions

Table 2.2

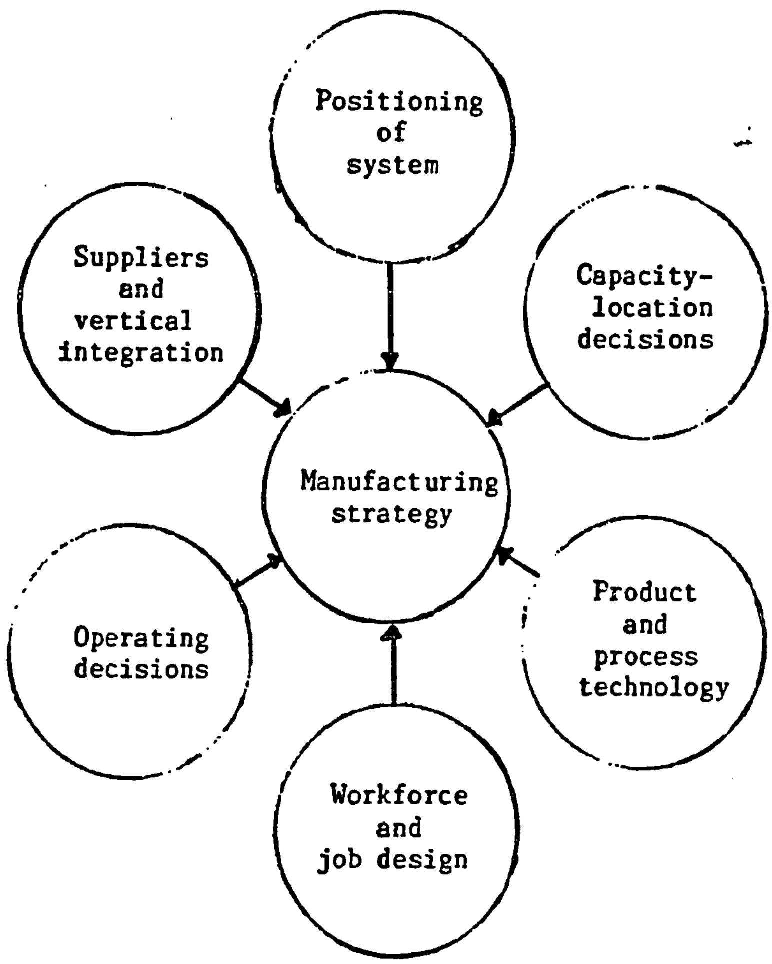
Decision Categories Composing a Manufacturing Strategy

1. Capacity - amount, timing, type
2. Facilities - size, location, focus
3. Technology - equipment, automation, connectedness
4. Vertical Integration - direction, extent, balance
5. Workforce - skill level, pay, security
6. Quality - defect prevention, monitoring, intervention
7. Production planing/materials control - computerization, centralization, decision rules
8. Organization - structure, reporting levels, support groups

Source: Wheelwright (1984)

Figure 2.2

Components of Manufacturing Strategy



Source: Buffa (1984)

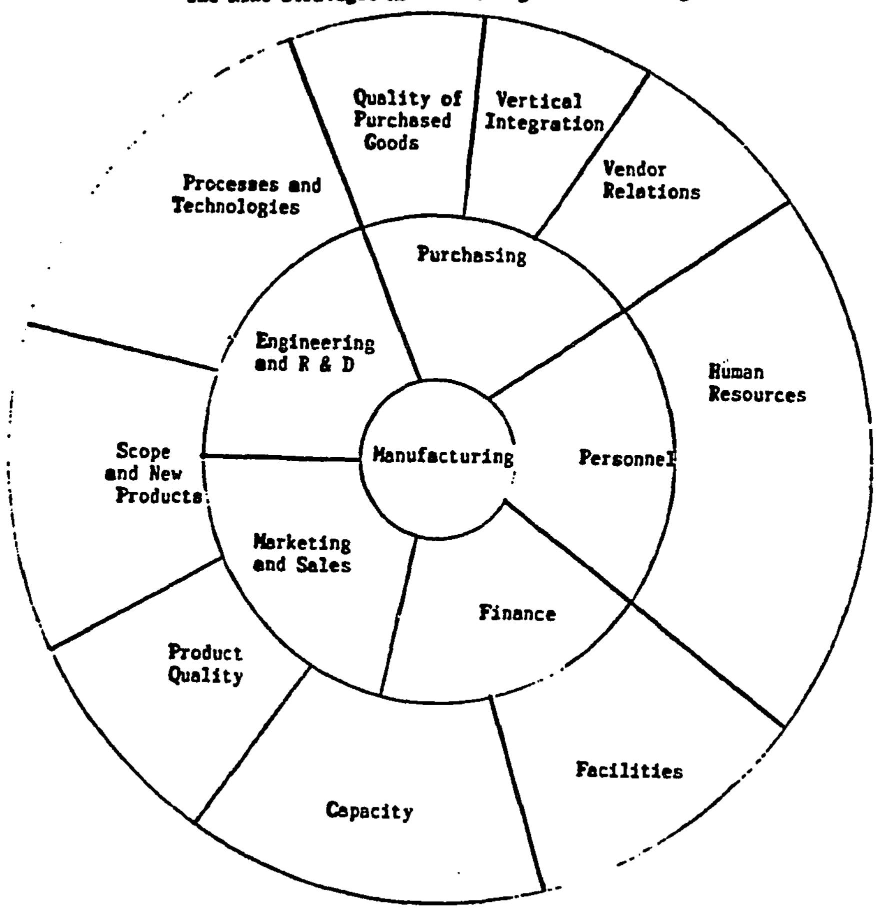
The first four decisions are similar to the decisions introduced by Hax (1985), Skinner (1984), Hayes and Wheelwright (1984). See Figure 2.3 and Table 2.2. These decision categories are basic to determining manufacturing strategy because there is a wide managerial choice available in each, and each affects the long-term competitive position of the firm by impacting cost, quality, product availability, and flexibility. The fifth category, positioning the production system is presented in the literature as a separate operations strategy by Krajewski and Ritzman (1987), Skinner (1984), Schroeder (1985) Cleveland (1986).

1. Capacity/Facility decisions.

How much to produce and where to produce are very important decisions in manufacturing strategy. Determination of productive capacity requirements is a major problem not only when we design a new system or expand an existing one but also for the shorter operating periods during which the plant size cannot be changed. Decisions about capacity are very important because they provide a linkage for both long and short term managerial planning. Shapiro (1977) describes the problems associated with capacity decision: It often takes a long time for a company to change its manufacturing capacity. If such a change requires a new or enlarged building, design and construction can take several years.

Figure 2.3

The Nine Strategic Manufacturing Decision Categories



Source: Fine and Hax (1985), p. 31

The addition of new equipment can take up to two years in most industries.

The major capacity decisions reported in Hax (1985) included how to deal with cyclical demand (holding excess capacity, holding seasonal inventories, peak-load pricing, subcontracting), whether to add capacity in anticipation of future demand (aggressive, flexible approach) or in response to existing demand (conservative, low-cost approach), and how to use capacity decisions to affect the capacity decisions of one's competitors.

Facilities decisions consider the following factors to be included in the long-term plan for manufacturing strategy: production inputs, process technology, and the environment. Schmenner (1979) assures that decisions of selecting plant location is more than choosing a site. He goes further to describe the selection process for a given firm in terms of the following: (1) a company's capacity needs, (2) the extent and quality of its present capacity, (3) the way in which its existing plants fit together in multiplant manufacturing strategy, and (4) expected demands on manufacturing, apart from mere space requirements. According to Hayes and Schmenner (1983), a key step in facilities policy-making for multifacility organizations is choosing how to specialize or focus each facility. This may be done by focusing on product groups, process types, volumes, or stage in the product life cycle.

Developing a well-thoughtout facility focus strategy automatically provides guidance to the firm in other facilities decisions such as determining the size, location, and capabilities of each facility (Hax, 1985).

2. Product and Process Technology.

Product planing is the whole spectrum of activities leading up to the introduction, revision or elimination of an organization's products and is an ongoing process. Such planning occurs primarily at the corporate strategy level which is also the logical starting point for formulating operations strategy because once the product characteristics are known, the production system can be effectively designed and operated. product planning has received greater attention recently because of intense competition, expiration of patents, and the rapid change of technological innovation. The next section in this chapter will provide the concept of product life cycle introduced by Hayes and Wheelwright, (1984). Chapter three is devoted to process technology.

3. The Workforce and Job Design.

Designing the processes and workforce of the production system must accommodate the positioning strategy (Krajewski and Ritzman, 1987). A process focus is characterized by more general purpose and less efficient equipment, more labor-intensive operations, and attention to labor costs. A process focus favors a more flexible workforce, enlarged jobs, informal promotion channels, fewer staff specialists, and frequent two-way communication with supervisors. The process design for a product focus strategy, on the other hand, is characterized by specialized equipment dedicated to a few products, capital intensive and automated, and attention to facility utilization and overhead costs. Workforce management channels, less frequent two-way communication with supervisors, and more staff specialists.

4. Suppliers and Vertical Integration.

According to Buffa (1984) vertical integration strategies may be thought of as involving major acquisitions or mergers of supplier and buyer (or vice versa), or establishing new processing facilities to a more modest, gradual vertical integration, that is characterized by the make-buy decision. The large-scale vertical integration decisions are bound to gain the attention of top management and become conscious strategic moves.

Vertical integration is treated in some extended length by Buzzell (1983). Hayes and Wheelwright (1984) devoted one chapter in their book to vertical integration. Williamson (1975) related it to contracting through market or non-market mechanisms. Porter (1980) considered it to be a major force behind the Japanese success of using a just-in-time system, where he called it a quasi-integrated market mechanism. Hayes (1985) related the following issues to vertical integration: the cost of the business to be entered, the degree of supplier reliability in the important factors of production, and the relative transaction cost.

5. Positioning the Production System.

The operations function involves organizing the production system for particular product plans and competitive priorities. This choice is called the positioning strategy and included, among other things, decisions concerning routing patterns for a specific sequence of operations (Krajewski & Ritzman (1990), Skinner (1984), Hayes and Wheelwright (1984)). Positioning strategy will be explained in a detailed fashion in the next section.

Strategic Implications of Operation Decisions

Strategy in operations management is a natural extension of corporate strategy and is similarly formulated (Krajewski & Ritzman (1987)). The focus of operations strategy is the development of methods to achieve organizational goals and execute strategy. Operational deficiencies are determined by comparing current and projected capability of the production system with the requirements of corporate strategy. Problems are resolved by methods such as taking advantage of distinctive competencies by modifying strategy for degree of automation, facility location, capacity, suppliers and inventories. If the shortcomings are not resolved with available resources, then corporate strategy must be revised (Hayes and Wheelwright (1979), Skinner (1984), Krajewski and Ritzman (1990)).

There are three important concepts in examining the strategic issues of operations management. First, operations can be a competitive weapon or a millstone (Skinner (1984), Hayes and Wheelwright (1984)). That is, operations concentrates on the resource side of corporate strategy and operations policies that reflect in inappropriate resource mixes for years into the future. Secondly, decisions in operations areas should be linked to achieve overall corporate strategy. Plans, policies, and actions within operations must all be focused in the same direction and be mutually supportive if organizational goals are to be met successfully. Therefore, individual decisions must be made within the context of the broader corporate strategy. Lastly, strategic planning suggests that the primary concern operations management is with first-order issues such as product plans and competitive priorities. Therefore, the central concern of operations management is to increase productivity by linking operations strategy to business strategy, corporate strategy, and process technology. Table 2.3 illustrates some important trade-off

Table 2.3
Some Important Trade-Off Decisions in Manufacturing - or "You Can't Have it Both Ways"

Decision Area	Decision	Alternatives
PLANT AND EQUIPMENT	Span of process	Make or buy
	Plant size	One big plant or several smaller ones
	Plant location	Locate near markets or locate near materials
	Investment decisions	Invest mainly in buildings or equipment or inventories or research
	Choice of equipment	General-purpose or special-purpose equipment
	Kind of tooling	Temporary, minimum tooling or "production tooling"
PRODUCTION PLANNING AND CONTROL	Frequency of inventory taking	Few of many breaks in production for buffer stocks
	Inventory size	High inventory or a lower inventory
	Degree of inventory control	Control in great detail or in lesser detail
	What to control	Controls designed to minimize machine downtime or labor cost or time in process, or to maximize output of particular products or material usage
	Quality control	High reliability and quality or low costs
	Use of standards	Formal or information or none at all
LABOR AND STAFFING	Job specialization	High specialized or not high specialized
	Supervisions	Technically trained first-line supervisors or nontechnically trained supervisors
	Wage system	Many job grades or few job grades, incentive wages or hourly wages
	Supervision	Close supervision or loose supervision
	Industrial engineers	Many or few such men
PRODUCT DESIGN/ ENGINEERING	Size of product line	Many customer specials or few specials or none at all
	Design stability	Frozen design or many engineering change orders
	Technological risk	Use of new processes unproved by competitors or follow-the-leader policy
	Engineering	Complete packaged design or design-as-you-go approach
	Use of manufacturing engineering	Few or many manufacturing engineers
ORGANIZATION AND MANAGEMENT	Kind of organization	Functional or product focus or geographical or other
	Executive use of time	High involvement in investment or production planning or cost control or quality control or other activities
	Degree of risk assumed	Decisions based on much or little information
	Use of staff	Large or small staff group
	Executive style	Much or little involvement in detail; authoritarian or nondirective style; much or little contact with organization

Source: Skinner (1969)

decisions in manufacturing recommended by Skinner (1969). The first four decision categories introduced in this section can be viewed as structural in nature because of their long-term impact. The rest of these categories are considered more tactical because they are associated with specific operating aspects of the business. Table 2.4 suggests the criteria for evaluating a given manufacturing strategy.

A Methodology for Structuring the Development of Manufacturing Strategy

In this section, the main efforts for developing a methodology of manufacturing strategy are illustrated. Those efforts adopted earlier in marketing such as product life cycle and the product-process matrix have proven to be an effective framework for looking at manufacturing strategy.

1. Product Life Cycles

The concept of product life cycle illustrates the need for introducing new products because an organization will decline unless it introduces new products periodically. The five stages of product life cycle as introduced by Hayes and Wheelwright (1984), Wasson (1978), and Abernathy & Utterback (1975), are product planning, introduction, growth, maturity, and decline. See Figure 2.4 and 2.5. In the product planning stage, ideas for

Table 2.4

Criteria For Evaluating a Manufacturing Strategy

A. Consistency

1. Between the manufacturing strategy and the overall business strategy
2. Among the manufacturing strategy and the other functional strategies within the business.
3. Among the decision categories that make up the manufacturing strategy.
4. Between the manufacturing strategy and the business environment (resources available, competitive behavior, governmental restraints, etc.)

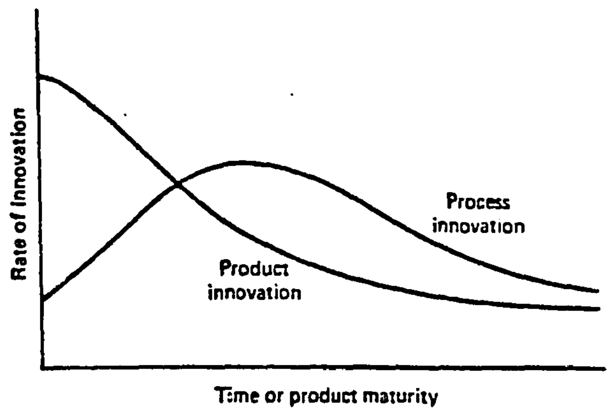
B. Emphasis (focus) on competitive success factors

1. Making trade-offs explicitly, allowing manufacturing to prioritize activities
2. Directing attention to opportunities that fit the business strategy.
3. Promoting clarity regarding the manufacturing strategy throughout the business unit.
4. Providing the manufacturing capabilities that will be required by the business in the future.

Source: Wheelwright (1984).

Figure 2.4

Patterns of Product and process innovation



	Fluid Pattern	Transitional Pattern	Specific Pattern
Competitive emphases on	Functional product performance	Product variation	Cost reduction
Innovation stimulated by	Information on users' needs and users' technical inputs	Opportunities created by expanding internal technical capability	Pressure to reduce cost and improve quality
Predominant type of innovation	Frequent major changes in products	Major process changes required by rising volume	Incremental for product and process, with cumulative improvement in productivity and quality
Product line	Diverse, often including custom designs	Includes at least one product design stable enough to have significant production volume	Mostly undifferentiated standard products
Production processes	Flexible and inefficient major changes easily accommodated	Becoming more rigid with changes occurring in major steps	Efficient, capital-intensive, and rigid; cost of change is high
Equipment	General purpose, requiring highly skilled labor	Some subprocesses automated, creating "islands of automation"	Special purpose, mostly automatic with labor tasks mainly monitoring and control
Materials	Inputs are limited to generally available materials	Specialized materials may be demanded from some suppliers	Specialized materials will be demanded if they are not available, vertical integration will be extensive
Plants	Small-scale, located near user or source of technology	General purpose with specialized sections	Large-scale, highly specific to particular products
Organizational control	Informal and entrepreneurial	Through liaison relationships, project and task groups	Through emphasis on structure, goals, and rules

Source: Abernathy and Utterback, 1975

Figure 2.6
Matching Major Stages of Product and Process Life Cycles - The Product - Process Matrix
Product Structure
Product Life Cycle Stage

Process Structure **Process Life Cycle Stages**	Low Volumes, Low Standardization, One of a Kind	Multiple Products, Low Volume	Few Major Proucts Products Higher Volume	High Volume, High Standardization Commodity Products
I **Jumbled flow (job shop)**	**Commercial Printer**			void
II **Disconnected Line Flow (batch)**		**Heavy Equipment**		
III **Connected Line Flow (assembly line)**			**Auto Assembly**	
IV **Continuous Flow**	void			**Sugar Refinery**

Source: Hayes and Wheelright (1984)

new products are generated, screened and developed. Profits are negative at this point because sales and revenues have not been generated, but developmental costs are incurred. During the introductory stage, sales begin and profits are generated. Production and marketing efforts are in the initial stages. In the growth stage, sales rise dramatically. Meeting demand is more important than efficiency. In the maturity stage, sales are level and profits begin to decline because of competition. Operations must now stress efficiency, and intensified marketing is often utilized to ease the pressure. Finally, in the decline stage, the product becomes obsolete, sales and profits decrease, and the product is eliminated by the organization. According to Shapiro (1977), there are eight major areas in which problems tend to arise between these two functions (marketing and manufacturing). In analyzing these eight problem areas, Shapiro focuses on such issues as evaluating and reward systems. These problem areas are shown in Table 2.5. Wasson (1978), introduced some dimensions of the product life cycle concept important to marketing.

Abernathy and Townsend (1975), have broken down the evolution of a production process into three major stages: early, middle and mature. For each stage they describe six important characteristics that are of concern to manufacturing managers. Table 2.6 suggests that a process life cycle begins with a production process: one that is highly flexible but not very cost

Table 2.5

Functional Level Interactions of Marketing and Manufacturing

Problem Area	Typical Marketing Comment	Typical Manufacturing Comment
Capacity planning and long-range sales forecasting	Why don't we have enough capacity?	Why didn't we have accurate sales forecasts?
Production scheduling and short-range sales forecasting	We need faster response. Our lead times are ridiculous	We need realistic customer commitments and sales forecasts that don't change like wind direction
Delivery and physical distribution	Why don't we ever have the right merchandise inventory?	We can't keep everything in inventory
Quality assurance	Why can't we have resonable quality at reasonable cost?	Why must we always offer options that are too hard to manufacture and that offer little customer utility?
Breadth of product line	Our customers demand variety	The product line is too broad--all we get are short uneconomical runs
Cost control	Our costs are so high that we are not competitive in the marketplace	We can't provide fast delivery, broad variety, rapid response to change, and high quality at low cost
New product introduction	New products are our life blood	Unnecessary design changes are prohibitively expensive
Adjunct services such as spare parts inventory support, installation, and repair	Field service costs are too high	Products are being used in ways for which they weren't designed

Source: Shapiro, 1977.

Table 2-6

Dimensions of Process Technology Evolution Important to Manufacturing Management

Stage in the Productive Unit Life Cycle	Material and Parts—Inputs	Process Characteristics Technology	Labor	Scale	Product	Modes of Process Change (in transition from one stage to the next)
1. Early	Raw materials and parts used as available from supplier Types and quality vary widely Limited influence over supplier	General-Purpose equipment and tools used as available from industry Special adaptations to general-purpose machines are made by user (jigs, fixtures, etc.) Flow-through process needs careful management control	Most workers have a broad range of performance skills Considerable flexibility exists in type of tasks each worker can and must perform Labor organization (if any) is along craft or skill (trade unionism)	Capacity ill defined Greater volume achieved by paralleling existing processes Short-run economies of scale achieved through learning curve improvement of manual operations Few scale barriers to entry into industry segment	Great variety of products with different features and quality Frequent design change Market relatively insensitive to price and quality (imperfect market that is price inelastic)	Process rationalization Standardize tasks Develop even flow through all process steps Automate easy tasks Introduce systematic or mechanized materials handling Redesign product and process to automate difficult tasks
II. Middle	Suppliers are strongly dependent Tailored material specifications imposed on supplier	Process automation is evident for some process tasks and systematized work flow Level of automation varies widely within process: islands of highly automated equipment are linked by manual operations Unique process equipment is designed for some tasks (often by outside firms)	Manual tasks are highly structured and standardized Labor is specialized with technical skills becoming more important Overhead labor functions such as maintenance scheduling and control are a significant cost	Capacity increased by equipment addition and advances to debottleneck particular operations Minimum size process necessary to compete in industry segment	Some segments of market sensitive to price and quality (encouraging standard products and scale economies) Significant volume achieved in some product lines	Systemic development Separate difficult-to-automate tasks from process or eliminate them Design products to have maximum common process elements Arrange administrative organization for congruence of control over process flow
III. Mature	Input's characteristics are optimized to process needs Supplier process integrated into overall process design Tasks that cannot be automated are segregated from process and are often subcontracted or performed by suppliers	Single units of equipment perform multiple process tasks and are integrated into automatic material handling equipment Formal systems engineering is required for process change Process equipment is designed as an integrated system, often by separate engineering groups or engineering companies Licensed technology may dominate, depending on the industry	Direct labor does monitoring and maintenance tasks Most important skills concern technical process equipment operation Labor classifications are rigid and are of primary concern to labor organization	Complete new facilities designed to achieve economies through spread costs Market growth and technological evolution pace scale increase Antitrust laws, logistics, or external factors eventually limit scale growth	Product variability is low and volume is high Standard products if price competition is prevalent or standard groups of products if product differentiation is prevalent Co- and by-products play greater rAle	Product and process realignment to meet changing markets and technological advances (may reset to earlier stage, 1 or 2 or stagnate during maturation)

Source: Abernathy and Townsend 1975.

efficient. Then it proceeds toward increasing standardization, mechanization, and automation until it eventually becomes very efficient, but more capital - intensive, interrelated, and hence less flexible than the original process. Schmenner (1983) states that most factories don't die suddenly, rather they go through stages. Factories go from the early or start-up years to maturity and finally to the fall years. By establishing a charter for the three phases of the life cycle, long and productive lives for the plants can be established.

2. The Product - Process Matrix

Hayes and Wheelwright (1979) first introduced the product-process matrix and correlated it with product life cycle. The product-process matrix usually begins with a fluid process which is highly flexible and moves toward a less flexible more standardized manufacturing process. The matrix in Figure 2.5 shows the interaction of the product-process life cycles. The positioning of a company can be determined by its stage in the product and process life cycles. The voided sections represent uneconomical solution. The concept of the product-process life cycle can be broken into three parts:

1. The concept of distinctive competence.
2. The management implications of selecting a particular product-process combination considering the competition.

3. The organizing of different operating units so that they can specialize in separate portions of the total manufacturing task while still maintaining overall coordination.

A company's distinctive competence deals with its attitude toward operations. Most companies would like to think of themselves as being in a better position than their competitors. Their goal is to either hold this position or improve it. The product-process matrix helps a company understand what its distinctive competence really is and which process decisions and alternatives to focus on.

As a company moves through different phases of the product and process cycles, the movement itself has an effect on the company's position. According to Hayes and Wheelwright (1984), "Along the process structure dimension, the key competitive advantage of a jumbled flow operation is its flexibility to both product and volume changes." When operations start moving toward more standardized processes the competitive edge starts shifting to reliability, predictability, and cost. If management decides to compete in the upper left hand corner of the matrix, managers need to know when to abandon a product or market, while management choosing the lower right side of the matrix must know when to enter the market.

The coordination of different operating units can have very effective results. For example, as a company increases the volume of its primary products causing a downward shift along the diagonal, the problem of being able to provide spare parts needs to be answered. This creates two different product and process structures since the production of the spare parts moves more toward the upper-left-hand corner of the matrix. The kind of task oriented analysis that the matrix offers can help a company come to grips with these kinds of problems. To stay competitive, a company must continually review operations. An understanding of the product-process matrix allows a company to position itself in a broader or narrower product line. These choices are made based on company objectives and competitors' present positions.

3. The Focused Manufacturing Strategy

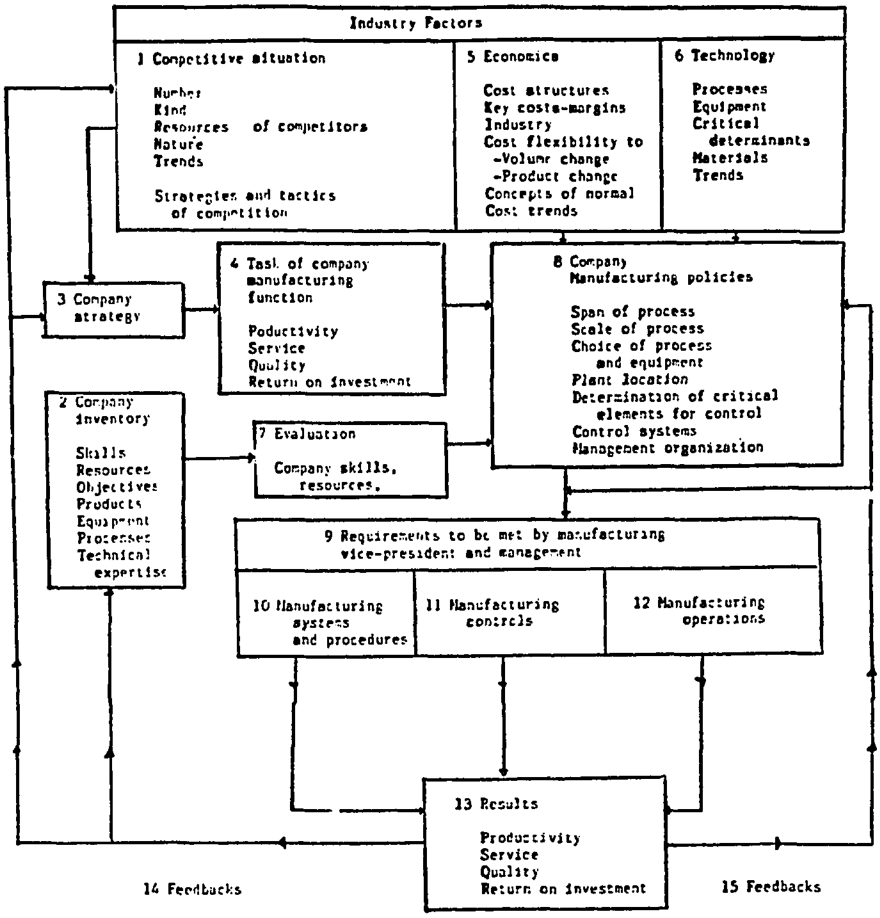
The focused factory approach introduced by Skinner (1974), stresses the importance of having a factory focused on a narrow product mix for a particular target market. Hill (1989) provides a chapter in his book on the concept of focus and the need to assign plants (or parts of a plant) a defined set of tasks. Wheelwright (1979) defines the degree of a facility's focus. Schmenner (1976) explains the economics of scope and criticized the economics of scale. A focused plant will out-perform one which has a broader mission, because its cost and overhead are lower than those of the conventional plant. The focused factory can concentrate on a limited task for one set of customers. According to Skinner there are many advantages to having factory focused on a specific task, with a set of customers in mind rather than trying to manufacture many products for numerous customers. These conventional factories add products, markets, technologies and quality levels which conflict and compete with each other.

Skinner's study showed that the major negative effect of being involved with too many products or processes is on the plant's ability to compete, and not on productivity. The focused plant is very rare. Skinner believes that plants should be kept focused so they can be more competitive and more efficiently managed. Focus also provides clear goals which can be readily understood and implemented by the members of the organization.

Figure 2.6 illustrate Skinner's model for the process of manufacturing strategy determination. Skinner (1985), explains the sequence by which manufacturing strategy begins. It is necessary to analyze the competitive situation, and how survival companies are competing in terms of product, market, policies, and channels of distribution. Management examines the number and kind of competitors and the opportunities open to its company. Next comes a critical appraisal of the company's skills and resources. The third step is the formulation of company strategy. The fourth step is to define the effects of company strategy in terms of

Figure 2.6

The Process of Manufacturing Policy Determination



Key

1. What others are doing
2. What we have or can get to compete with
3. How we can compete
4. What we must accomplish in manufacturing in order to compete
5. Economic constraints and opportunities common to the industry
6. Constraints and opportunities common to the technology
7. Our resources evaluated
8. How we should set ourselves up to match resources, economics, and technology to meet the tasks required by our competitive strategy
9. The implementation requirements of our manufacturing policies
10. Basic systems in manufacturing (e.g., production planning, use of inventories, use of standards, and wage systems)
11. Controls of cost, quality, flows information, inventory, and time
12. Selection of operations or ingredients critical to success (e.g., labor skills, equipment utilization, and yields)
13. How we are performing
14. Changes in what we have, effects on competitive situation, and review of strategy
15. Analysis and review of manufacturing operations and policies

Source: Skinner, 1985

specific manufacturing tasks. The fifth and sixth steps are to study the limitations imposed by economics and the technology of the industry. The seventh and eight steps are to integrate all prior steps into a broad manufacturing strategy. The final phase in the Skinner model outlines steps working out programs of implementation, controls, performance for measures, and review procedures.

This chapter presented major developments in the area of manufacturing strategy. Most of the literature are conceptual in nature. However, there is very little empirical evidence in the literature that deals with how these conceptual model actually work in manufacturing. Most of the empirical research done so far has a very small sample and most of it considered to be case studies for implementing a specific framework. The next chapter will explain in detail advanced manufacturing technology as an important element of manufacturing strategy.

Chapter Three

Advanced Manufacturing Technology

(AMT)

This chapter provides an overview of the new development in manufacturing technology. It will focus on the main components of Advanced Manufacturing Technology.

A strong relationship exists between the health of the United States domestic economy and the competitive position of the United States in the international industrial market. Likewise, there is a relationship between the economy of the United States and the performance of its manufacturing sector. The competitive position of the United States manufacturing sector can be achieved by implementing advanced manufacturing technology to improve performance. Manufacturing performance in this research is evaluated according to three main factors: (1) low cost (2) high flexibility (3) high quality.

The rationale behind focusing on the manufacturing sector is:

1. Two-thirds of the goods of the economy are produced by this sector (MSB/NRC, 1987).
2. It supports employment throughout the economy.
3. Increase in the overall level of employment and the rate of creation of new jobs depend upon the cost-effective production of goods (AAES, 1982).

According to Kaplan (1983), AMT is purchased to achieve two types of benefits: (1) ultimate survival and (2) changes in the production process expected to maintain organizational growth. Organizational survival benefits may include growth in a share of an existing market, entrance into new markets, or just maintaining position in relation to other companies. Benefits of changes in the production process include reduced scrap, work-in-process and end-product inventory, high machine utilization, reduced change over time, and increased throughput. Research directed toward the adoption and implementation of advanced manufacturing technology supports that integration is a significantly more complex process than the adoption and implementation of any of the individual manufacturing technology subsystems (MSB/NRC, 1984).

The major component of advanced manufacturing technology consists of the following: (1) design and engineering: Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) (2) the execution part of AMT: Flexible Manufacturing System, Group Technology, Manufacturing Cell (FMS, GT, MC, Robotics) (3) the transportation for AMT: Automated Guided Vehicle, Distribution Requirement Planning (AGV, conveyers, transporter automation, FPT DRP). (4) physical control and tracking: Automated Storage/Retrieval Systems (AS/RS). (5) planning and control: Material Requirement Planning II, Just In Time (MRPII, JIT Process monitoring equipment, Automated testing, Automated inspection equipment). The following section presents the chronological development of AMT. Explanations of each component and its relationship to the competitive position of the "using firm" as well as its effect on manufacturing performance, will follow.

Chronological Development of Advanced Manufacturing Technology

The historical development of AMT goes back to the introduction of Henry Fords's conveyor assembly line in 1913. In 1924 Morris Motors developed the first transfer machine. At the same time, H.H. Aiken introduced the automatic sequence-controlled calculator. In 1946, S.P. Mitrofanov (U.S.S.R.), introduced the concept of group technology; this was followed by George Devol developed the magnetic controller and a playback device, J.P. Eckert and John Mauchley built the ENIAC computer at the University of Pennsylvania, the Bullard Company developed and sold the Man-Au-Trol automatic machine control system. In 1953 the basic concepts of office automatic by J. Lyons (U.K.) were introduced. In 1954 the first NC machine, was designed by J. Parsons at M.I.T. and George Devol developed the first programmable robot. The introduction of the Auto-Programming Language (APL) was introduced in 1955. A big step forward towards achieving flexibility and efficiency was the introduction of the first numerically controlled machining center by Kearney & Trecker in 1958. Yet the dream of a versatile centrally controlled system was not realized until 1962 when Western Electric's computer controlled automation was introduced. In 1962 General Motors installed the first robot in its assembly lines. In 1964, IBM developed the IBM 360 Universal Electronic Computer as the forerunner to FMS. The direct digital control process (DDC) for process automation was introduced in 1965. In 1966, Sundstrand built the first computer controlled system called the direct numerical control system (DNC), in which the computer replaced punched tape for controlling machinery operations (Broshery, 1967; Frienberg, 1968). At about the same time Ingersoll Rand's heavy machining center, consisting of six machine tools interfaced with a conveyor delivery of parts and was installed by Sundstrand in a Roanoke, Virginia.

All computer-controlled, integrated batch manufacturing systems were termed "computerized manufacturing systems" (Browne, et al 1984). This system involved a lot of software control strategies and decision algorithms. The idea of flexible manufacturing systems was developed in 1967 in the United States. Developments now exist all over the world. although many flexible manufacturing systems exist, there is not much written documentation on their benefits. One flexible manufacturing system which does provide documentation and probably is the most sophisticated in the world today is located in Augsburg, Federal

Republic of Germany. It operates at Messerochmitt-Bolkew-Blohm (MBB) and produces the center section of the Tornado fighter plane. It has been utilized for the past several years and the system includes: (1) 28 numerically controlled machining centers and multi-spindle gantry and traveling - column machines, (2) a fully automated tool flow and changing system, (3) an automated workpiece transport system, and (4) a coordinated computer control of all these elements (Kusiak, 1986).

Another notable exemplary unique flexible manufacturing system exists in Japan. This system runs unattended at night. It is located at the Kowasaki Plant of Toshiba Tungaloy Company, Ltd. It began operations in August, 1980, and produces milling, cutter and single-point cutting tool bodies. The system operates under hierarchical computer control and consists of one NC lathe, one vertical machining center, three five-axis machining centers, and one multi-spindle NC grinder. The system can handle 4,000 different types of parts. The required number of machine tools has been reduced from fifty to six and manpower has decreased from seventy to sixteen persons. The average utilization of the machine has greatly improved from 20% to 73% and the required floor space has been drastically reduced from 1500 square meters to 350 square meters, a 76% reduction.

The overall advances in manufacturing technologies are occurring rapidly. Many trends are currently being undertaken and will be more widely accessible in the future. One such trend is the movement from monolithic systems to modular systems. This will enable both hardware and software to change with the long term needs of the company. It also allows the user the freedom to progress in phases which will help avoid drastic changes.

The Major Components of Advanced Manufacturing Technology

Design and Engineering (CAD/CAM)

Computer-aided manufacturing refers to the process whereby a product is made by means of computer assisted control of operations. The connection between information processing and the control of machine tools has introduced this concept.

CAM is a computer aided preparation for manufacturing. It includes software design techniques and artifical intelligence, manufacturing with different types of automation (NC-M. NC-MC, NC-FMS, NC machining cells), and different types of realization (CNC-single unit technology, DNC - group technology) Kochan, 1986. CAD/CAM resulted from the discovery of numerically controlled operations. Numerically controlled machine tools are capable of handling control systems that contain programs for instructions to complete a task. The programs are coded by numbers or other signals. The complexity of the control programs is based on whether the numerical control is for one machine, a machining center, a flexible manufacturing system, or a machining cell.

This depends on the degree of integration. Figure 3.1 describes the degrees of integration that have been established.

Execution and Transportation phases of Advanced Manufacturing Technology.

FMS consists of three major components.

a. Potentially independent NC machines.

b. A mechanism to move parts between machines to and from fixturing (loading) stations.

c. A method of overall control, that coordinates the machine tools and the conveyance system.

This is based on definitions by (Groover, 1980), Stecke, 1983), Ranky, 1983), (Young and Greene, 1986), (Chen 1986), (Carter 1986), Sims, 1983). The process of an FMS cell as designed by C.M., is described as follows: each machine has a 900-CNC control and FMS interface, and is equipped with tort - controlled machining and probes for unmanned sensing of work pieces. A docking station is located next to the pallet shovel in front of each machine where wire-guided vehicles can pick up and deliver pallets with fixtured parts. Provisions have also been made for exchanging tools automatically at the rear of the storage matrix on each machining center during the cutting cycle. The four

Figure 3.1

DEGREE OF INTEGRATION

Automated Machining	Automated Machining Sequence	Automated Manufacturing Sequence
Includes Machining With Positioning Measuring NCM	Includes Machining with - Positioning - Measuring Tool Exchange	Includes Machining with - Positioning - Measuring Tool Exchange
NC MC (Machining Centers)		Workpiece Change Storage and Transfer - Workpiece tools
NC MS (FMS)		Total Control - Flow of Information - Flow of Material

Level of automation of different NC Manufacturing Systems machining centers in the system have the same productive capacity as ten similar machines operating in a conventional shop. Once the unmachined parts have been fixtured, the operator signals the system control that he has completed the operation. The system control then takes over and sends a wire-guided vehicle to pick up the pallet and deliver it to its proper processing station. Tools are assembled according to the group technology concept (GT), in a designated tool-setting area where the toolsetter is given a listing of the required cutting on a CRT. As each tool is set up, the operator places the tool in the electronic tool gauge where the system automatically records the toll length. This value is then compared to the maximum and minimum values which have been pre-determined to be sure the tool has been set properly. If the tool length is unacceptable, the operator is instructed to reset the tool. Once the tool has been properly set the system stores the tool data for download to the machine when the tool is delivered. The tools are then loaded into pallet-mounted mobile chain matrixes, and the FMS computer is notified that the tooling is ready for delivery. When needed, the tooling is delivered to the tool matrix on the proper T-30 machining center by a wire-guided vehicle. At the machine, the new tooling is automatically interchanged with worm or broken tooling in the machining matrix. The tool exchange will take place automatically without causing any interruption to the cutting cycle. Special tooling required for machining particular parts is also delivered in the same manner.

During the exchange, the tool assemblies are identified by code so that appropriate tool data previously uploaded to the FMS computer from the tool setting area can then be downloaded to the A-30 CNC control. Three queue stations have been provided to accommodate temporary storage of the portable tool matrix. If the tool matrixes final destination is inaccessible, the wire-guided vehicle will place the matrix in these locations until it can be placed in its ultimate destination. The storage racks at the east end of the building are used to store both machined and unmachined parts.

The control room which houses all the computers that control the system is the "nerve center" for the FMS. The intelligence of the system is also housed in the control room. This FMS is modular in design, which facilitates easy configuration, controlling virtually any combination of machine tools and support equipment. Its control system features a full two-way communications interface between the machine tools and the FMS controller. Tool data and NC apart programs are downloaded to each machining center's computer numerical control. Similarly, information such as process control messages, current tool data, and production status is sent from the CNC to the FMS controller.

Material handling is controlled by interfacing the system's software provided by the equipment supplier. The software is "married" to the FMS controller through a traffic-control software module. This provides Millicron with the capability of interfacing numerous types of material handling equipment with the system.

The real time control of the system is the work order processor, as it drives the system and monitors its performance. Three planning software modules provide data to the work order processor: (1) the tool and operations module, (2) the schedule, and (3) the simulation module.

Millicron has far surpassed the previous FMS software by creating "the second generation of FMS". The two specific characteristics that separate this FMS from those of the first generation are: (1) parts are scheduled through the system using a pull-schedule theory, not a push theory, and (2) activities of the support organizations are being directed by the FMS.

Millicron engineers have measured an increase of ten to twenty percent in throughput using this control system. An automatic workstation with a ten pallet capacity has been installed in the system. It is used as a queueing station for pallets in the system. If all of the workstations are busy, a pallet being sent in must wait until the machining center is ready for it. In this way, the queueing station serves a a "temporary parking place." As soon as the machining center is available, the FMS computer sends a wire-guided vehicle to the queueing station to retrieve the pallet and take it to its next destination.

The parked position for a calibration queue is located on the left of the queue station. This queue is precisely manufactured to close tolerances. When positioned on the table of one of the four machining centers, it provides the means of quickly determining machine alignment accurately through the use of the probe. Once a machine's initial alignment parameters have been established during runoff, the calibration tube is used to record its alignment values. Any deviation can quickly be determined by comparing the machine's current alignment with those recorded during runoff.

An automatic wash and dry station is located at the westend of the station near the queue station. Immediately after machining, fixtured parts are delivered to the wash station. Here the pallet fixtured parts are slowly rolled over 360 degrees while high-pressure coolant is sprayed on them in an effort to flush away chips and debris. Once the cleaning cycle has been completed, the pallet fixtured parts are dried and discharged. At this point, a wire-guided vehicle transports them to an coordinate measuring measure machine. At the coordinate measuring machine all critical part dimensions are checked to be sure they are acceptable. If they pass inspection, the FMS system computer sends a wire-guided vehicle to pick them up from the discharge end of the coordinate measuring machine and deliver them to the load/unload station. If any part fails to pass inspection, a message appears on the system's CRT screen to bring the problem to the attention of the operator.

A centralized coolant chip system is another pertinent feature, it is located beneath the floor and provides a filtered coolant supply to each of the four T-30 machining centers. During the cutting cycle, it flushes chips and debris from the cutting station and conveys them to a collection tank filter unit outside the building. In the collection unit, the chips and coolant is filtered and recirculated back to the machining centers, while the chips are sent to chip tubs for recycling or disposal. The coolant mix ratio is automatically sampled, and coolant concentrate is added as needed to maintain consistent quality. The coolant temperature is also controlled to stabilize the part fixture temperature to improve part accuracy and lengthen tool life. Figure 3.2 illustrates a typical FMS configuration for Cincinnati Millicron. Another form of the execution is cellular manufacturing which is the physical layout of the factory floor into compact groups of machines and tools that are responsible for producing a family of parts. These groups of families are composed of arts with basic similarities in manufacturing. Group Technology is used to classify and code parts according to sommeliers in geometric characteristics, material, or manufacturing requirements. Within this compact cell, material handling costs are reduced. Scheduling families of parts with similar machining requirements reduces set up time. Storing the tools necessary to produce a family of parts at the cell simplifies tool storage, tool transportation and control procedures. Therefore, cellular manufacturing simplifies routings and material handling. Improved quality and worker motivation will often result because the worker is involved in a greater portion of the production sequence, rather than in only one machining operation. With cellular manufacturing, delivery lead time is reduced because the cells can respond quickly. Careful attention to scheduling will ensure smooth material flow to the cell.

Manufacturing Resource Planning (MRPII)

Material Requirements Planning (MRP) in its simplest form, decides how much and when to produce for individual products so that shortages can be predicted and avoided. It provides managers with detailed information for each individual component of the end product. This is referred to as closed loop MRP when it includes capacity planning, shop floor control and purchasing. When financial matters of the organization are also considered, it is called Manufactured Resource Planning II or MRPII. Figure 3.3 illustrates a closed loop MRP system. (Weight, 1984).

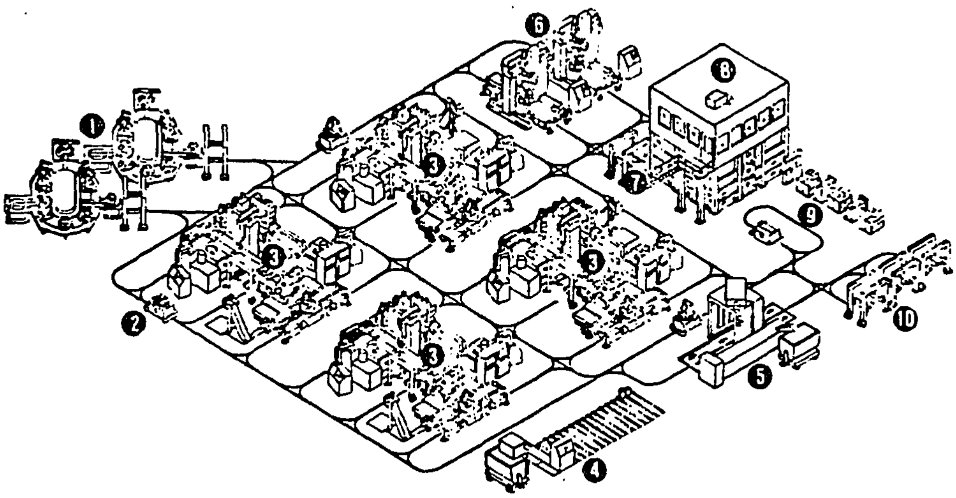
Before the master schedule is prepared, a rough-cut capacity plan is made to assure management that the production plan attainable. The rough-cut capacity plan states the number of hours required in each part of production, i.e. fabrication, and assembly. The material requirements plan is used in production control to release orders to factories and vendors and to re-schedule orders with the same. The re-scheduling or orders used to update priorities and provide input to capacity requirements planning. Capacity Requirements Planning generates a report that states what capacity will be required at a certain work center in order for the plan to be executed. MRP can simulate "what-if" situations to determine how much money is required for a new facility and what the best way to invest it would be. This is very important for facilities planning. Input-output reports are generated to compare hours of output to the production plan to see that the plan is being followed. While output is controlled by the input-output reports, input is controlled by the master schedule, which states clearly what is going to be produced. If the master schedule is unrealistic, the shortage list is used again.

Closed-loop MRP provides important information for planning, controlling, capacity, and scheduling.

Figure 3.2

FMS Configuration

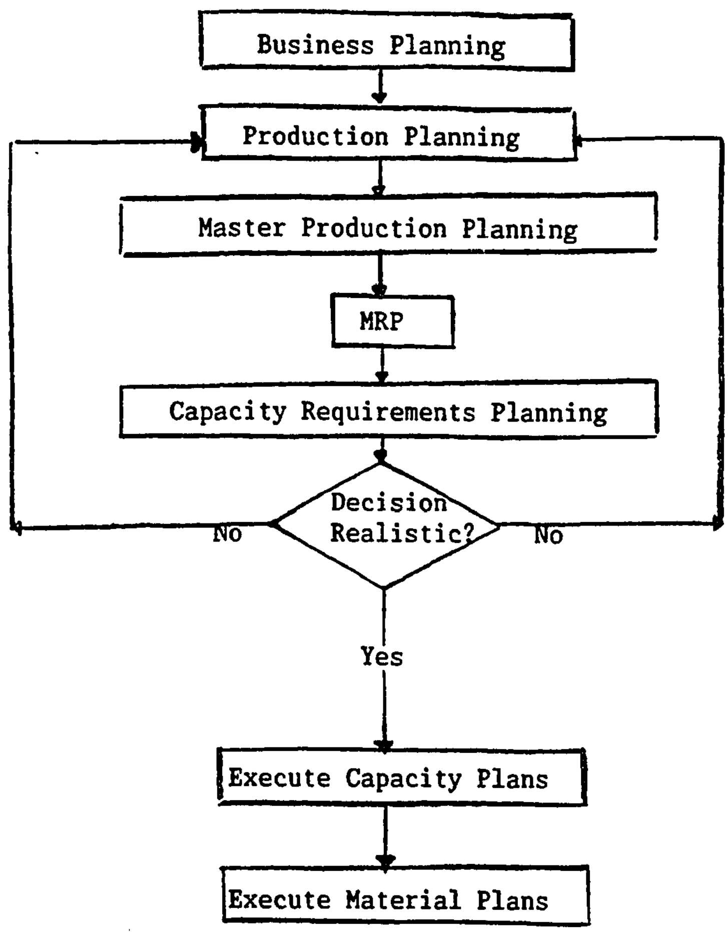
1. 10-pallet part load/unload stations
2. Computer-controlled cart with wire-fuided path
3. CNC machining centers
4. Automatic chip removal system
5. Automatic part cleaning module
6. Automatic inspection module
7. Manual inspection station
8. Master computer control center
9. Cart maintenance station
10. Standby parking



Courtesy of Cincinnati Milacron

Figure 3.3

Closed Loop MRP System



Source: Weight, 1984

Physical control and tracking

The final phase in the AMT manufacturing system consists of the following: (1) automated storage retrieval system (AS/RS) (2) automated time reporting (3) real time Work In Process tracking and process management (4) statistical process control.

Automated storage and retrieval systems (AS/RS) provide the integration with the balance of the AMT that completely automates the material handling task. Early AS/RS consisted of one or/more rows of high-rise storage racks. The racks would be stocked with bins or palletized items. A automated vehicle would travel down the rows to transfer the contents to and from the specified locations, with a centralized operator interface station. The records of what was stacked at each location were maintained manually. The designation of location and whether to retrieve the contents or pick up and return were then fed into the system by an operator. The containers were returned to the location they originated from. The system must now interface with the material handling system supplying the AMT in the plant, completing the automation of the facility. Often, parts are supplied from the AS/RS in smaller batches and on as needed basis (Just in time). With the changes in inventory that are possible with a truly flexible operation, maintaining locations for parts in an AS/RS may result in underutilizaton of the space. In order to minimize this problem, a temporary location operating format can be adapted for all or part of the AS/RS. With this format the part location will be assigned from a list of spaces when the part enters the system. When the parts are retrieved from the system, the location will be noted as available for storage and the parts location will be traced through the manufacturing facility.

Strategic Justification and the Competitive Factors of AMT

Strategic Justification of AMT

Managerial attitudes and policies are major obstacles to AMT. According to Gold (1982), managers try to use characteristics of traditional manufacturing systems when evaluating AMT. These traditional equipment characteristics are: (1) the direct application of equipment only to limited sections of the production process, (2) known and stable capabilities, best judged by qualified engineers and supervisors, and (3) making an easily measurable contribution to process efficiency and cost reduction. The advantages of AMT don't lie in the area of cost reduction. They are instead in more strategic areas such as shorter lead times, simpler scheduling, and more consistent quality. Managers must understand and evaluate AMT on its own terms (Fotseh, 1983), (Grud, 1984), (Meredith, 1985). Two characteristics of AMT make the justification process complex, and require special consideration. One characteristic is that AMT is more flexible than conventional equipment. The value of the equipment is thus maintained in the long run. In other words, the equipment does not depreciate. The second characeristic of AMT is that synergy occurs when systems are linked together. The qualitative benefits that result from the system linkage are more important than normal cost savings. This synergy increases the return on investment. Economic and analytic justification are well covered in the literature (Saaty, 1980), (Michael and Millen, 1984), (Meyers, 1984), (Meredith, 1985), (Kaplan, 1984), (Fotsch, 1983), (Carter, 1986).

Strategic justification approaches are less technical than the analytic and economic approaches but they are often used in combination with them. The advantage of strategic justification is that it is directly related to the goals of the firm. Both economic and analytic factors should be considered of all impacts of the project. The following strategic justification approaches were presented by Meredith and Suresh (1986).

The first strategic approach focuses on the technical importance of AMT. With this approach two projects must be completed in order for a desired follow-on activity to take place. The project is a prerequisite for the desired activity. The project's return can be negligible or even disadvantageous. Later, more desirable work can't be done unless the project is implemented. Such projects are grouped together with the desirable later project and approved by the firm.

The second strategic approach is the use of business objectives. Under this approach the project is justified because it accomplishes the firm's business objectives.

The third strategic approach focuses on competitive advantage. Implementation of a project may give the firm an opportunity to gain a significant advantage over its competitors. This advantage is too important to ignore, although it may not have been one of the firm's strategic business objectives. Related to the competitive advantage is the competitive necessity; a project that must be implemented if the firm wants to remain competitive.

The final strategic approach emphasis on research and development. Managers consider the possibility that a project may fail but the project has enough strategic promise to justify investment. Eventually, one of the many projects may succeed and will make up for the those which failed.

Competitive Factors of AMT

The competitive advantage of AMT presented in the literature deals only with specific implementation. Some examples of this competitive advantage are:

1). The CM flexible machining system produces 600 designs. The total savings is 25 million dollars in machining costs for these parts by manufacturing in 70,000 hours instead of 200,000 hours by conventional methods (Meridith, 1988).

2). As noted in Aggarwal (1985) firms which employ AMT obtain greater productivity. Production utilization of most general purpose machines is between 6% to 30%. These systems are expected to increase machinery utilization to an 80% or even 90% level.

3). According to Young (1986), the installation of GE AMT in Erie, Pennsylvania obtained these results:

a. A 240% overall increase in productivity

b. Improved part quality and consistency

c. A reduction in cycle time from 16 days to 16 hours

d. A 38% increase in capacity

e. A 25% reduction in floor space.

4). According to a survey in the machine tools industry, (FMS Magazine, 1984) the following advantages were achieved:

a. Number of machine tools decreased by 52.6%

b. Workforce was reduced by 2.6%

c. Tooling costs were reduced by 30%

d. Throughput increased by 25%

e. Capital investment was 10% less than for standalone equipment

f. Annual costs were decreased by 24%

5). According to Manufacturing Studies Board (NRC, 1984) for the companies which adopted CAD/CAM, the following benefits were achieved:

a. 15-30% reduction in engineering design cost

b. 30-60% reduction in overall lead time

c. Increased product quality as measured by yield of acceptance product 2-5 times that of previous level

d. Increased engineering 3-5 times capability (as measured by extent and depth of analysis)

e. Productivity of production operations increased 40-70%

f. Productivity (operating time) of capital equipment increased 2-3 times

g. 30-60% reduction of work in process

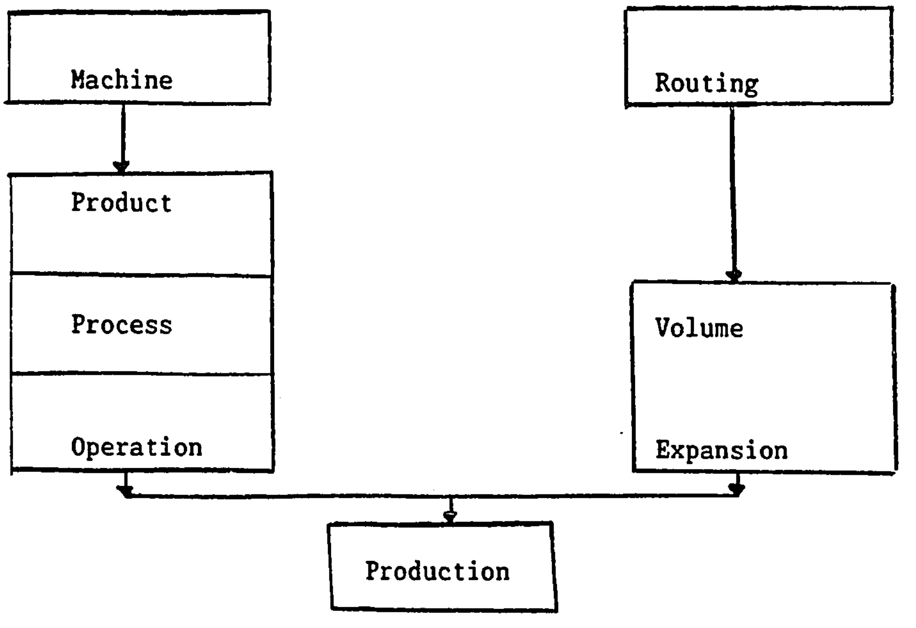
h. 5-20% reduction of personnel costs

The central characteristic of AMT is flexibility. Six possibilities have been noted by Kegg and Freist (1986). These include: (1) Mix flexibility - the ability to process various members of parts within the name family without losing time by the required change for set-ups, (2) parts flexibility - allowing for the ability to add new parts to the family, (3) routing flexibility, which includes two ideas. One, the ability to send different parts to workstations in different sequences, and two, transporting given part numbers through different machining routes depending on the machine availability, (4) design change flexibility, which refers to the ease of changing the designs of parts already in the manufacturing process, (5) Volume flexibility - the ability to change the workload without increasing the cost, losing utilization, or lowering productivity, (6) factory systems flexibility - the easy accommodation of the AMT hardware, software, and information systems to new factory hardware and software.

As shown in Figure 3.4 the following relationship exists among the flexibility types. The amount of machine flexibility needed is determined by goals for routing process, and production flexibilities. Process flexibility is derived primarily from machine flexibility, whereas, product flexibility is derived from features such as machine flexibility, operating procedures, software, ship floor control, and workforce skills and attitudes. Product and process flexibility impact on the normal operating mode of the factory (Chatterjee, 1984). Production flexibility is derived primarily from the variety of machinery in the factory and its machine flexibility. Volume and expandability flexibility require routing flexibility and all of them are required for production flexibility (Stecke, 1983). In this chapter the major element of advanced manufacturing technology has been introduced. However, there is very little empirical evidence in the literature that deals with the issue of integrating advanced manufacturing technology with manufacturing strategy. The greatest impact of advanced manufacturing technology appears to be the strategic planning phase, while a lesser effect is observed in the design and implementation phase. This study investigates the impact of advanced manufacturing technology on manufacturing strategy. The strategic element of AMT has been largely ignored in the literature and that is the focus of Chapter Four.

Figure 3.4

Relationships Among Flexibility Types



Source: Browne et al. (1984)

Chapter Four

Research Methodology

Phase One: Factor Analysis

Exploratory factor analysis is considered to be a general description for a number of specific computational techniques. The objective is to reduce a large number of measures to some smaller number by telling us, what measures belong together and which seem to measure the same thing. In other words, it reduces the number of variables. The first step in factor analysis begins by correlating each pair of scale items. The second step is to construct a new set of variables on the basis of relationships in the correlation matrix. Which can be done by using principal component analysis where a set of variables is transformed into a new set of composite variables that are not correlated with each other. The third step is to obtain factors from step two, which can be done by finding the best linear combination of variables as far as accounting for the variance in the data as a whole. Such a combination makes up the first principal component and is the first factor. The second principal component is defined as the best linear combination of variables in terms of explaining the variance not accounted for by the first factor. This process can continue until all for the variance is accounted for, but as a practical matter, it is usually stopped after a small number of factors have been extracted. The other type of extracting initial factors is the maximum likelihood method (Lawley and Maxwell, 1971) and procedures based on maximizing the determinants of a residual partial correlation matrix (Browne, 1968).

There are basically three different approaches to rotate the initial factors obtained by he principal component solution. Where that initial factors are orthogonal and that are arranged in a descending order of importance. There are two properties of the factor solution are not inherent in the data structure; they are arbitrary impositions placed on data to make the solutions unique and definable in some sense. The consequences of making these arbitrary impositions are that (1) The factorial complexity of variables is likely to be greater than one, that is, variables will have substantial loadings on more than one factor; (2) except for the first factor, that is, some variables have positive loadings on a factor while others have negative loading. (Kim and Mueller, 1976). The first approach is to examine the pattern of variables graphically and then rotate the axis. (See Figures 4.1 - 4.7) The second approach is to rely on some analytic rotation method that is free of subjective judgment. The varimax method is the most popular of these methods and is often used to rotate principal compcnents solutions. The procedure seeks to rotate factors so that the variation of the squared factor loadings for a given factor is made large (Dillon and Goldstein, 1984). (See

(Table 1.6). The third approach is to define a target matrix before actual rotation. The objective is to find the factor patterns that are closest to the given target matrix. To determine the number of factors in this study the following rules are utilized: (1) Eigenvalue specification, where the number of factors determined by retaining factors with eigenvalues greater than one when the correlational matrix is decomposed (Kaiser 1974). (2) Scree-test, which advocated by Cattell (1965). The rule directs one to examine the graph of eigenvalues, and stop factoring at the point where the eigenvalues begin to level off forming a straight line with an almost horizontal slope. (3) significance tests, Kim and Mueller (1976) argue that the large sample X2 test associated with the maximum likelihood solution is the most satisfactory solution from a purely statistical point of view, provided that the assumptions of the method are adequately met.

Phase Two: Industry Analysis

In this research the data was collected and analyzed from:

(1) Automotive Industry
(2) Machine Tool Industry
(3) Computer Industry
(4) Electronic Industry
(5) Aerospace Industry

Discriminant analysis is a statistical technique for classifying industries into mutual exclusive and exhaustive groups on the basis of a set of independent variables, Dillon and Goldstein (1984).

Phase Three: Multivariate Analysis of Variance (MANOVA)

Multivariate analysis of variance will be utilized to test the hypotheses among advanced manufacturing technology users and non users for all items introduced early.

Pilot Study

The Sample

The sample consists of the major industrial corporations in the United States and covers the following industries: Aerospace, Computer and Office Equipment, Electronics, Industrial and Farm Equipment, and Motor Vehicle. Table 1.2 shows the number of companies in each industry according to Fortune 500 (p. 15). Table 1.3 shows the geographical distribution for major U.S. corporations (p. 16). Also, the initial procedure was discussed in p. 14. The total number of responses utilized for the analysis in the pilot study stage was thirty nine responses.

Preliminary Results

The first model (competitive advantages of advanced manufacturing technology) is explained by three factors. the first factor (flexibility consideration) has large positive loading for the following variables: material flexibility (0.87389), product mix flexibility (0.82669), component flexibility (0.77842), development to market (0.73847), volume flexibility (0.69751). The second factor (cost consideration) has large positive loading for the following variables: cost of increasing production operations productivity (0.77678), cost of controlling entire production process (0.69420), engineering cost (0.55702), personnel cost (0.54122), setup cost (0.51193). The third factor (quality consideration) has also positive loading for the following variables: product quality (0.62469), utilization of capital equipment (0.55448), ability to meet delivery dates (0.47235), and statistical quality control (0.50406). The final commonality estimates show that all the variables are well accounted for by three factors, with final commonality estimates ranging form 0.63934 for control of entire production process to 0.892515 for material flexibility. Table 4.1 explains the factor pattern using principal component analysis. Table 4.2 illustrates rotated factor pattern using the Varimax method which shows a higher loading for the first factor as does the principal component method, the method shows a difference in loading for the second and third factor. Table 4.3, rotated factor pattern using the Promax method, which confirms the Varimax method, allows the researcher to utilize the result obtained by Varimax. Kaiser's measure of sampling adequacy (MSA) is presented in Table 4.4 which explains the partial correlations controlling factors. Figures 4.1 - 4.9 present plots of factor pattern for factor one, two and three.

The second model which presents forty six variables with eight factors, explains 72% of the standardized variance. The variance explained by each factor respectively are: 11.361176, 9.571141, 8.764151, 5.160520, 3.940403, 3.410125, 2.993951, and 2.682075. Table 4.5 presents rotated factor pattern for eight factors considered in the second model. Table 4.6 illustrates the same factors using the Varimax method. Table 4.7 presents rotated factor pattern using Promax method. The orthogonal transformation for developing all eight factors are explained in Table 4.8 - 4.10. Table 4.11 presents the final commonalty estimates for the second model.

TABLE 4.1
FACTOR PATTERN
PRINCIPAL COMPONENT

	FACT 1	FACT 2	FACT 3	
V134	0.87389	-0.14798	-0.13078	FLEXIBILITY
V129	0.82669	-0.17434	0.08168	CONSIDERATION
V131	0.808669	-0.35644	0.07599	VARIANCE EXPLAINED
V130	0.80600	-0.44048	0.04981	BY FACTOR ONE IS
V132	0.77842	-0.25913	-0.07338	6.088650
V128	0.73847	-0.03170	0.00201	
V133	0.69751	-0.00433	-0.41430	
V120	0.58793	0.11604	-0.16821	
V117	0.42045	0.77678	0.14573	COST CONSIDERATION
V116	0.17945	0.69420	0.03530	VARIANCE EXPLAINED
V121	0.23971	0.55702	-0.30337	BY FACTOR IS ONE
V125	0.47398	0.54122	-0.15779	3.250776
V122	0.32491	0.51193	0.29415	
V118	0.42355	0.22243	0.62469	QUALITY CONSIDERATION
V124	-0.16299	-0.48485	0.55448	VARIANCE EXPLAINED
V126	0.45826	0.40969	0.47235	BY FACTOR THREE IS
V123	-0.21796	0.34733	0.50406	2.031543

TABLE 4.2
ROTATED FACTOR PATTERN (STD REF COEFS)
METHOD: PROMAX

	FACTOR 1	FACTOR 2	FACTOR 3
V134	0.89891	0.03890	-0.02233
V133	0.87094	0.00353	-0.10905
V132	0.84449	-0.14244	0.11767
V129	0.84144	-0.05337	0.16626
V131	0.77585	-0.01423	0.06800
V130	0.76189	0.00370	0.01278
V128	0.69297	0.18081	-0.07255
V121	-0.10714	0.92289	-0.17956
V125	0.01565	0.88263	0.07264
V120	0.13488	0.54738	0.10155
V116	-0.01244	0.52609	0.18373
V122	0.00304	-0.09336	0.85619
V118	0.30758	-0.26305	0.76846
V126	-0.11785	0.34607	0.64896
V117	0.10348	0.33191	0.60224

TABLE 4.3
ROTATED FACTOR PATTERN
METHOD: VARIMAX

	FACTOR 1	FACTOR 2	FACTOR 3
V134	0.89192	0.15056	0.07223
V129	0.84855	0.04180	0.21163
V132	0.83712	-0.04065	0.13890
V131	0.81852	0.04694	0.10468
V130	0.81711	0.04937	0.04506
V133	0.79792	0.11390	-0.03239
V128	0.70304	0.26253	0.05545
V121	-0.00532	0.85008	-0.04827
V125	0.16092	0.84713	0.18687
V120	0.29863	0.56668	0.17302
V116	0.01366	0.52583	0.27196
V122	0.07122	0.06175	0.82429
V118	0.33084	-0.14341	0.73552
V126	0.06215	0.41853	0.69389
V117	0.15821	0.43736	0.66197

TABLE 4-4

PARTIAL CORRELATIONS CONTROLLING FACTORS

	V115	V116	V117	V118	V119	V120	V121	V122	V123	V124	V125	V126	V127	V128	V129	V130	V131	V132	V133	V134
V115	1.00																			
V116	-0.24	1.00																		
V117	0.22	-0.26	1.00																	
V118	0.02	-0.02	-0.07	1.00																
V119	-0.07	-0.33	0.19	0.41	1.00															
V120	0.07	-0.34	0.43	0.09	-0.04	1.00														
V121	0.03	-0.14	-0.37	-0.13	-0.33	-0.16	1.00													
V122	-0.17	-0.12	-0.24	-0.48	0.14	-0.07	0.35	1.00												
V123	0.11	-0.52	-0.21	-0.42	-0.29	0.36	0.16	0.16	1.00											
V124	0.48	-0.06	0.42	-0.29	0.14	-0.03	0.11	0.45	-0.31	1.00										
V125	0.19	0.00	-0.13	-0.03	0.06	-0.39	-0.59	-0.17	0.12	-0.10	1.00									
V126	0.22	-0.05	-0.19	0.09	0.25	-0.65	0.03	-0.34	-0.14	-0.05	0.28	1.00								
V127	0.29	0.24	0.02	0.32	0.59	-0.52	-0.27	-0.05	-0.53	0.32	0.34	0.50	1.00							
V128	0.31	-0.35	0.27	0.36	0.13	0.55	-0.02	0.01	-0.09	0.17	-0.26	-0.43	-0.26	1.00						
V129	0.31	-0.16	0.41	-0.02	-0.25	0.21	-0.09	-0.60	0.07	-0.16	-0.09	0.16	-0.19	0.09	1.00					
V130	0.38	0.29	0.11	-0.23	-0.41	-0.02	-0.16	-0.04	0.01	0.16	0.22	-0.21	0.01	0.06	0.23	1.00				
V131	-0.01	0.17	-0.46	-0.51	-0.53	0.01	0.51	0.49	0.46	0.05	-0.21	-0.27	-0.34	-0.19	-0.41	0.01	1.00			
V132	0.02	0.19	-0.53	-0.36	-0.56	-0.40	0.44	0.01	0.37	-0.21	0.13	0.27	-0.18	-0.45	-0.17	-0.12	0.58	1.00		
V133	-0.45	-0.08	-0.21	0.11	0.58	-0.26	-0.11	0.31	-0.51	0.03	0.07	0.32	0.31	-0.31	-0.48	-0.35	-0.14	-0.26	1.00	
V134	-0.68	0.06	-0.05	-0.23	-0.01	-0.12	-0.04	0.15	-0.02	-0.17	0.02	-0.14	-0.23	-0.49	-0.19	-0.31	-0.04	0.06	0.19	1.00

TABLE 4.5

ROTATED FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8
V66	0.88098	-0.03623	-0.11974	0.04192	0.04323	0.01340	0.00052	0.01590
V67	0.85034	0.07293	-0.00487	0.02763	-0.12861	-0.10858	-0.06867	0.05492
V68	0.79021	0.09434	-0.12740	0.18953	0.21902	0.17504	-0.04764	0.12740
V65	0.76323	-0.16177	-0.05130	0.15040	-0.00833	-0.05644	-0.24060	-0.09759
V69	0.72324	0.13475	-0.04053	0.03999	0.10005	-0.09554	-0.02924	0.04101
V64	0.70732	-0.08586	-0.20456	0.08665	-0.17446	0.24496	-0.03644	-0.11662
V59	0.69281	-0.16804	-0.02819	-0.26782	0.23293	0.12364	0.13510	-0.32572
V60	0.54693	-0.21491	-0.27509	-0.11788	-0.06339	-0.07226	0.28250	-0.41719
V57	0.63962	-0.26539	0.09784	0.47685	0.03873	0.04481	-0.02981	-0.25492
V63	0.61050	-0.15341	-0.01866	0.23076	-0.48195	0.03620	0.16039	0.05248
V56	0.55800	-0.14470	-0.06667	0.39039	-0.11723	0.06137	-0.08535	-0.16824
V62	0.52584	0.07944	-0.32481	-0.00227	-0.37909	0.13169	0.34763	-0.28556
V70	0.51294	0.44403	-0.04658	-0.01790	-0.00835	0.08674	0.17225	0.18446
V61	0.51081	-0.02511	-0.26801	-0.23312	-0.41697	-0.06974	0.30851	-0.24152
V130	-0.12318	0.95308	-0.03459	0.00001	0.00207	0.11408	0.03433	0.00793
V131	-0.09281	0.89537	0.00500	0.11419	0.06362	0.03399	-0.12293	-0.00279
V128	0.06711	0.83117	-0.1783	0.02324	0.18404	0.10880	-0.19315	-0.09271
V132	-0.08914	0.78903	0.03790	-0.01053	-0.18128	-0.19594	-0.17552	0.37834
V133	-0.02276	0.73249	-0.00398	0.09872	-0.18845	0.14065	0.13539	0.22086
V134	0.12970	0.56277	-0.15405	-0.02745	0.03173	0.21377	-0.05440	0.55984
V34	-0.20375	0.02932	0.88565	0.10635	0.10802	0.08676	0.04623	0.07675
V35	-0.23017	-0.27210	0.84213	0.22712	0.04779	-0.15224	-0.01545	0.11273
V32	0.10445	0.05809	0.79425	-0.08299	0.19301	0.03454	-0.05750	-0.04148
V33	-0.18935	0.04714	0.76797	-0.20143	0.09553	0.10341	-0.15904	-0.00593
V36	-0.14715	0.08536	0.53884	0.30001	0.35678	0.15046	-0.03408	-0.29034
V31	0.06269	0.14027	0.50448	0.20030	0.22546	0.41954	-0.13612	0.07229
V45	-0.01496	0.00025	0.09885	0.86713	0.19648	-0.08471	-0.04494	0.03552
V44	0.16280	0.16351	-0.03719	0.85378	0.17297	0.05711	-0.17470	0.06291
V43	0.30309	0.11070	0.17113	0.67969	0.19965	0.06389	-0.18002	-0.07735
V47	0.09289	0.01897	0.41372	0.47195	0.33125	-0.14642	0.20727	-0.01381
V49	0.07496	0.00199	0.07663	0.10374	0.89389	0.03338	-0.04444	-0.02750
V50	-0.01371	-0.04526	0.09662	0.10284	0.87712	-0.02693	-0.16732	-0.04446
V46	-0.04529	-0.07366	0.04521	0.35241	0.56048	-0.04460	0.43804	0.08314
V51	-0.20749	0.23028	0.00445	0.14444	0.55146	0.01036	-0.16585	-0.10711
V142	0.00728	-0.06893	-0.01381	-0.08754	-0.09534	0.85989	-0.03373	0.06193
V144	0.22750	0.29045	-0.18586	-0.08179	-0.03827	0.73949	0.10416	0.04114
V141	0.11549	0.14913	0.27718	0.15215	0.04926	0.07278	0.19242	0.18469
V143	0.04479	0.27517	0.17074	-0.13515	0.03239	0.56430	0.16292	0.14549
V137	-0.15301	0.17930	0.02979	0.07984	0.04577	0.55599	0.30417	0.53960
V16	0.06191	-0.15301	-0.03256	-0.13745	-0.03378	0.08780	0.93797	-0.00861
V15	0.09366	0.13759	-0.01842	-0.03716	-0.28147	0.13283	0.73200	0.09846
V117	-0.29902	-0.05951	0.15281	0.01358	0.13667	0.03284	-0.12897	0.79542
V136	-0.03471	0.19555	0.02574	-0.11244	-0.18513	0.16538	0.11235	0.78329
V138	-0.05866	0.15299	0.06282	-0.00799	-0.01161	0.56849	0.32151	0.57621
V135	0.11271	0.07968	-0.22412	0.09043	-0.26753	0.13169	0.10246	0.53856
V125	-0.36359	0.33118	-0.11626	0.17009	-0.17812	0.26544	-0.04491	0.41763

TABLE 4.6
ROTATED FACTOR PATTERN
SECOND MODEL

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8
V66	0.88098							
V67	0.85034							
V68	0.79021							
V65	0.76323							
V69	0.72324							
V64	0.70732							
V59	0.69281							
V60	0.65693							
V57	0.63962							
V63	0.61050							
V56	0.55800							
V62	0.52584							
V70	0.51294							
V61	0.51081							
V130		0.95308						
V131		0.89537						
V128		0.83117						
V132		0.78903						
V133		0.73249						
V134		0.56277						
V34			0.88565					
V35			0.84213					
V32			0.79425					
V33			0.76797					
V36			0.53884					
V31			0.50448					
V45				0.86713				
V44				0.85378				
V43				0.67969				
V47				0.47195				
V49					0.89389			
V50					0.87712			
V46					0.56048			
V51					0.55146			
V142						0.85989		
V144						0.73949		
V141						0.70272		
V143						0.56403		
V137						0.55599		
V16							0.93797	
V15							0.73200	
V117								0.79542
V136								0.78329
V138								0.57621
V135								0.52856
V125								0.41763
V14							0.42773	
V139						0.40733		
V129		0.55614						
V58	0.46096							
V48					0.45415			

TABLE 4.7
ROTATED FACTOR PATTERN
SECOND MODEL

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8
V67	0.85303							
V66	0.79807							
V68	0.79745							
V69	0.78329							
V65	0.77589							
V64	0.76565							
V56	0.71460							
V63	0.68938							
V57	0.66361							
V60	0.64367							
V59	0.62913							
V62	0.56796							
V61	0.52993							
V130		0.93038						
V131		0.88372						
V128		0.83031						
V132		0.79039						
V133		0.73326						
V134		0.61292						
V142			0.87959					
V141			0.81199					
V143			0.75921					
V144			0.75731					
V137			0.61963					
V138			0.59159					
V34				0.85841				
V32				0.85082				
V35				0.82670				
V33				0.78728				
V31				0.62210				
V36				0.52766				
V49					0.92343			
V50					0.90404			
V51					0.69846			
V46					0.66005			
V136						0.82107		
V135						0.77588		
V125						0.60141		
V44							0.85244	
V45							0.82008	
V43							0.80323	
V15								0.86755
V16								0.82665

VARIANCE EXPLAINED BY EACH FACTOR

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8
	7.307262	4.853797	4.067539	4.049145	4.043404	3.773609	3.235720	2.880093

TABLE 4.8

PREROTATION METHOD: VARIMAX

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8
1	0.82343	-0.31319	-0.10981	-0.27727	-0.12089	-0.28818	0.04223	0.18766
2	0.25922	0.49098	0.54109	-0.20388	-0.26426	0.47026	-0.01237	0.25469
3	0.35810	0.21795	0.13927	0.42034	0.55631	0.03996	0.51904	-0.20688
4	-0.05116	-0.60933	0.49939	0.50645	-0.10269	0.08295	-0.02224	0.31356
5	-0.00299	0.18604	0.28211	-0.06803	0.56810	-0.40117	0.54416	0.27240
6	0.15411	0.40962	-0.09504	0.58640	-0.48362	-0.40033	-0.18264	-0.05911
7	-0.20004	0.15901	-0.28508	0.04183	0.01387	-0.12366	0.42486	0.77279
8	0.24067	-0.02874	-0.46800	0.30989	0.17068	0.56355	-0.45189	0.14884

TABLE 4.9

PROCRUSTEAN TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8
1	0.87398	0.01121	-0.01824	0.10330	0.00880	0.06129	-0.04725	-0.04725
2	0.00178	0.83389	-0.06946	0.03919	-0.00725	-0.03705	0.02146	0.03282
3	-0.06675	-0.09351	0.80517	0.08815	-0.01232	-0.04331	-0.01057	-0.07428
4	0.10659	0.03062	-0.05031	0.93515	-0.04941	0.00817	-0.07422	0.03097
5	0.02267	-0.02902	-0.00314	-0.08921	0.71984	0.01474	-0.05967	0.07486
6	0.16335	-0.12603	-0.10178	0.02185	0.02478	0.72530	-0.06170	0.01494
7	-0.08900	0.01223	-0.01688	-0.13862	-0.05345	-0.05348	0.80680	0.01647
8	-0.11350	0.08962	-0.11880	0.07279	0.09674	-0.00513	0.03435	0.74993

TABLE 4.10

INTER-FACTOR CORRELATIONS

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8
FACT1	1.00000							
FACT2	-0.03628	1.00000						
FACT3	0.06970	0.16361	1.00000					
FACT4	-0.23681	-0.03781	0.11483	1.00000				
FACT5	-0.10031	0.04394	0.01923	0.22955	1.00000			
FACT6	-0.24166	0.22652	0.18767	0.04176	-0.00886	1.00000		
FACT7	0.07799	-0.02612	0.08916	0.22382	0.17393	0.11552	1.00000	
FACT8	0.23444	-0.11640	0.19749	0.16711	-0.27082	-0.04722	-0.08066	1.00000

TABLE 4.11

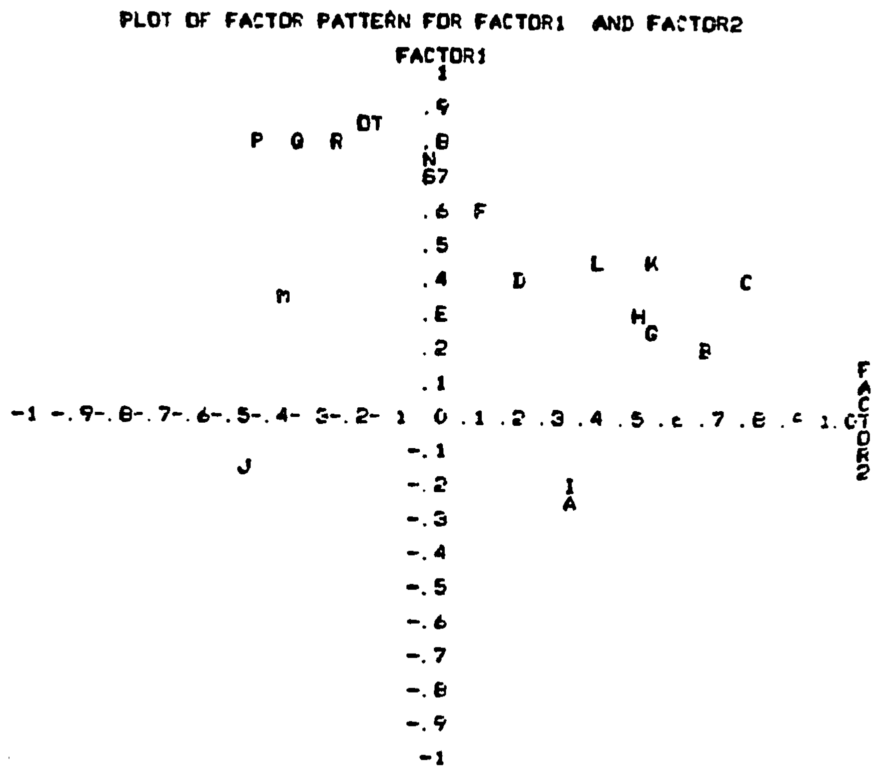
FINAL COMMUNALITY ESTIMATES

FOR THE SECOND MODEL

V66	V67	V68	V65	V69	V64
0.931529	0.819714	0.844858	0.826981	0.778399	0.777577
V59	V60	V57	V63	V56	V62
0.773129	0.889868	0.845810	0.892809	0.855952	0.894151
V61	V130	V131	V128	V132	V133
0.932528	0.919482	0.868301	0.870259	0.887473	0.776245
V134	V34	V35	V32	V33	V36
0.762228	0.849202	0.942569	0.850810	0.063505	0.746201
V31	V45	V44	V43	V49	V50
0.780594	0.872787	0.854699	0.902257	0.952321	0.914213
V51	V142	V144	V141	V143	V137
0.792137	0.875569	0.849279	0.944456	0.885724	0.916378
V16	V15	V136	V138	V135	V125
0.841743	0.887811	0.869254	0.794094	0.862356	0.795147

Figure 4.1

Principal Components Method



V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

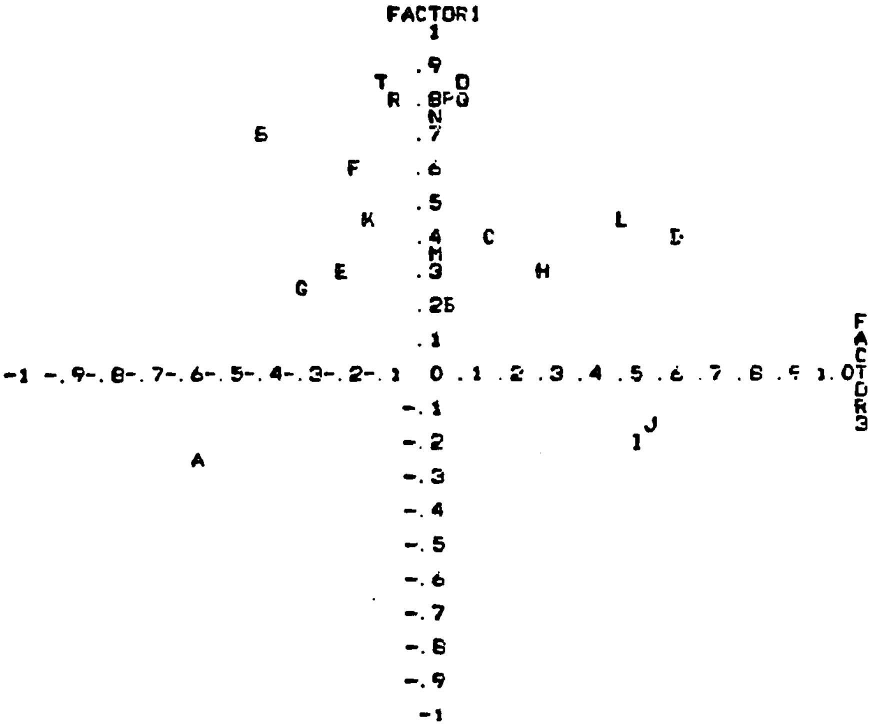
V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.2

Principal Components Method

PLOT OF FACTOR PATTERN FOR FACTOR1 AND FACTOR3



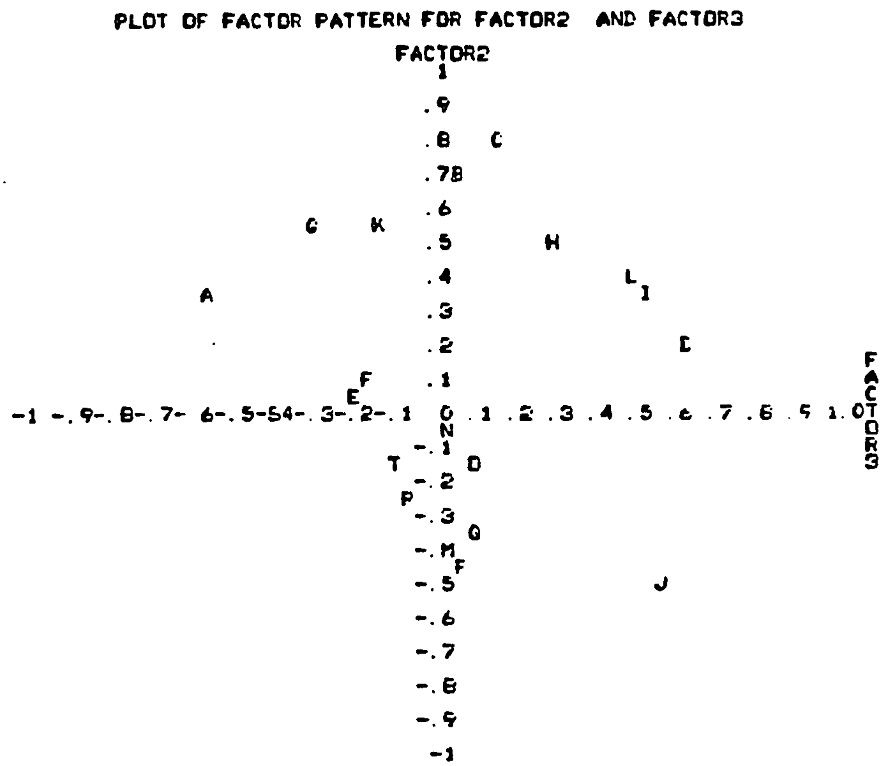
V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.3

Principal Components Method



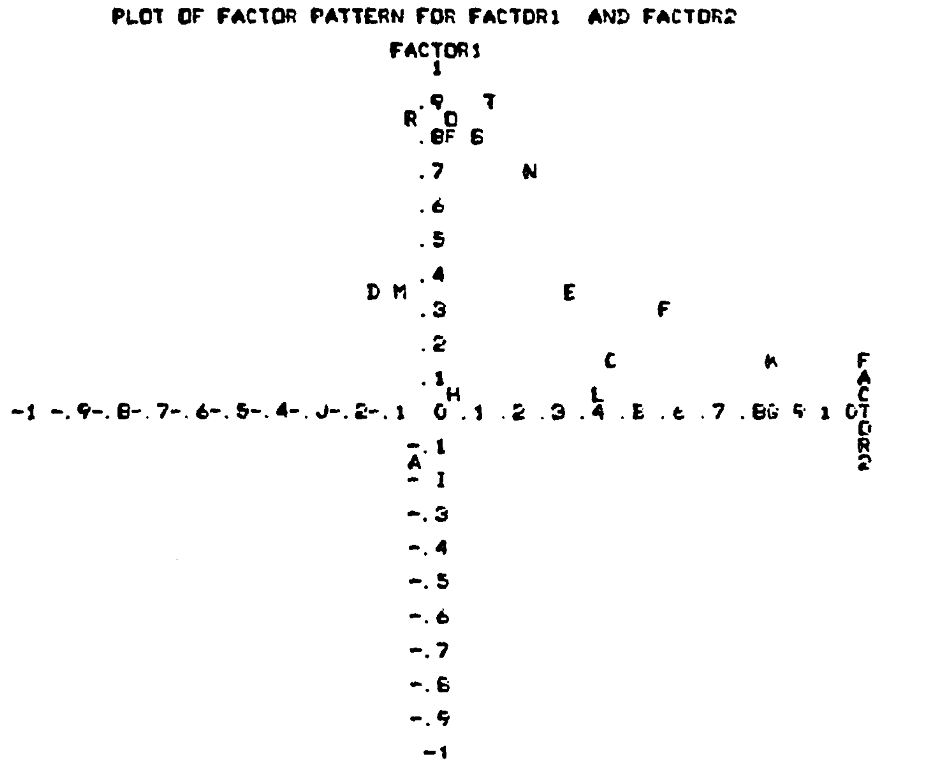
V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.4

Prerotation Varimax Method



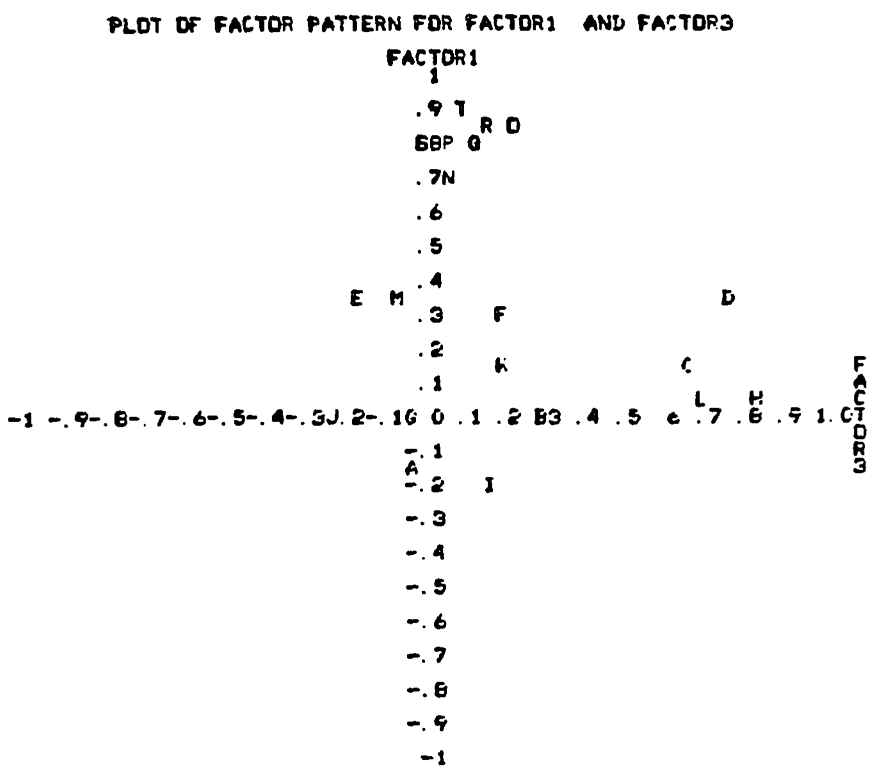
V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.5

Prerotation Varimax Method



V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

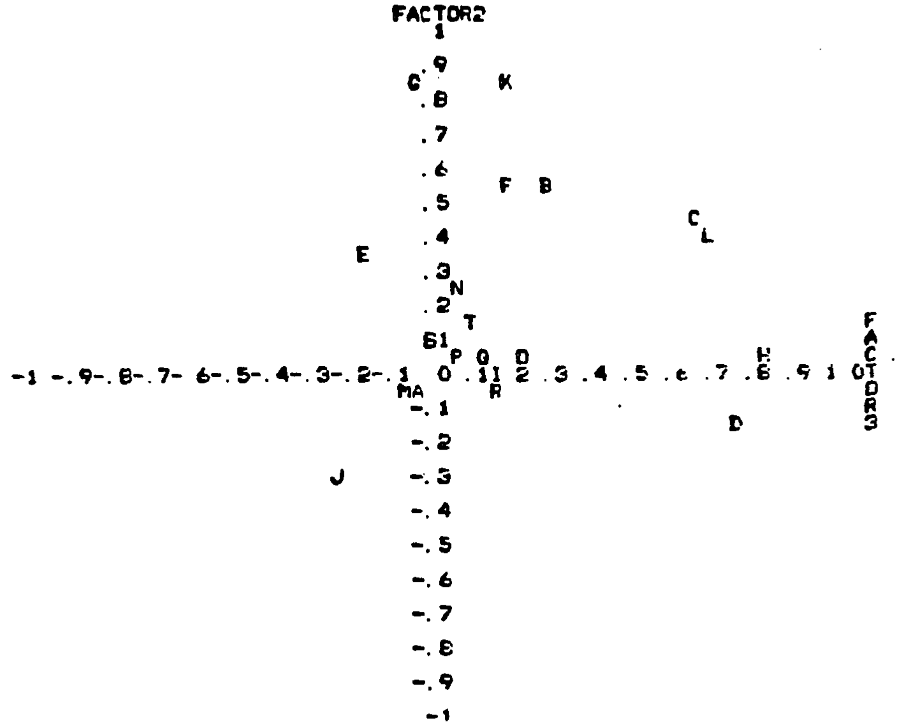
V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.6

Prerotation Varimax Method

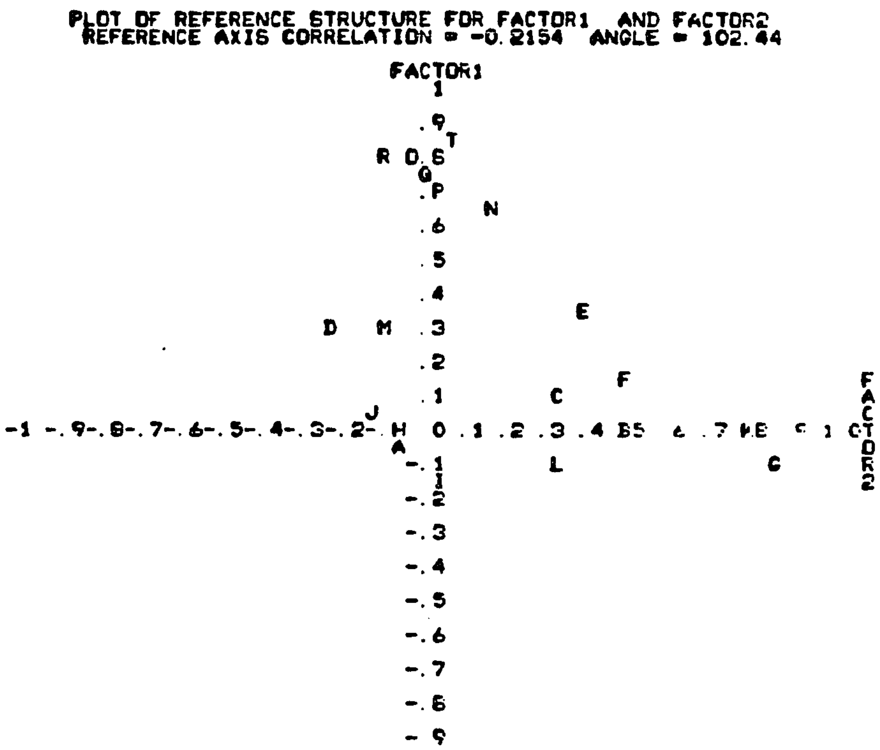
PLOT OF FACTOR PATTERN FOR FACTOR2 AND FACTOR3



V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H
V123=I V124=J V125=K V126=L V127=M V128=N V129=O
V130=P V131=Q V132=R V133==S V134=T

Figure 4.7

Rotation Method: Promax



V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

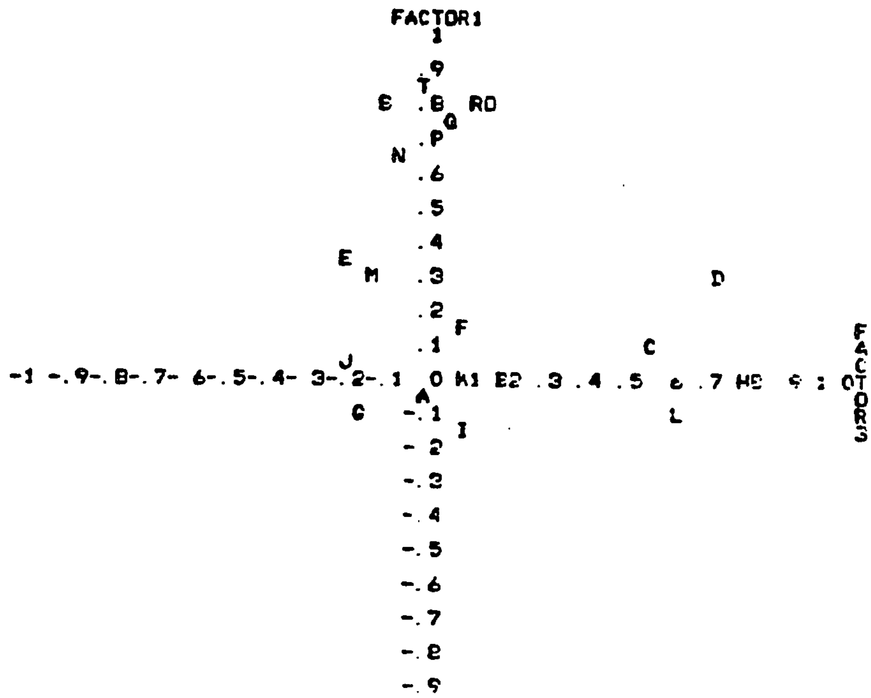
V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.8

Rotation Method: Promax

PLOT OF REFERENCE STRUCTURE FOR FACTOR1 AND FACTORS
REFERENCE AXIS CORRELATION = -0.1347 ANGLE = 97.74



V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H

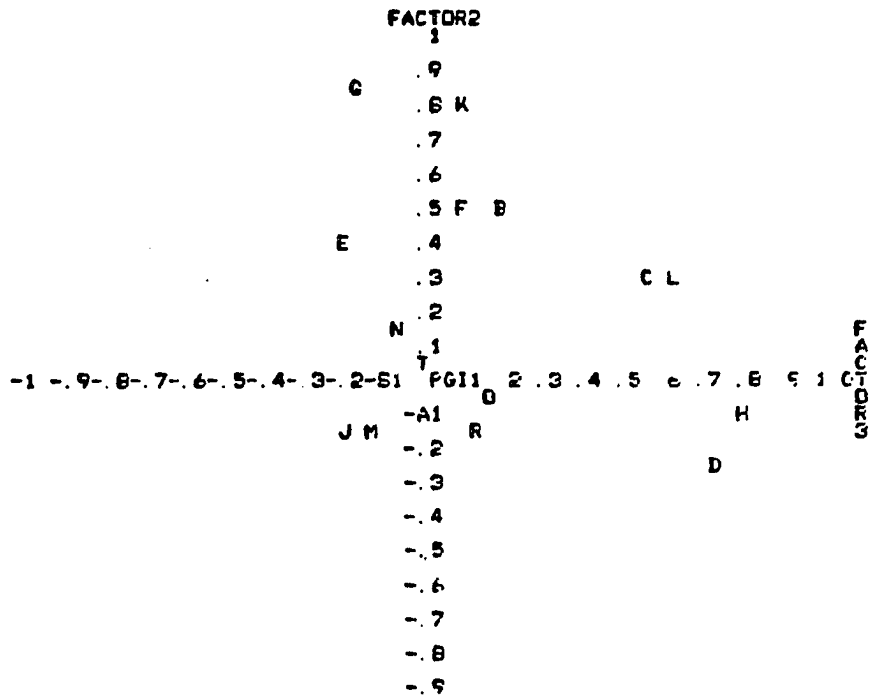
V123=I V124=J V125=K V126=L V127=M V128=N V129=O

V130=P V131=Q V132=R V133==S V134=T

Figure 4.9

Rotation Method: Promax

PLOT OF REFERENCE STRUCTURE FOR FACTOR2 AND FACTOR3
REFERENCE AXIS CORRELATION = -0.2688 ANGLE = 105.60



V115=A V116=B V117=C V118=D V119=E V120=F V121=G V122=H
V123=I V124=J V125=K V126=L V127=M V128=N V129=O
V130=P V131=Q V132=R V133==S V134=T

MAJOR VARIABLES

V66 = SHOP FLOOR CONTROL

V67 = SHOP FLOOR DATA COLLECTION

V68 = MANUFACTURING SIMULATION SYSTEM

V65 = AUTOMATED DATA ENTRY

V69 = MANUFACTURING OPTIMIZATION SYSTEM

V64 = ROBOTICS

V59 = AUTOMATED GUIDED VEHICLE SYSTEM

V60 = AUTOMATED MATERIAL TRACKING

V57 = PROCESS CONTROL EQUIPMENT

V63 = AUTOMATED ASSEMBLY EQUIPMENT

V56 = PROCESS MONITORING EQUIPMENT

V62 = AUTOMATED INSPECTION EQUIPMENT

V70 = DISTRIBUTION REQUIREMENT PLANNING

V61 = AUTOMATED TESTING

V58 = AUTOMATED STORAGE/AUTOMATED RETRIEVAL SYSTEM

....

V130 = CAPABILITY TO SUBSTITUTE NEW COMPONENTS

V131 = INCORPORATION OF COMPONENT DESIGN CHANGES

V128 = DECREASE IN OVER ALL LEAD TIME

V132 = ABILITY TO CHANGE OPERATION (MACHINE SEQUENCE)

V133 = ABILITY TO CHANGE AGGREGATE PRODUCTION AMOUNTS

V134 = ABILITY TO HANDLE VARIABILITY IN RAW MATERIALS INPUT

V129 = SIMULTANEOUS PRODUCTION OF DIFFERENT PRODUCTS

....

V34 = DEFECT PREVENTION

V35 = MONITORING QUALITY

V32 = WORKFORCE PAY INCREASE

V33 = WORKFORCE SECURITY

V36 = INERVENTION

V31 = WORKFORCE SKILLS LEVEL

....

V45 = COMPUTER AIDED DESIGN FOR DRAFTING

V44 = COMPUTER AIDED DESIGN FOR ANALYSIS

V43 = COMPUTER AIDED MANUFACTURING

V47 = COMPUTER INTEGRATED MANUFACTURING

....

V49 = GROUP TECHNOLOGY FOR CELLULAR MANUFACTURING

V50 = GROUP TECHNOLOGY FOR SUPPORT OF COMPUTER AIDED PROCESS PLANNING

V46 = COMPUTER AIDED PROCESS PLANNING

V51 = GROUP TECHNOLOGY FOR SUPPORT OF MATERIALS FUNCTIONS

V48 = GROUP TECHNOLOGY FOR SUPPORT OF CAD

....

V142 = MANUFACTURING STRATEGY AS AN INTEGRAL ASPECT OF THE BUSINESS UNIT'S STRATEGIC PLANNING PROCESS

V144 = COMPATIBILITY OF AMT GOALS WITH BUSINESS UNIT STRATEGY

V141 = ACCEPTANCE BY THE MANAGERS OF THE BUSINESS UNIT OF THE FORMAL COMMITMENT BY THE BUSINESS UNIT TO IMPROVING MANUFACTURING PRODUCTIVITY

V143 = DIRECT INVOLVEMENT OF OPERATIONS MANAGEMENT IN BUSINESS UNIT'S STRATEGIC PLANNING PROCESS

V137 = UNDERSTANDING, BY THE MANAGERS OF THE BUSINESS UNIT, OF THE FORMAL COMMITMENT BY THE BUSINESS UNIT TO IMPROVING MANUFACTURING PRODUCTIVITY

....

V16 = FACILITIES (FOCUS)

V15 = FACILITIES LOCATION

V14 = FACILITIES SIZE

....

V117 = INCREASE IN PRODUCTIVITY OF PRODUCTION OPERATIONS

V136 = UNDERSTANDING BY THE GENERAL POPULATION OF EMPLOYEES OF THE BUSINESS UNIT, OF THE FORMAL COMMITMENT BY THE BUSINESS UNIT TO IMPROVING MANUFACTURING PRODUCTIVITY

V138 = UNDERSTANDING BY THE GENERAL POPULATION OF EMPLOYEES OF THE BUSINESS UNIT, OF THE RELATIONSHIP OF AMT OBJECTIVES TO THE FORMAL COMMITMENT BY THE BUSINESS UNIT TO IMPROVING MANUFACTURING

V135 = FORMAL COMMITMENT BY THE BUSINESS UNIT TO IMPROVING MANUFACTURING PRODUCTIVITY

V125 = REDUCTION OF PERSONNEL COST BY IMPLEMENTING AMT

Reliability and Validity

According to Nunnally (1978) and Sellitz (1976), there are four methods used to assess the reliability of empirical measurements:

(1) the retest method,

(2) the alternative form method,

(3) split-halves method, and

(4) the internal consistency method.

The first three have major limitations such as requiring two independent forms of the measuring instrument on the same group of people, which is impossible in this kind of study. The fourth method, the internal consistency method were used to assess the reliability, factor score has been found for each item, the result as shown before shows high loading on all factors. The internal consistency can be estimated using a reliability coefficient such as Cronbach's alpha (Cronbach, 1951).

Validity is the extent to which any measuring instrument measures what it is intended to measure (Carmines and Zeller, 1979). Three different types of validity are generally considered: (1) content validity, (2) criterion-related validity, and (3) construct validity. Content validity depends on how well the researchers created measurement items to cover the content domain of the variable being measured (Nunnally, 1967). Criterion-related validity is at issue when the purpose is to use an instrument to estimate some important form of behavior that is external to the measuring instrument itself, the latter being referred to as the criterion (Nunnally, 1978). Both have limited usefulness for assessing the validity of empirical measures of theoretical concepts employed in the social sciences. However, construct validity involves three major steps: (1) the theoretical relationship between the concepts themselves must be specified, (2) the empirical relationship between the measures of empirical evidence must be interpreted in terms of how it clarifies the construct validity of the particular measure (Carmines and Zeller (1979). Because of insufficient sample size, the reliability and validity was not performed at this point. Factor analysis has been used in this research to measure the reliability and validity.

HYPOTHESES

Based on the literature review, as well as thirty-nine responses and personal interviews in the preliminary stage, six major hypotheses with a total of twenty-four sub-hypotheses will be examined.

HYPOTHESIS ONE

There is no significant difference between different levels of advanced manufacturing technology users in flexibility decisions involved in manufacturing and maintaining competitive advantage.

H-1 advanced manufacturing technology users are most likely to increase machine flexibility than non-users.

H1-2 advanced manufacturing technology users are most likely to increase product flexibility than non-users.

H1-3 advanced manufacturing technology users are more likely to increase process flexibility than non-users.

H1-4 advanced manufacturing technology users are more likely to increase operation flexibility than non-users.

H1-5 advanced manufacturing technology users are more likely to increase routing flexibility than non-users.

H1-6 advanced manufacturing technology users are more likely to increase volume flexibility than non-users.

H1-7 advanced manufacturing technology users are more likely to increase expansion flexibility than non-users.

H1-8 advanced manufacturing technology users are more likely to increase production flexibility than non-users.

HYPOTHESIS TWO

There is no significant difference between different levels of advanced manufacturing technology users and non-users in manufacturing cost and maintaining competitive advantage.

H2-1 advanced manufacturing technology users are more likely to reduce product cost than non-users.

H2-2 advanced manufacturing technology users are more likely to decrease engineeering design cost than non-users.

H2-3 advanced manufacturing technology users are more likely to reduce work-in-process inventory than non-users.

H2-4 advanced manufacturing technology users are more likely to reduce materials/supplies costs than non-users

H2-5 advanced manufacturing technology users are more likely to reduce overall lead time than non-users.

H2-6 advanced manufacturing technology users are more likely to get control of the entire production process than non-users.

HYPOTHESIS THREE

There is no significant difference between different levels of advanced manufacturing technology users with quality consideration in maintaining the competitive edge.

H3-1 advanced manufacturing technology users are more likely to increase product quality than non-users.

H3-2 advanced manufacturing technology users are more likely to meet delivery dates than non-users.

H3-3 advanced manufacturing technology uses are more like to prevent defect than non-users.

H3-4 advanced manufacturing technology users are more likely to monitor quality than non-users.

H3-5 advanced manufacturing technology users have a greater capacity for quality intervention than non-users.

HYPOTHESIS FOUR (MANUFACTURING STRATEGY)

H4-1 There is no significant difference between different levels of advanced manufacturing technology users in manufacturing strategy capacity decisions.

H4-2 There is no significant difference between different levels of advanced manufacturing technology users in manufacturing strategy facilities decisions.

H4-3 There is no significant difference between different levels of advanced manufacturing technology uses in manufacturing strategy vertical integration decisions.

H4-4 There is no significant difference between different levels of advanced manufacturing technology users in manufacturing strategy production planning and control decisions.

H4-5 There is no significant difference between different levels of advanced manufacturing technology users and non-users in manufacturing strategy organization structure decisions.

HYPOTHESIS FIVE

There is no significant performance change between different levels of advanced manufacturing technology users.

HYPOTHESIS SIX

There is no significant difference between different levels of advanced manufacturing technology users in the degree of compatibility between corporate, business, and manufacturing strategies.

CHAPTER 5

Results of Statistical Tests

Initially 686 questionnaires were mailed and distributed among companies that operate in the U.S. within the seven chosen industries. Chemicals industry and Metal Product were excluded from the sample, because they operate under different manufacturing conditions. The remaining five industries are: Motor Vehicles, Industrial and Farm Equipment, Computers, Electronics, and Aerospace Industry. One hundred twelve company responses were received in total, roughly responding an 18% response rate. Out of the one hundred twelve company responses, five were from the Motor Vehicle Industry, thirty were from Industrial and Farm Equipment Industry, twenty-six were from the Computer Industry, thirty-one were from the Electronic Industry, and twenty-two were from the Aerospace Industry. Firm size and manufacturing technology were the criterion for sample selection. Table 5.1 summarizes the response rate for the selected industry.

Three levels of manufacturing technologies were examined in this research. The first level is highly dominated by the Electronic and Computer Industry. The major elements are the following: automated storage, automated retrieval system, manufacturing simulation system, automated data entry, shop floor data collection, computer aided design for analysis,

Table 5.1

Industry	# of companies responded	# of companies in the Fortune 500	% of Response
Motor Vehicle	5	8	62.5%
Industrial and Farm Equipment	30	34	88.2%
Computers	26	25	104%*
Electronics	31	46	67.4%
Aerospace	22	18	122.2%*
Total	112	150	

*denote more than one response in that industry

manufacturing optimization system, shop floor control, automated material tracking, automated guided vehicle system, automated inspection equipment, automated assembly equipment, robotics, process monitoring equipment, distribution requirements planning, automated testing, process control equipment, and computer aided design, for design.

The second level includes the following: group technology, for support of computer aided process planning; group technology, for support of computer aided design; group technology, for cellular manufacturing; group technology, for support of materials functions; computer aided process, manufacturing resource planning, and computer integrated manufacturing. The second level is highly dominated by Motor Vehicle and Aerospace Industries.

The third level of manufacturing technologies examined in this research include the following: computer numerical control, numerical control, direct numerical control, flexible manufacturing system, and computer-aided manufacturing.

The third level is dominated by industrial and farm equipment. The classification of companies which fall into one of these levels is determined by the mean score for each observation; when the average is above 3.0, it is considered to be in the first level, when the average is between 2.3 and 2.9, it is considered to be in the second level, and when the average is below 2.3, it is considered to be in the third level. The scale of all elements of manufacturing technology is a 4-point scale, where one refers to no plans for use, and four is the current use. Figure 5.1 presents a scree plot of eigenvalues. Table 5.2 presents a principal component factor analysis and the variance explained by each factor along with final commonality estimates for each variable. Table 5.3 presents varimax to rotate the factors presented in Table 5.2.

The Competitive Advantages of AMT

The results of statistical tests for the competitive advantage of advanced manufacturing technology is explained by these factors. The first factor which explains the flexibility consideration includes the following items: V131 modification flexibility, V130 component flexibility, V129 product flexibility, V133 volume flexibility, V132 rerouting flexibility, V120 engineering flexibility, and V134 material flexibility. The second factor which explains the cost consideration includes the following: V115 decrease in product cost, V116 control of entire production process, V117 cost of production operations, V118 utilization of capital equipment, V119 engineering design cost, V123 reduction of work-in-process inventory, V124 reduction in materials/supplies costs, and V125 reduction in engineering change costs. The third factor which explains the quality consideration in improving the company performance includes the following: V122 increase in product quality, V126 increase in ability to meet delivery dates, V127 increase in order fill rate, V125 reduction of personnel cost, and V128 development to market. Figure 5.2 illustrates the scree plot of eigenvalues. Table 5.4 illustrates the rotated factor for the competitive advantages of AMT with the variance explained by each factor and the final communality estimates for each item.

Hypotheses Testing for the Competitive Advantages of AMT

The multivariate analysis of variance (MANOVA) technique is utilized to test the first three hypotheses associated with the competitive advantage of AMT. The level of significance, alpha =.05, is selected.

The hypotheses were tested between the three levels of automation together, then a test between every two levels is

Figure 5.1

Scree Plot Of Eigenvalues

```
E       7+  1
I
G
E
N       6 +
V
A
L
U       4 +
E
S             2
                3

        2 +
                   4 5
                       6 7 8
                            9 0 1

        0 +                       2 3 4 5 6 7 8 9 0 1 2 3 4
                                                            5 6 7 8 9



        -2 +---------+---------+---------+---------+---------+---------+
           0         5        10        15        20        25        30
           NUMBER
```

Table 5.2

Initial Factor Method: Principal Factors

(Advanced Manufacturing Technology)

Item	Factor 1	Factor 2	Factor 3	Communality
AS/AR	0.67931	-0.19475	-.02938	0.510397
MSS	0.66093	0.22415	-0.14631	0.508470
ADE	0.65363	-0.42725	-0.05252	0.612533
SFDC	0.64466	0.20958	-0.03776	0.460931
CADA	0.63583	-0060985	-0.10050	0.415632
MOS	0.63227	0.22754	-0.12365	0.444208
SFC	0.61237	0.15463	0.19789	0.370069
AMT	0.58375	0.12297	-0.29718	0.352238
AGFS	0.57918	0.27085	-0.08262	0.360260
AIE	0.56483	0.43560	-0.04032	0.364327
AAE	0.54567	0.11473	0.09325	0.307760
ROB	0.53928	0.27458	-0.06205	0.301865
PME	0.51788	0.18100	-0.08247	0.438060
DRP	0.51667	0.30865	0.04598	0.381155
AT	0.50680	0.20829	-0.04040	0.243141
PME	0.48042	0.38489	0.05741	0.319610
CADD	0.45110	0.06806	-0.41597	0.336521
GTCAPP	0.42600	0.11432	0.24437	0.882892
GTCAD	0.39431	0.32374	0.27611	0.786299
GTCM	0.38966	0.24332	-0.17917	0.768731
GTMF	0.38024	0.33730	-0.31922	0.696584
CAPP	0.33140	-0.45993	0.00123	0.612533
MRP	0.56295	-0.60141	-0.13182	0.321362
CIM	0.5825	-0.64735	-0.06034	0.500252
CNC	0.64543	-0.66176	-0.16850	0.731376
NC	0.41845	-0.05602	0.74373	0.629648
DNC	0.32950	-0.05115	0.72004	0.512628
FMS	0.36543	-0.09729	0.60797	0.254264
CAM	0.17198	-0.03858	0.27939	0.109124
VARIANCE	7.999759	3.191566	2.225842	

KEY

AS/AR	Automated Storage/ Automated Retrieval System	AT	Automated Testing
MSS	Manufacturing Simulation System	PCE	Process Control Equipment
ADE	Automated Data Entry	CADD	Computer Aided Design for Drafting
SFDC	Shop Floor Data Collection	GTCAPP	Group Technology for Support of CAPP
CADA	Computer Aided Design for Analysis	GTCAD	Group Technology for Support of CAD
MOS	Manufacturing Optimisation System	GTCM	Group Technology for Cellular Manufacturing
SFC	Shop Floor Control	GTMF	Group Technology for Support of Materials Functions
AMT	Automated Material Testing	CAPP	Computer Aided Process Planning
AGVS	Automated Guided Vehicle System	MRP	Manufacturing Resource Planning
AIE	Automated Inspection Equipment	CIM	Computer Integrated Manufacturing
AAE	Automated Assembly Equipment	CNC	Computer Numerical Control
ROB	Robotics	NC	Numerical Control
PME	Process Monitoring Eqipment	DNC	Direct Numerical Control
DRP	Distribution Requirements Planning	FMS	Flexibile Manufacturing Systems

CAM Computer Aided Manufacturing

Table 5.3

Rotation Method: Varimax

(Advanced Manufacturing Technology)

Item	Factor 1	Factor 2	Factor 3
AS/AR	0.69875		
MSS	0.67770		
ADE	0.65165		
SFDC	0.62816		
CADA	0.62515		
MOS	0.59913		
SFC	0.59119		
AMT	0.57858		
AGFS	0.57281		
AIE	0.56518		
AAE	0.52568		
ROB	0.52195		
PME	0.50939		
DRP	0.49629		
AT	0.48860		
PME	0.46235		
CADD	0.41922		
GTCAPP		0.92514	
GTCAD		0.86481	
GTCM		0.86159	
GTMF		0.82418	
CAPP		0.71698	
MRP	0.55624		
CIM		0.53756	
CNC			0.83914
NC			0.78795
DND			0.69355
FMS			0.36898
CAM			0.32002
VARIANCE	5.975762	4.611247	2.830158

KEY

AS/AR Automated Storage/ Automated Retrieval System
MSS Manufacturing Simulation System
ADE Automated Data Entry
SFDC Shop Floor Data Collection
CADA Computer Aided Design for Analysis
MOS Manufacturing Optimisation System
SFC Shop Floor Control
AMT Automated Material Testing
AGVS Automated Guided Vehicle System
AIE Automated Inspection Equipment
AAE Automated Assembly Equipment
ROB Robotics
PME Process Monitoring Eqipment
DRP Distribution Requirements Planning
AT Automated Testing
PCE Process Control Equipment
CADD Computer Aided Design for Drafting
GTCAPP Group Technology for Support of CAPP
GTCAD Group Technology for Support of CAD
GTCM Group Technology for Cellular Manufacturing
GTMF Group Technology for Support of Materials Functions
CAPP Computer Aided Process Planning
MRP Manufacturing Resource Planning
CIM Computer Integrated Manufacturing
CNC Computer Numerical Control
NC Numerical Control
DNC Direct Numerical Control
FMS Flexibile Manufacturing Systems
CAM Computer Aided Manufacturing

Figure 5.2

Scree Plot of Eigenvalues

Competitive Advantages of AMT

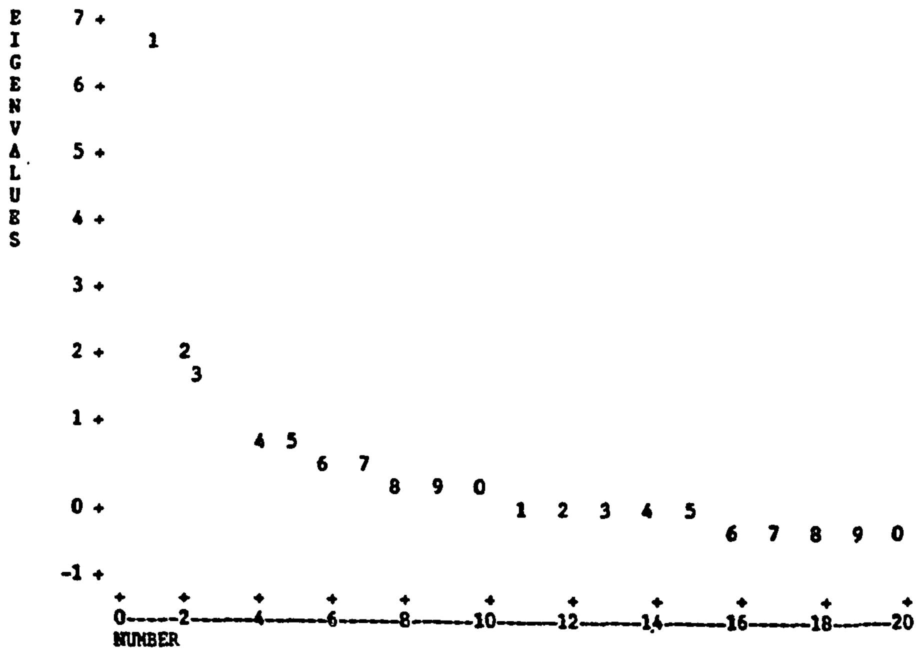


Table 5.4

Rotated Factor: Varimax

Competitive Advantage of AMT

	Factor 1	Factor 2	Factor 3	Communality
V131	0.78632	0.14289	0.14879	0.660850
V130	0.76232	0.05229	0.15773	0.608747
V129	0.71631	0.08139	0.28448	0.600650
V133	0.71577	0.00070	0.24117	0.570494
V132	0.52986	0.14501	0.24802	0.363298
V120	0.48418	0.24177	-0.02203	0.293076
V134	0.48345	0.34064	0.08588	0.357137
V116		0.82869	0.19556	0.739397
V117		0.77713	0.16673	0.648520
V118		0.71796	0.32103	0.637265
V115		0.70797	0.25992	0.569810
V119		0.55106	0.07719	0.434642
V123		0.45836	0.33609	0.428884
V124		0.39710	0.38068	0.325858
V121		0.38840	0.08260	0.261473
V126			0.74635	0.615053
V127			0.66868	0.602171
V125			0.66679	0.468587
V122			0.53734	0.383162
V128			0.48230	0.419906
VARIANCE	3.736382	3.519648	2.732950	

KEY

V115 decrease in product cost
V116 increase in control of entire production process
V117 increase in productivity of production operations
V118 increase in utilization of capital equipment
V119 reduction in engineering design cost
V120 increase in capability of engineers
V121 reduction in engineering change costs
V122 increase in product quality
V123 reduction of work-in-process inventory
V124 reduction in materials/supplies costs
V125 reduction of personnel costs
V126 increase in ability to meet delivery dates
V127 increase in order fill rate
V128 decrease in overall lead time
V129 increase in product mix flexibility
V130 increase in component flexibility
V131 increase in modification flexibility
V132 increase in rerouting flexibility
V133 increase in volume flexibility
V134 increase in material flexibility

performed. The conclusion depends on the value of F; if the obtained F exceeds the table value of F at a preselected level of significance, so we reject the null hypothesis.

The overall evaluation for the competitive advantages of AMT shows no significant difference between the three levels of automation. According to Wilks' criterion, the exact F with degrees of freedom (40,178), F(40,178 =1.3. Since the level of significance at 0.05 is not greater than the probability of exact F, Prob > F = 0.2910, we are led to accept the null hypothesis. Based on my sample of company responses, there does not seem to be significant difference between the three levels of automation in terms of their impact on competitive advantages.

In order to determine which factor is not significantly different, I have used MANOVA to test the significant difference for each factor score. The overall results led us to conclude that the advanced manufacturing technology does not significantly affect competitive advantage such as flexibility, cost, and quality. As shown in Table 5.5, there is only significant difference for modification flexibility, product flexibility, volume flexibility, and engineering flexibility. The first three were found significant only between level one and two automation. The last one between both level one and three and level one and two automation.

Table 5.5
Test of Significance
(Competitive Advantages of AMT)
alpha = 0.05

Factor	Items	PR > F	PR > F	PR > F
	V131	0.2647	(0.0061)*	0.2692
	V130	0.3964	0.0929	0.6311
	V129	0.3086	(0.0375)*	0.5020
1	V133	0.3525	(0.0490)*	0.5114
	V132	0.7507	0.6666	0.9874
	V120	(0.0014)*	(0.0001)*	0.7980
	V134	0.3261	0.9255	0.3214
	V116	0.9459	0.9615	0.9840
	V117	0.2671	0.5019	0.6391
	V118	0.1597	0.6764	0.1531
	V115	0.9505	0.9605	0.9819
2	V119	0.0693	0.2576	0.3605
	V123	0.2839	0.2841	0.8236
	V124	0.3460	0.3282	0.8435
	V121	0.8446	0.9678	0.8355
	V126	0.8307	0.9686	0.8328
	V127	0.8673	0.2719	0.5046
3	V125	0.6312	0.9737	0.6645
	V122	0.1556	(0.0116)*	0.5741
	V128	0.1172	(0.0436)*	0.9963

* Refers that, there is a significant difference.

KEY

V115 decrease in product cost
V116 increase in control of entire production process
V117 increase in productivity of production operations
V118 increase in utilization of capital equipment
V119 reduction in engineering design cost
V120 increase in capability of engineers
V121 reduction in engineering change costs
V122 increase in product quality
V123 reduction of work-in-process inventory
V124 reduction in materials/supplies costs
V125 reduction of personnel costs
V126 increase in ability to meet delivery dates
V127 increase in order fill rate
V128 decrease in overall lead time
V129 increase in product mix flexibility
V130 increase in component flexibility
V131 increase in modification flexibility
V132 increase in rerouting flexibility
V133 increase in volume flexibility
V134 increase in material flexibility

According to Table 5.5 for the second factor (cost consideration), there is no significant difference among all groups.

In the third factor (quality consideration), we found, also, no significant difference among all levels, except product quality and development to market, was found to be significant.

For the first three hypotheses, the statistical result led us to reject the null hypotheses.

Manufacturing Strategy Decision Categories

Manufacturing strategy decision categories presented in Chapter 2 and the hypotheses associated with it are tested. The overall evaluation for the manufacturing strategy and compatibility between manufacturing, business, corporate strategy, and its association with advance manufacturing technology within the three levels explained earlier, are now tested. First of all, I will introduce factor analysis results, then testing the hypotheses will follow.

The four factors determined by scree test are shown in Figure 5.3. The first factor considered is the compatibility between manufacturing and corporate strategy. The second factor is the organizational structure and production planning and material control. The third factor considered in this study is the capacity and facility decisions. The fourth factor considered

Figure 5.3

Scree Plot of Eigenvalues

(Manufacturing Strategy Decisons Categories)

```
E        8 +
I            1
G
E
N        6 +
V
A
L
U        4 +    2
E
S


         2 +        3
                      4

                        5 6
                            7 8 9 0
         0 +                        1 2 3 4 5 6 7 8 9 0 1 2 3 4 5


        -2 +---------+---------+---------+----------+---------+
           0         5         10        15          20        25
           NUMBER
```

in this study is vertical integration. Table 5.6 illustrates the four main factors.

The first factor explains the compatibility between corporate, business, and manufacturing strategy and the impact of different levels of automation. A total of ten items represented the compatibility factor to improve manufacturing productivity. Seven items explained the second factor. Capacity and facility factors are explained by a total of five items. Finally, the vertical integration factor is explained by only three items.

For the last three hypotheses at the predetermined level of significance 0.05, the statistical results show a significant difference between the three levels of advanced manufacturing technology, where PR > F = 0.0002.

Hypothesis Four

H4-1 There is no significant difference between different levels of advanced manufacturing technology users in the capacity decisions.

H4-2 There is no significant difference between different levels of advanced manufacturing technology users in the facilities decisions.

These two hypotheses are explained by the third factor in terms of the following: V13 size of facility, V10 the amount of

Table 5.6

Rotated Factor for Manufacturing Strategy Decisions Categories

Varimax

		Factor 1	Factor 2	Factor 3	Factor 4	Communality
	V141	0.85633				0.772622
	V140	0.82058				0.709286
Compatibility	V139	0.80816				0.712483
	V135	0.79120				0.641008
	V137	0.78878				0.684777
	V143	0.76840				0.603427
	V142	0.74439				0.599727
	V138	0.72606				0.58237
	V136	0.71876				0.540358
	V39		0.71865			0.548990
Production	V38		0.71194			0.529445
Planning/	V41		0.70904			0.528092
material	V37		0.70902			0.540816
control and	V40		0.69676			0.514507
organization	V36		0.65988			0.505502
structure	V31		0.56352			0.392600
	V32		0.44747			0.262534
Capacity	V13			0.72341		0.622576
and	V10			0.71838		0.635166
Facility	V14			0.66487		0.560743
	V12			0.64710		0.652423
	V11			0.64131		0.597305
Vertical	V28				0.86108	0.778729
integra-	V29				0.83604	0.740713
tion	V27				0.82376	0.712509
Variance		6.044376	3.764672	2.817006	2.342821	

KEY

- V10 the amount of capacity involved in manufacturing strategy
- V11 the timing of capacity decision
- V12 the type of capacity decision
- V13 the size of facility
- V14 the location of facility
- V27 the direction of vertical integration
- V28 the extent of vertical integration
- V29 the balance of vertical integration
- V31 the workforce skill level requirments
- V32 the workforce security assurance
- V36 computerization of manufacturing planning
- V37 centralization of of production planning and material control
- V38 decision rules
- V39 organization structure
- V40 organization reporting levels
- V41 organization support groups
- V135 the company provides an organized, comprehensive understanding of manufacturing productivity improvements
- V136 improving manufacturing productivity
- V137 the mangerial comprehension for improving productivity
- V138 employee understanding of AMT
- V139 managerial understanding of AMT goals
- V140 employee acceptance of improving productivity
- V141 managerial acceptance of the company's commitment to the goal of productivity improvements
- V142 the integration of the manufacturing strategy with the overall company's strategic planning process
- V143 the company's inclusion of operations managers in the development of the overall strategic plan

capacity, V14 location of facility, V12 type of capacity, and V11 the timing factor in capacity decision.

The MANOVA results are shown in the table below:

Table 5.7
MANOVA Summary Table (V10)

Source	DF	SS	MS	F value	PR>F
Between AMT Level	2	4.9827	2.4913	2.49	0.0874
Error	108	107.9189	0.9994		

According to the results shown in Table 5.7, there is no significant difference between all levels of AMT and the amount of capacity involved in manufacturing strategy. But there is a significant difference between the first and third level automation for the same item, where PR > F = 0.0230. At the mean time, there is no difference between high and moderate automation, where PR > F = 0.2950. The same result obtained at the level of moderate and low automation, where PR > F = 0.1526, there is no difference. The timing factor in capacity decision V11 shows no significant difference at all levels. The type of capacity V12 shows also no difference at all three levels, where PR > F = 0.1468. Table 5.8 - 5.9 illustrates the results for the facility size and location.

Table 5.8
MANOVA Summary For V13

Source	DF	SS	MS	F value	PR>F
Model	2	11.8016	5.9008	3.98	0.0215
Error	108	160.1083	1.4825		

Table 5.9
MANOVA Summary For V14

Source	DF	SS	MS	F value	PR > F
Model	2	14.6713	7.3357	4.53	0.0128
Error	108	174.6980	1.6157		

Table 5.8 and 5.9 shows significant difference between different levels of automation; where this holds true only for high and low level automation. But between moderate and low automation there is no difference for V14 where PR > F = 0.2060. Also there is no difference between high and moderate automation for both variables. According to Wilks' criterion where F value with (10,208) degree of freedom is equal to 2.38, with PR > F = 0.0109, which it shows significant difference for these factors (capacity and facility) over all the three levels. This leads us to reject the null hypotheses (H4-1 and H4-2).

H4-3 There is no significant difference between different levels of AMT users in manufacturing strategy vertical integration decisions.

This hypothesis is explained by factor four in Table 5.6, and was presented by three items as follows: V28 with factor loading 0.86108, V29 with factor loading 0.83604, and V27 with factor loading 0.82376. The communality of each of these items are 0.778729, 0.740713, and 0.712509.

The multivariate analysis of variance results shows no significant difference among all three levels of advanced manufacturing technology under the predetermined level of significance, which leads us to accept the null hypothesis. Table 5.10 illustrates the result for the vertical integration factor.

Table 5.10
MANOVA Summary for Factor Four

	Source	DF	SS	MS	F value	PR>F
V27	Model	2	1.2813	0.6406	0.43	0.6502
	Error	108	160.0880	1.4822		
V28	Model	2	4.4626	2.2313	1.77	0.1760
	Error	108	136.5102	1.2639		
V29	Model	2	6.0563	3.0281	2.54	0.0838
	Error	108	128.9166	1.1936		

H4-4 There is no significant difference between different levels of advanced manufacturing technology users in manufacturing strategy production planning and control decisions.

H4-5 There is no significance difference between different levels of advanced manufacturing technology users and non-users in manufacturing strategy organization structure decisions.

Hypotheses 4-4 and 4-5 are explained by six items loaded on the second factor. The production planning and material control presented by the following items computerization (V36), centralization (V37), decision rules (V38), organization structure (V39), reporting levels (V40), and organization support groups (V41). The factor loading for these items are shown in Table 5.6.

MANOVA results shows significant difference among the three levels of advanced manufacturing technology. According to Wilks' criterion, the exact F with 12 and 206 degrees of freedom is equal to 3.07 and the PR>F is equal to 0.0005, which lead to reject the null hypotheses (H4-4 and H4-5). Table 5.11 illustrates the result for the production planning and organization structure factor.

Table 5.11
MANOVA Summary for Factor Two

	Source	DF	SS	MS	F value	PR>F
V36	Model	2	6.9921	3.4960	3.10	(0.0491)
	Error	108	121.7826	1.1276		
V37	Model	2	2.4120	1.2060	0.93	0.3974
	Error	108	139.9303	1.2956		
V38	Model	2	6.4529	3.2264	2.64	0.0759
	Error	108	131.9434	1.2216		
V39	Model	2	25.4758	12.7379	12.24	(0.0001)
	Error	108	96.632	0.8947		
V40	Model	2	7.1081	3.5540	3.99	(0.0214)
	Error	108	96.3153	0.8918		
V41	Model	2	4.4154	2.2077	2.22	0.1134
	Error	108	107.3322	0.9938		

Table 5.11 shows significant difference for the following items V36, V39, an V40 with alpha = 0.05.

In order to determine which level of automation shows significant difference, comparison between each two levels were examined separately. The overall result of MANOVA between the first level and third level automation shows significant difference with F(6, 64) = 3.43 with prob>F = 0.0054. Table 5.12 illustrates the results between first and third level automation.

Table 5.12
MANOVA Summary
First and Third Level AMT

	Source	DF	SS	MS	F value	PR>F
V36	Model	1	6.9078	6.9078	5.88	(0.0179)
	Error	69	81.0076	1.1740		
V37	Model	1	0.7629	0.7629	0.58	0.4494
	Error	69	90.9553	1.3181		
V38	Model	1	3.8203	3.8203	3.26	0.0755
	Error	69	80.9684	1.1734		
V39	Model	1	12.6215	12.6215	16.79	(0.0001)
	Error	69	51.8572	0.7515		
V40	Model	1	6.6427	6.6427	7.57	(0.0076)
	Error	69	60.5403	0.8773		
V41	Model	1	3.0793	3.0793	3.11	0.0823
	Error	69	68.3572	0.9906		

As shown in Table 5.12, the same items (V36, V39, V40) show significant difference in Table 5.11. The overall result of MANOVA between the first and second level automation, indicate a significant difference with F(6, 87) = 4.43. At the 0.05 level of significance, the F value with PR>F is 0.0006 which leads us to reject the null hypothesis. Table 5.13 presents all items for the first and second level automation to determine which items significantly differ.

Table 5.13
MANOVA Summary for
First and Second Level AMT

	Source	DF	SS	MS	F value	PR>F
V36	Model	1	1.2411	1.2411	1.22	0.2715
	Error	92	93.3120	1.0142		
V37	Model	1	2.2373	2.2373	1.77	0.1869
	Error	92	116.4009	1.2652		
V38	Model	1	4.6723	4.6723	3.90	(0.0512)
	Error	92	110.1787	1.1975		
V39	Model	1	20.5366	20.5366	25.24	(0.0001)
	Error	92	74.8675	0.8137		
V40	Model	1	2.1584	2.1584	2.79	0.0984
	Error	92	71.2564	0.7745		
V41	Model	1	2.7409	2.7409	3.34	0.0710
	Error	92	75.5675	0.8213		

Only V38 and V39 shows significant difference between the first and second level automation. The last two levels of automation (second and third) shows no significant difference where the exact F statistic based on 6 and 50 degrees of freedom is 1.07. Since the PR>F = 0.397, we are led to accept the null hypothesis for these two levels of automation. Comparing the last three tables, V39 (organization structure) shows significant difference among all levels of automation, first and second level, and first and third level automation. V36 and V40 shows significant difference only between first and third level automation. In the other hand V38 shows significant between first and second level.

Hypothesis Five

H-5 There is no significant performance change between different levels of advanced manufacturing technology users.

Hypothesis Six

H-6 There is no significant difference between different levels of advanced manufacturing technology users in the degree of compatibility between corporate, business, and manufacturing strategies.

Hypotheses five and six are explained by the first factor which include a total of nine items as shown in Table 5.6. The factor loading in all items was very high and positive as shown below. V135 (formal commitment by the business unit to improving manufacturing productivity) = 0.79120; V136 (improving manufacturing productivity, is comprehended by the company's employees, as an organized goal which the company is pursuing) = 0.7876; V137 (improving manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing) = 0.78878; V138 (employee comprehension of the relationship between advanced manufacturing technology and the company's organized goal of manufacturing improvements) = 0.72606; V139 (managerial comprehension of the relationship between advanced manufacturing technology and the company's organized goal of manufacturing improvements) = 0.80816; V140 (employee acceptance of the company's commitment to the goal of productivity improvements) = 0.82058; V141 (managerial acceptance of the company's commitment to the goal of productivity improvement) = 0.85633; V141 (the integration of the manufacturing strategy with the overall company's strategic planning process) = 0.74439; V143 (the marriage of advanced manufacturing technology goals with the overall strategic plan) = 0.78878.

At the 0.05 level of significance, the critical F value, according to Wilks' criterion, is 1.77 and PR>F = 0.0316 which leads us to reject the null hypotheses. Table 5.14 summarizes the MANOVA results for all three levels of automation. Among the seven items which are explained by factor one, V135; V137; V142; and V143 show high significance difference than the rest.

In order to determine which level of advanced manufacturing technology significantly differ, MANOVA was used between every two levels of automation. The MANOVA results shows only, significance difference between first and second level of advanced manufacturing technology.

Table 5.15 shows the MANOVA result for these two levels. At the 0.05 level of significance, the exact F according to Wilks' criterion is 2.43 and PR>F is 0.0166 which leads us to reject the null hypothesis. Since the exact F for the first and third level

Table 5.14
MANOVA Summary
The Compatibility Factor for All Levels of AMT

	Source	DF	SS	MS	F value	PR>F
V135	Model	2	14.1684	7.0842	6.35	(0.0025)
	Error	108	120.5342	1.1160		
V136	Model	2	3.5685	1.7842	1.99	0.1413
	Error	108	96.7017	0.8953		
V137	Model	2	8.9431	4.4715	3.85	(0.0243)
	Error	108	125.4532	1.1616		
V138	Model	2	1.2737	0.6368	0.5	0.6068
	Error	108	137.0686	1.2691		
V139	Model	2	6.5055	3.2527	2.86	0.0617
	Error	108	122.8638	1.1376		
V140	Model	2	5.3622	2.6811	2.54	0.0837
	Error	108	114.0612	1.0561		
V141	Model	2	5.0259	2.5129	2.16	0.1203
	Error	108	125.6767	1.1636		
V142	Model	2	19.2512	9.6256	7.99	(0.0006)
	Error	108	130.1721	1.2052		
V143	Model	2	6.1519	3.0759	3.35	(0.0323)
	Error	108	93.7039	0.8676		

KEY
V135 the company provides an organized, comrehensive understanding of manufacturing productivity improvements
V136 improving manufacturing productivity
V137 the mangerial comprehension for improving productivity
V138 employee understanding of AMT
V139 managerial understanding of AMT goals
V140 employee acceptance of improving productivity
V141 managerial acceptance of the company's commitment to the goal of productivity improvements
V142 the integration of the manufacturing strategy with the overall company's strategic planning process
V143 the company's inclusion of operations managers in the development of the overall strategic plan

Table 5.15
MANOVA Summary
First and Second Level AMT

	Source	DF	SS	MS	F value	PR>F
V135	Model	1	13.9338	13.9338	11.60	(0.0010)
	Error	92	110.5342	1.2014		
V136	Model	1	3.5416	3.5416	3.75	(0.0559)
	Error	92	86.9370	0.9449		
V137	Model	1	8.7645	8.7645	6.92	(0.0100)
	Error	92	116.5120	1.2664		
V138	Model	1	1.1347	1.1347	0.84	0.3628
	Error	92	124.8333	1.3568		
V139	Model	1	6.1780	6.1780	5.22	(0.0247)
	Error	92	108.9814	1.1845		
V140	Model	1	3.9187	3.9187	3.54	0.0630
	Error	92	101.8259	1.1068		
V141	Model	1	5.0241	5.0241	4.06	(0.0469)
	Error	92	113.9120	1.2381		
V142	Model	1	17.6676	17.6676	13.98	(0.0003)
	Error	92	116.2898	1.2640		
V143	Model	1	5.2453	5.2453	5.94	(0.0167)
	Error	92	81.2333	0.8829		

KEY
V135 the company provides an organized, comprehensive understanding of manufacturing productivity improvements
V136 improving manufacturing productivity
V137 the managerial comprehension for improving productivity
V138 employee understanding of AMT
V139 managerial understanding of AMT goals
V140 employee acceptance of improving productivity
V141 managerial acceptance of the company's commitment to the goal of productivity improvements
V142 the integration of the manufacturing strategy with the overall company's strategic planning process
V143 the company's inclusion of operations managers in the development of the overall strategic plan

of AMT is 1.61 and PR>F is 0.1322, and between the second and third level of AMT the exact F is 0.75 and PR>F is 0.6602. Therefore the null hypothesis cannot be rejected.

Comparing the results of MANOVA between Table 5.14 and 5.15, some items show significant differences except V136, V139 and V141 which do not indicate statistical differences.

Discussion of the results obtained in this chapter are explained in more detail in Chapter Six. Concluding remarks, and suggestions for future research will follow in Chapter Seven.

The results obtained from industry analysis for each industry are very much compatible with overall results obtained from all responses. Table 5.16 shows the results of competitive advantage between different levels of advanced manufacturing technology for five industries. The Motor Vehicles & Parts Industry seems to focus on quality as their main concern, then flexibility and finally cost consideration.

Scoring coefficienct estimated by regression and squared multiple correlations of variables with each factor for motor vehicle and parts industry are: 0.99, 0.99 and 1.00. The results of the Motor Vehicle and Parts Industry differ from the results obtained for all responses in this research, where flexibility is considered to be the main factor when competitive advantage of advanced technology is concerned. The Industrial and Farm Equipment Industry pretty much agreed with all responses, where flexibility with scoring coefficient 0.93, quality with scoring coefficient 0.95, and quality with scoring coefficient estimated by regression is 0.89. Computers and Office Equipment Industry differ from all responses where quality scored as the first priority with scoring coefficient 0.94, then cost comes second with scoring coefficient of 0.95, and finally flexibility factor with scoring coefficient 0.97. The Electronic Industry results as indicated in Table 5.16 shows also the quality as their main concern, with scoring coefficient 0.94, the cost consideration in the Electronic Industry comes as second priority with scoring coefficient 0.92, and finally flexibility with scoring coefficient 0.85. The Aerospace Industry appears to be similar to Industrial and Farm Equipment, the flexibility factor comes first with scoring coefficient 0.88, quality with scoring coefficient 0.87, and finally cost with scoring coefficient of 0.79. Discriminant analysis results shows that the number of all responses classified into industry type is presented in Table 5.17.

Manufacturing strategy decision categories classified by industry are shown in Table 5.18, indicate that all industries except Motor Vehicles and Parts and Electronic Industry, consider compatibility among all levels of the organization and advanced manufacturing technology as their first factor. The scoring coefficient estimated by regression for these industries are: Industrial and Farm Equipment 0.98; Computer and Office Equipment

Table 5.16

Major Factors Classified by Industry
Competitive Advantages of AMT

Motor Vehicles & Parts

Items	F1	F2	F3
V123	0.85		
V134	0.85		
V116	0.83		
V124	0.83		
V130	-0.93		
V117	-0.93		
V132		0.98	
V127		0.97	
V125		0.94	
V121		0.91	
V126		0.83	
V122		0.62	
V120		-0.92	
V133			0.93
V129			0.84
V131			0.78
V119			0.72
V118			0.72
V128			0.70
V115			
Var	6.3	5.9	4.9
Squared Multiple Correlations	0.99	0.99	1.00

Industrial and Farm Equipment

Items	F1	F2	F3
V131	0.80		
V134	0.68		
V133	0.64		
V130	0.64		
V121	0.62		
V120	0.60		
V129	0.58		
V119	0.56		
V132	0.52		
V123	0.51		
V117		0.84	
V118		0.87	
V116		0.68	
V115		0.58	
V128		0.57	
V127		0.39	
V125			0.83
V124			0.74
V122			0.70
V126			0.65
Var	4.4	3.7	3.4
Squared Multiple Correlations	0.93	0.95	0.89

Computers Office Equipment

Items	F1	F2	F3
V116	0.81		
V121	0.72		
V119	0.69		
V117	0.66		
V118	0.65		
V123	0.62		
V122	0.56		
V128	0.54		
V126		0.74	
V125		0.72	
V115		0.68	
V127		0.67	
V132		0.63	
V133			0.81
V130			0.79
V134			0.70
V131			0.67
V120			0.56
V129			0.55
V124			0.37
Var	4.3	4.2	3.9
Squared Multiple Correlations	0.94	0.95	0.97

Electronics

Items	F1	F2	F3
V115	0.82		
V116	0.80		
V117	0.79		
V118	0.49		
V133	-0.54		
V131	-0.63		
V129	-0.68		
V130	-0.68		
V126		0.75	
V128		0.74	
V123		0.69	
V127		0.67	
V125		0.64	
V122		0.53	
V120		0.35	
V121			0.77
V119			0.69
V132			0.55
V124			0.53
V134			0.51
Var	4.1	4.0	2.5
Squared Multiple Correlations	0.94	0.92	0.85

Aerospace

Items	F1	F2	F3
V133	0.94		
V129	0.90		
V130	0.84		
V131	0.83		
V132	0.73		
V120	0.64		
V116		0.94	
V117		0.89	
V115		0.82	
V118		0.72	
V119		0.59	
V126		0.57	
V128		0.56	
V127		0.56	
V122		0.46	
V121			0.58
V134			0.57
V124			-0.37
V123			-0.60
V125			-0.49
Var	5.0	4.9	3.8
Squared Multiple Correlations	0.88	0.87	0.79

Scoring coefficient Estimated by Regression
Squared Multiple Correlations of the Variables with each factor

KEY

V115 decrease in product cost
V116 increase in control of entire production process
V117 increase in productivity of production operations
V118 increase in utilization of capital equipment
V119 reduction in engineering design cost
V120 increase in capability of engineers
V121 reduction in engineering change costs
V122 increase in product quality
V123 reduction of work-in-process inventory
V124 reduction in materials/supplies costs
V125 reduction of personnel costs
V126 increase in ability to meet delivery dates
V127 increase in order fill rate
V128 decrease in overall lead time
V129 increase in product mix flexibility
V130 increase in component flexibility
V131 increase in modification flexibility
V132 increase in rerouting flexibility
V133 increase in volume flexibility
V134 increase in material flexibility

Table 5.17
Discriminant Analysis

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO V201:

FROM V201	1	2	3	4	5	TOTAL
1	4	0	0	0	1	5
	80.00	0.00	0.00	0.00	20.00	100.00
2	1	14	2	7	7	31
	3.23	45.16	6.45	22.58	22.58	100.00
3	1	4	13	3	2	23
	4.35	17.39	56.52	13.04	8.70	100.00
4	0	7	6	15	3	31
	0.00	22.58	19.35	48.39	9.68	100.00
5	0	2	3	5	12	22
	0.00	9.09	13.64	22.73	54.55	100.00
TOTAL	6	27	24	30	25	112
PERCENT	5.36	24.11	21.43	26.79	22.32	100.00
PRIORS	0.2000	0.2000	0.2000	0.2000	0.2000	

Key

V 201	type of industry
1	motor vehicles & parts industry
2	industrial and farm equipment industry
3	computers & office equipment industry
4	electronics industry
5	aerospace industry

Table 5.18

Major Factors Classified by Industry
Manufacturing Strategy

Motor Vehicles & Parts

Items	F1	F2	F3	F4
V135	0.93			
V10	0.93			
V11	0.93			
V12	0.93			
V27	0.91			
V28	0.88			
V41	-0.69			
V31	-0.96			
V136		0.94		
V29		0.94		
V138		0.87		
V40		-0.76		
V13		-0.80		
V39		-0.80		
V14		-0.81		
V141			0.96	
V137			0.96	
V140			0.70	
V38			-0.64	
V37			-0.76	
V36				0.87
V143				0.59
V32				0.59
V142				0.00
V139				-0.69
Var	8.82	6.49	4.95	3.49
Squared Multiple Correlation	1.00	0.98	0.93	0.96

Industrial and Farm Equipment

Items	F1	F2	F3	F4
V141	0.89			
V137	0.87			
V135	0.85			
V140	0.84			
V139	0.79			
V11	0.78			
V142	0.77			
V143	0.75			
V138	0.72			
V12	0.70			
V136	0.63			
V10	0.61			
V13	0.54			
V14	0.45			
V36		0.76		
V37		0.74		
V41		0.63		
V39		0.56		
V38		0.54		
V40		0.53		
V28			0.87	
V27			0.76	
V29			0.59	
V32				0.70
V31				0.61
Var	7.88	2.86	2.59	2.23
Squared Multiple Correlation	0.98	0.90	0.92	1.00

Computers Office Equipment

Items	F1	F2	F3	F4
V12	0.86			
V142	0.85			
V136	0.84			
V140	0.82			
V141	0.81			
V138	0.79			
V139	0.77			
V11	0.76			
V38	0.74			
V143	0.73			
V137	0.71			
V135	0.69			
V39	0.63			
V10	0.53			
V37	0.47			
V40	0.46			
V13		0.85		
V14		0.75		
V41		0.68		
V36		0.53		
V28			0.92	
V29			0.83	
V27			0.75	
V31				0.77
V32				0.58
Var	8.93	3.56	2.98	2.18
Squared Multiple Correlation	0.94	0.90	0.84	0.89

Electronics

Items	F1	F2	F3	F4
V39	0.85			
V37	0.81			
V40	0.80			
V41	0.78			
V38	0.76			
V36	0.72			
V139		0.79		
V143		0.76		
V137		0.76		
V135		0.73		
V136		0.68		
V138		0.65		
V142		0.60		
V141		0.59		
V14			0.80	
V10			0.77	
V13			0.74	
V11			0.71	
V12			0.64	
V140			0.56	
V27				0.88
V28				0.83
V29				0.81
V31				0.69
V32				0.53
Var	4.58	4.45	3.95	3.55
Squared Multiple Correlation	0.95	0.94	0.92	0.94

Aerospace

Items	F1	F2	F3	F4
V143	0.91			
V138	0.89			
V140	0.88			
V141	0.83			
V139	0.81			
V136	0.77			
V137	0.73			
V135	0.65			
V142	0.57			
V40		0.89		
V38		0.86		
V37		0.84		
V41		0.81		
V39		0.77		
V36		0.76		
V11			0.84	
V10			0.83	
V13			0.79	
V27			0.71	
V12			0.68	
V14			0.65	
V31				0.77
V32				0.68
V29				0.66
V28				0.58
Var	6.06	4.77	4.07	2.09
Squared Multiple Correlation	1.00	0.96	0.93	0.94

Scoring Coefficient Estimated by Regression
Squared Multiple Correlation of the Variable with each Factor

KEY

- V10 the amount of capacity involved in manufacturing strategy
- V11 the timing of capacity decision
- V12 the type of capacity decision
- V13 the size of facility
- V14 the location of facility
- V27 the direction of vertical integration
- V28 the extent of vertical integration
- V29 the balance of vertical integration
- V31 the workforce skill level requirments
- V32 the workforce security assurance
- V36 computerization of manufacturing planning
- V37 centralization of of production planning and material control
- V38 decision rules
- V39 organization structure
- V40 organization reporting levels
- V41 organization support groups
- V135 the company provides an organized, comprehensive understan-ing of manufacturing productivity improvements
- V136 improving manufacturing productivity
- V137 the mangerial comprehension for improving productivity
- V138 employee understanding of AMT
- V139 managerial understanding of AMT goals
- V140 employee acceptance of improving productivity
- V141 managerial acceptance of the company's commitment to the goal of productivity improvements
- V142 the integration of the manufacturing strategy with the overall company's strategic planning process
- V143 the company's inclusion of operations managers in the development of the overall strategic plan

0.94; Electronic Industry 0.95; and Aerospace Industry 1.00. Due to the low response in the Motor Vehicle Industry, only five responded. I intended to neglect this industry from my conclusion. The Electronics industry consider compatibility as the second priority. The primary factor for the Motor Vehicle Industry is facility and capacity decisions and for the Electronic Industry is production planing and material control. The vertical integration factor in Computers and Office Equipment, Industrial and Farm Equipment loaded in the third factor which differ from all responses, where vertical integration loaded in the fourth factor (see Table 5.6) Aerospace and Electronic Industries agreed with the result obtained early for the vertical integration factor. Discriminant analysis results shows that, the number of all responses classified into industry type is presented in Table 5.19.

This chapter presented the results of statistical analysis for the competitive advantage of advanced manufacturing technology and manufacturing strategy decision categories. Factor analysis were used to explore the main factors explaining the responses obtained from leading American manufacturers.

Although industry analysis were used with the help of factor and discriminant analysis to classify the responses and compare the industries with primary factors obtained from all responses.

The next chapter will be devoted for discussion of these results and concluding remarks and directions for future research.

Table 5.19

NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED INTO V201:

FROM V201	1	2	3	4	5	TOTAL
1	4	0	0	0	1	5
	100.00	0.00	0.00	0.00	0.00	100.00
2	0	16	4	6	5	31
	0.00	51.61	12.90	19.35	16.13	100.00
3	0	4	16	0	3	23
	0.00	17.39	69.57	0.00	13.04	100.00
4	0	1	6	20	4	31
	0.00	3.23	19.35	64.52	12.90	100.00
5	0	2	0	2	18	22
	0.00	9.09	0.00	9.09	81.82	100.00
TOTAL	5	23	26	28	30	112
PERCENT	4.46	20.54	23.21	25.00	26.79	100.00
PRIORS	0.2000	0.2000	0.2000	0.2000	0.2000	

KEY

V 201	type of industry
1	motor vehicles & parts industry
2	industrial and farm equipment industry
3	computers & office equipment industry
4	electronics industry
5	aerospace industry

CHAPTER 6

Discussion of Results

Primary results of this research was obtained through use of a mailed questionnaire addressing manufacturing strategy decision categories and competitive advantages of advanced manufacturing technology, factors thought to influence the decision to adopt advanced manufacturing technology have been studied. One hundred and twelve United States manufacturers in various stages of advanced manufacturing technology participated in this research as primary source business units. These manufacturers vary considerably in the length of time AMT has been in process in their business units and in the extent to which components are integrated. Most of the business units are major divisions of corporations. They produce a variety of products, employ multiple types of production processes in their operations, and vary extensively in the lot sizes they use and in the number of parts they produce per year. The questionnaire and a letter explaining the purpose of the study were mailed to six hundred and nineteen divisions from leading American manufacturers. At the first screening those questionnaires that were incomplete were eliminated. At this stage 112 usable responses, representing a 18 percent response rate, were available for statistical analysis. Most of the companies who did not reply were small and not well known. Therefore, any conclusions made are based mainly on major American manufacturers.

I asked each company surveyed what types of business units they are. Twenty three percent of those who responded were corporations and seventy seven were major divisions of corporations. What is the size by employees? Most of the companies had more than 10,000 employees. For example, one hundred percent of the responses were in the Aerospace Industry and Automative Industry. Eighty two percent of Machine Tool and Farm Equipment responses were 5,001 to 10,000 employees. Eighteen percent of this industry were 501 to 2,000 employees. Electronic Industry responses were seventy two percent for that size and twenty eight percent of the responses were 5,001 to 10,000 employees. The average sales volume for most of the corporations participated in this research were over 500 million. Only five percent of the respondents were from the Motor Vehicle Industry, twenty eight percent were from Machine Tools and Farm Equipment Industry, twenty percent were from the Computer and Calculating Equipment Industry, twenty eight percent were from the Electronics Industry, and nineteen percent of the respondents were from the Aerospace Industry.

The results were not entirely consistent among all industries. Some similarities, however, were found among the industries studied.

Three levels of advanced manufacturing technology are presented in this research with a total of twenty eight items explaining all components of automation. Among the one hundred twelve responses, thirty six percent classified as first level automation, fortynine percent classified as third level automation. Eighty four percent of respondents believe advanced manufacturing technology is a competitive necessity within their industry. Responding to the question of how would you characterize your overall advanced manufacturing technology project to date? The third level automation responses characterized it as successful, first and second level automation characterized as a failure.

The results from the first hypothesis indicate that flexibility consideration in maintaining the competitive advantage between different levels of AMT is not as important as the second level automation. In particular, it seems that product mix flexibility, modification flexibility, and volume flexibility are the most flexible among the second level automation.

However, advanced manufacturing technology seems to have no effect on reduction in product cost, reduction in engineering design cost, and overall lead time.

The results from the third hypothesis suggest that, advanced manufacturing technology for the first and second level automation has not had much of an impact on the quality consideration in maintaining the competitive advantage. The result of the second level automation shows an impact on increasing product quality, defect prevention, and monitoring quality. It seems that the competitive advantage of advanced manufacturing technology has not yet been achieved due to the short time of implementation in most of American manufacturers.

Based on the results from the fourth hypothesis, it seems that, advanced manufacturing technology has made more of a contribution in manufacturing strategy decision categories among all different levels of automation. The first and second level automation indicates more impact on capacity and facility decisions, production planing and control decisions, and organization structure. Although the results support vertical integration decisions between first and third level automation.

In terms of improving productivity and compatibility among corporate, business, and manufacturing strategy, the results suggest that advanced manufacturing technology has a great impact at all different levels of automation.

In terms of improving productivity and compatibility among corporate, business, and manufacturing strategy, the results suggest that advanced manufacturing technology has a great impact at all different levels of automation. The results from fifth and sixth hypotheses indicate that, formal commitment by the business unit to improving manufacturing productivity, employees involvement, managers involvement, employee understanding of advanced manufacturing technology, integration of the manufacturing strategy with the overall company's strategic planning process, and the marriage of advanced manufacturing technology objectives with the overall strategic plan appear to be more effective to second and third level automation.

Effect of advanced manufacturing technology implementation on maintaining the competitive advantages and improving productivity has a positive effect in machine tools and farm equipment industry, computers and calculation equipment industry, and motor vehicle industry. Whereas it has no effect on electronic and aerospace industries.

The Motor Vehicle Industry

The percentage of responses in motor vehicle industry counted for about 62.5% of the total companies in Fortune 500. The sample of data collected from the motor vehicle industry suggest that, to maintain competitive advantage it should focus on the following: component flexibility, capability of engineers to improve quality, product cost, managerial comprehension of the relationship between AMT objectives and the company's goal to improve productivity, inclusion of operations managers in the development of the overall strategic plan, integration of manufacturing strategy with overall strategic planning process.

Machine Tools and Farm Equipment Industry

Industrial and farm equipment responses was very high in the data collected in this research, the total responses was 30 companies which represent 88.2% of the Fortune 500. Unlike the Motor Vehicle Industry, the Machine Tool Industry should focus on the following: product mix and rerouting flexibility, product cost, engineering design cost, and work-in-process inventory, to maintain competitive advantage and improve manufacturing productivity.

Computers and Calculating Equipment Industry

The data collected in that industry covered all companies listed in Fortune 500, more than that, some of the companies have more than one response. The percentage of response in that industry counted for 104%. Based on the results, it seems that manufacturers of computers and calculating equipment place higher weight on maintaining the competitive advantage of advanced manufacturing technology than the other industries. But the following need to be considered to maintain more of the market share in the future: product mix flexibility, focus on product quality, and material supply cost.

Electronic Industry

According to the sample of data collected from electronic industry, which represent 67.4% of the companies listed in Fortune 500, it seems that, this industry is the most troubled among the rest. The results shows no focus at all in the different type of flexibility, utilization of capital equipment, capability of engineers, product quality, and managerial and employee acceptance of the company's commitment to the goal of productivity improvements.

Aerospace Industry

Aerospace industry very well represented in this research, where more than a hundred percent of the companies listed in Fortune 500 responded to the questionnaire. It seems that quality consideration is the great challenge for this industry to survive. This industry is regulated and protected by the government, and the threat to face other industries in terms of foreign competition is missing in the Aerospace Industry.

In order to gain competitive advantage this industry should focus on the following: material flexibility, product quality, ability to meet delivery dates, engineering design cost, work-in-process inventory, material supply cost, and the integration of manufacturing strategy with the overall company's strategic planning process.

The following tables summarize and compare the results for all different industries considered in this research.

LEVEL OF PRIORITY IN MAINTAINING THE COMPETITIVE ADVANTAGE OF AMT
Flexibility Consideration

Industry	Higher Priority	Lower Priority
Motor Vehicle	Product mix flexibility Modification flexibility Rerouting flexibility Volume flexibility Material flexibility	Component flexibility
Machine Tools and Farm Equipment	Component flexibility Modification flexibility Volume flexibility Material flexibility	Product mix flexibility Rerouting flexibility
Computers and Calculating Equipment	Component flexibility Modification flexibility Volume flexibility Material flexibility	Product mix flexibility
Electronic		Product mix flexibility Component flexibility Modification flexibility Rerouting flexibility Volume flexibility Material flexibility
Aerospace	Product mix flexibility Component flexibility Modification flexibility Rerouting flexibility Volume flexibility	Material flexibility

LEVEL OF PRIORITY IN MAINTAINING THE COMPETITIVE ADVANTAGE OF AMT
Quality Consideration

Industry	Higher Priority	Lower Priority
Motor Vehicle	Control of entire production process Utilization of capital equipment Product quality Ability to meet delivery date Increase in order fill rate	Productivity of produc-operations Capability of engineers
Machine Tools and Farm Equipment	Control of entire production Utilization of capital equipment Capability of engineers Product quality Ability to meet delivery date	Increase in order fill rate
Computers and Calculating Equipment	Control of entire production process Productivity of production operations Ability to meet delivery Increase in order fill rate	Capability of engineers Product quality
Aerospace	Control of entire production process Productivity of production Capability of engineers	Product quality Ability to meet delivery dates Order fill rate

LEVEL OF PRIORITY IN MAINTAINING THE COMPETITIVE ADVANTAGE OF AMT
Cost Consideration

Industry	Higher Priority	Lower Priority
Motor Vehicle	Engineering change costs Work-in-process inventory material supplies costs Personnel costs Engineering design cost	Product cost
Machine Tools and Farm Equipment	Engineering change cost Materials supplies costs Personnel costs	Product cost Engineering design cost Work-in-process inventory
Computers and Calculating Equipment	Product cost Engineering design cost Engineering change cost Work-in-process inventory Personnel costs	Material supply cost
Electronic	Product cost Engineering design cost Engineering change cost Work-in-process inventory Personnel costs	Material supply cost
Aerospace	Product cost Engineering change costs	Engineering design cost Work-in-process inventory Materials supplies costs Personnel costs

LEVEL OF PRIORITY
MANUFACTURING STRATEGY DECISION CATEGORY
Productivity and Compatibility Factor

Industry	Higher Priority	Lower Priority
Motor Vehicle	Managerial acceptance of the company's commitment to improve productivity Employee acceptance of the company's commitment to to improve productivity The company provides an organized, comprehensive understanding of manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing Employee comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements Improving manufacturing productivity, is comprehended by the company's employees, as an organized goal which the company is pursuing	Managerial comprehension of the relationship between AMT objectives and the company's goal to improve productivity The company's inclusion of operations managers in the development of the overall strategic plan. The integration of the manufacturing strategy with the overall company's strategic planning process.
Machine Tools and Farm Equipment	Managerial acceptance of the company's commitment to improve productivity Improving manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing The company provides an organized, comprehensive understanding of manufacturing productivity improvements Employee acceptance of the company's commitment to the goal of productivity improvements	

	Managerial comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements
	The company's inclusion of operations managers in the development of overall strategic plan
	The integration of the manufacturing strategy with the overall productivity improvements
	Employee comprehension of the relationship between AMT objectives and the company's employees, as an organized goal which the company is pursuing
Computers and Calculating Equipment	Managerial acceptance of the company's commitment to the goal of productivity improvements
	Employee acceptance of the company's commitment to the goal of productivity improvements
	Managerial comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements
	The company provides an organized, comprehensive understanding of manufacturing productivity improvements
	Improving manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing
	The company's inclusion of operations managers in the development of the overall strategic plan
	The integration of the manufacturing strategy with the overall company's strategic planning process

	Employee comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements Improving manufacturing productivity, is comprehended by the company's employees, as an organized goal which the company is pursuing	
Electronic	Managerial comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements The company provides an organized, comprehensive understanding of manufacturing productivity improvements Improving manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing The company's inclusion of operations managers in the development of the overall strategic plan The integration of the manufacturing strategy with the overall company's strategic planning process Employee comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements Improving manufacturing productivity, is comprehended by the company's employees, as an organized goal which the company is pursuing	Managerial acceptance of the company's commitment to the goal of productivity improvements Employee acceptance of the company's commitment to the goal of productivity improvements
Aerospace	Managerial acceptance of the company's commitment to the goal of productivity improvements	The integration of the manufacturing strategy with the overall company's strategic

Employee acceptance of the company's commitment to the goal of productivity improvements	planning process
Managerial comprehension of the relationship between AMT objectives and the company's organized goal of manufacturing improvements	
The company provides an organized, comprehensive understanding of manufacturing productivity improvements	
Improving manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing	
The company's inclusion of the operations managers in the development of the overall strategic plan	
Employee comprehension of the relationship between AMT and the company's organized goal of manufacturing improvements	
Improving manufacturing productivity, is comprehended by the company's employees, as an organized goal which the company is pursuing	

LEVEL OF PRIORITY
MANUFACTURING STRATEGY DECISION CATEGORY
Production Planning/Material Control and
Organization Structure

Industry	Higher Priority	Lower Priority
Motor Vehicle	Workforce security	Organization structure Decision rules Support groups Centralization Reporting levels Computerization Workforce skills level
Machine Tools and Farm Equipment	Support groups Centralization Computerization Workforce skills level Workforce security	Organization structure Decision rules Reporting levels
Computers and Calculating Equipment	Organization structure Decision rules Support groups Workforce skills level	Centralization Reporting levels Computerization Workforce security
Electronic	Organization structure Decision rules Support groups Centralization Reporting level Computerization Workforce skills level	Workforce security
Aerospace	Organization structure Decision rules Support groups Centralization Reporting levels Computerization Workforce skills level Workforce security	

LEVEL OF PRIORITY
MANUFACTURING STRATEGY DECISION CATEGORY
Capacity and Facility Decisions

Industry	Higher Priority	Lower Priority
Motor Vehicle	Amount of capacity Timing of capacity Type of capacity	Size of facility Facility location
Machine Tools and Farm Equipment	Amount of capacity Type of capacity Timing of capacity	Size of facility Location of facility
Computers and Calculating Equipment	Size of facility Location of facility Type of capacity Timing of capacity	Amount of capacity
Electronic	Size of facility Amount of capacity Location of facility Type of capacity Timing of capacity	
Aerospace	Size of facility Amount of capacity Location of facility Type of capacity Timing of capacity	

LEVEL OF PRIORITY
MANUFACTURING STRATEGY DECISION CATEGORY
Vertical Integration

Industry	Higher Priority	Lower Priority
Motor Vehicle	Extent of vertical integration Balance of vertical integration Direction of vertical integration	
Machine Tools	Extent of vertical integration Direction of vertical integration	Balance of vertical integration
Computer and Calculating Equipment	Extent of vertical integration Balance of vertical integration Direction of vertical integration	
Electronic	Extent of vertical integration Balance of vertical integration Direction of vertical integration	
Aerospace	Balance of vertical integration Direction of vertical integration	Extent of vertical integration

CHAPTER 7

Conclusions

Contributions and Limitation of Study

In this study, the results are largely based on the responses from major American manufacturers, therefore, they may prove to be instructive to other companies within the same industry. However, most of the companies who responded were large firms. Small firms showed no interest due to lack of the resources to cooperate in any academic research.

The general consensus seems to be that improving manufacturing productivity as perceived by the company's employees and managers, and the integration of the manufacturing strategy with the overall company's strategic planning process are very important elements for successful implementation of advanced manufacturing technology. In addition, managerial and employee comprehension, at all levels in the organization, and the relationship between advanced manufacturing technology objectives and the company's organized goal of manufacturing improvement are very important factors for successful implementation of AMT. The contribution of this study may fall into two categories, the specific and the general.

At the specific level, this research draws attention to the importance of studying the role of advanced manufacturing technology, compatibility, flexibility, quality, and cost to manufacturing strategy research and practice. Further, the proposed diagnostic framework of strategic importance of advanced manufacturing technology to maintain the competitive advantages a non-financial methods to justify automation, were most of manufacturing technology to maintain the competitive advantages as non-financial ways to justify automation.

At the general level, this study contributes to the development of a manufacturing strategic theory by adding to the existing body of literature on the subject. In addition to that, this study to the very best of my knowledge, it takes an important step in the direction of the empirical development of such a theory.

Finally, the integration of literature from several related fields and organization of data base for five different industries and categorization of new technology and concepts, relevant to the study of manufacturing strategy sets new directions for more future research.

The following guidelines can be important to justify future use of advanced manufacturing technology:

- An understanding by all levels in the organization that advanced manufacturing technology is necessary to each independent functional area as well as to the company as a whole;

- Top management support, managerial and employee competence with advanced manufacturing technology.

- Previous experience with different levels of advanced manufacturing technology.

- Corporate strategic analysis determining what level of automation is needed and the availability of employees with advanced manufacturing skills in the workforce.

- Oversight groups composed of executives directing the advanced manufacturing technology effort as it relates to the entire business strategy.

The response rate was very high compared to many empirical studies in the area of manufacturing strategy, but this study was limited by the five chosen industries, although the sample size were low in Motor Vehicle Industry. The main reason for the low response rate was due to the length of the questionnaire. Apart from that, there were some similarities between the industries results, but no general conclusions can be drawn about American industry as a whole.

Suggestions for Future Research

Similar studies utilizing the proposed framework can be made based upon the input from different industries other than those I have selected in this research.

The same framework and same methodology can be utilized in the services sector where it has been neglected. The human side of automation is a very important issue, which I have not considered in this research, but the data collected has some items related to this issue. Some of the related questions are: Is the use of advanced manufacturing technology an inevitability? Is it technologically imperative? Must such use lead to downsizing?

Advanced automation has irrevocably changed the face and nature of work, yet the adjustment of the American worker has not been easy or quick. While there are those who feel utterly victimized by such change, there are those who feel that without it, whole industries - including the job opportunities they may offer - would be lost to competition.

Adler (1988), Ebel (1986) and Ranson (1986) have examined the impact of advanced automation on the worker. Among their findings were:

1. The obvious impact of unemployment. surveys have found that second generation robots, for instance, can eliminate two to seven production jobs per application (Ebel, 1986).

2. Since under an advanced integrated technological system, a single error can multiply and affect other areas of operations, errors have become more costly and time consuming.

3. As automation pushes workers out of fabrication and into peripheral interface functions, certain abstraction of tasks and of goals are created. Intellectual mastery, therefore, becomes a key performance factor. Manual labor becomes more mental and workers must become aware and learn to deal with any abnormalities, irregularities or malfunctions. Thus, higher skills are required.

4. Through advanced automation workers lose their autonomy and become members of an integrated system, where they must rely on one another for success.

Obviously, while some of these consequences show a cost-cutting impact, others show the opposite effect. When such opposite effect is present, it is usually not limited to financial consequences (Elsayed et al. 1990).

The area of quality management and advanced manufacturing technology is another direction for empirical development. Some of the following factors should be considered:

A - Total Quality Control: which may include the following items:

1. Meeting customer requirements
2. Quality operations organization
3. Quality control in terms of
    - product inspection
    - employee suggestions and awards programs
    - quality circles and quality action teams
    - employee drug testing
4. Quality assurance in terms of the following:
    - design assurance
    - quality assurance
    - procured material

B - Total Preventative Maintenance: which may include the following:

1. Problem resolution in terms of:

- immediate resolution of obstacles
- reduce and eliminate recurring problem causes
- striving for continuous improvement

C - Total People Involvement

1. Responsibility of every individual in the organization
2. Individual awareness and team solving atmosphere
3. Successes, failure and communications

One last observation I would like to mention is the need for studying the interorganizational conflict arisen when the decision to adopt such manufacturing technology occur and how such conflict effect the justification of advanced manufacturing technology.

Concluding Remarks

This dissertation covered many related factors of advanced manufacturing technology and its relationship to manufacturing strategy. Significant additional research is required before AMT can be adopted on a more widespread basis. The strategic justification through the competitive priorities of AMT is a very important factor before the implementation phase. Compatibility among all levels of the organization is a very important ingredient for maintaining the competitive advantages of AMT. The responses gathered in this research are considered to be very large compared to many other studies related to the manufacturing sector, which the results obtained can be generalized as a guideline for the manufacturer pursuing AMT. According to the results of this research, the United States manufacturing sector is not healthy. Competition for manufactured goods is now global, and U.S. manufacturers have been slow to adopt the advanced manufacturing technology that is the basis of competition in many industries. Most manufacturers who already adopted AMT have not achieved the competitive advantages from it. The lack of knowledge and understanding of executive management to the objectives of AMT, is a very important issue to focus in education in order to achieve high performance in the future.

APPENDIX I

1. Cover Letter
2. Follow up Letter
3. The Questionnaire

HOFSTRA UNIVERSITY HEMPSTEAD NEW YORK 11550

Prof. Sayed M. Elsayed
Department of Management
203 Davison Hall
Hofstra University
Hempstead, New York 11550
516-560-5729

January 3, 1990

Dear ,

By completing the following questionnaire, you will be providing important input to a doctoral research project which I am conducting at the City University of New York - Baruch College.

The purpose of the study is to investigate the relationship and degree of compatibility between corporate, business and manufacturing strategy in advanced manufacturing technology industries.

Your responses are to be mailed directly to my office in the envelope provided. The identities of participating firms and divisions will be reported in coded form only. This information is exclusive to the researcher.

A summary of the results will be available at your request upon completion of this project.

Sincerely,

Elsayed M. Elsayed
Department of Management

SME:lac
Enclosure

HOFSTRA UNIVERSITY HEMPSTEAD, NEW YORK 11550

Prof. Sayed M. Elsayed
Department of Management
203 Davison Hall
Hofstra University
Hempstead, New York 11550
516-560-5729

Dear

A few weeks ago, I mailed you a questionnaire regarding Manufacturing Strategy for Advanced Manufacturing Technology. If you have already returned the questionnaire, please accept my "thanks" for your valuable help.

If you have not had a chance to do it as yet, may I ask you to return the completed questionnaire now? Your opinions are most important to me.

Thank you for your cooperation.

Sincerely,

Sayed M. Elsayed
Dept. of Management

SME:lac

QUESTIONNAIRE
MANUFACTURING STRATEGY
FOR
ADVANCED MANUFACTURING TECHNOLOGY
(AMT)

The anonymity of your responses will be protected through the synthesis of all companies participating in this research

May the name of your company appear in any publication which is based on the informati n collected through this questionnaire?

Yes _____ No _____

Your company name ______________________________
Please sign below ______________________________

RESPONDENT DATA

1. Your name: ______________________________
2. Your telephone number: ___________________
3. Your title: ______________________________
4. Brief description of your responsibilities: ______________
   ____
   ____
5. Length of time in this job:
   ________ years and/or _________ months
6. Are you willing to receive telephones questions from me concerning clarification and/or expansion of responses to this questionnaire?
   _____ Yes
   _____ No

Manufacturing Strategy Decision Categories
To what extent are the following Decision categories
involved in manufacturing strategy for this business unit?

	Is not Directly Involved				Is Extensively Involved
1. Capacity					
Amount	1 ___	2 ___	3 ___	4 ___	5 ___
Timing	1 ___	2 ___	3 ___	4 ___	5 ___
Type	1 ___	2 ___	3 ___	4 ___	5 ___
2. Facilities					
Size	1 ___	2 ___	3 ___	4 ___	5 ___
Location	1 ___	2 ___	3 ___	4 ___	5 ___
Focus	1 ___	2 ___	3 ___	4 ___	5 ___
3. Technology					
Equipment	1 ___	2 ___	3 ___	4 ___	5 ___
Automation	1 ___	2 ___	3 ___	4 ___	5 ___
Connectedness	1 ___	2 ___	3 ___	4 ___	5 ___
4. Vertical Integration					
Direction	1 ___	2 ___	3 ___	4 ___	5 ___
Extent	1 ___	2 ___	3 ___	4 ___	5 ___
Balance	1 ___	2 ___	3 ___	4 ___	5 ___
5. Workforce					
Skill Level	1 ___	2 ___	3 ___	4 ___	5 ___
Pay	1 ___	2 ___	3 ___	4 ___	5 ___
Security	1 ___	2 ___	3 ___	4 ___	5 ___
6. Quality					
Defect Prevention	1 ___	2 ___	3 ___	4 ___	5 ___
Monitoring	1 ___	2 ___	3 ___	4 ___	5 ___
Intervention	1 ___	2 ___	3 ___	4 ___	5 ___

7. Production Planning/

Material Control

Computerization	1 ___	2 ___	3 ___	4 ___	5 ___
Centralization	1 ___	2 ___	3 ___	4 ___	5 ___
Decision Rules	1 ___	2 ___	3 ___	4 ___	5 ___

8. Organization

Structure	1 ___	2 ___	3 ___	4 ___	5 ___
Reporting Levels	1 ___	2 ___	3 ___	4 ___	5 ___
Support Groups	1 ___	2 ___	3 ___	4 ___	5 ___

Advanced Manufacturing Technology

Indicate current operational and future use of each of the following AMT components. For each item, check the column which applies.

	(1) No plans for use	(2) Use in 3 years or more	(3) Use within 1-3 years	(4) Current Use
1. Manufacturing Resource Planning (MRP)	1	2	3	4
2. Computer Aided Design (CAD) for design	1	2	3	4
3. Computer Aided Design, for analysis	1	2	3	4
4. Computer Aided Design, for drafting	1	2	3	4
5. Computer Aided Process Planning (CAPP)	1	2	3	4
6. Computer Integrated Manufacturing (CIM)	1	2	3	4
7. Group Technology, for cellular manufacturing	1	2	3	4
8. Group Technology, for support of CAD	1	2	3	4
9. Group Technology, for support of CAPP	1	2	3	4
10. Group Technology, for support of materials functions	1	2	3	4
11. Numerical control (NC)	1	2	3	4
12. Direct numerical control (DNC)	1	2	3	4
13. Direct numerical control (CNC)	1	2	3	4
14. Flexible manufacturing Systems (FMS)	1	2	3	4
15. Process monitoring equipment	1	2	3	4
16. Process control equipment	1	2	3	4
17. Automated storage/ automated retrieval system (AS/AR)	1	2	3	4

	(1) No plans for use	(2) Use in 3 years or more	(3) Use within 1-3 years	(4) Current Use
18. Automated guided vehicle system (AGVS)	1	2	3	4
19. Automated material	1	2	3	4
20. Automated testing	1	2	3	4
21. Automated inspection equipment	1	2	3	4
22. Automated assembly equipment	1	2	3	4
23. Robotics	1	2	3	4
24. Automated data entry (bar code, CCR, voice recognition, etc.)	1	2	3	4
25. Shop floor control	1	2	3	4
26. Shop floor data collection	1	2	3	4
27. Manufacturing simulation system	1	2	3	4
28. Manufacturing optimization system	1	2	3	4
29. Distribution requirements planning (DRP)	1	2	3	4

THE IMPACT OF ADVANCED MANUFACTURING TECHNOLOGIES
(AMT)
Evaluating Advanced Manufacturing Technologies

Do you believe AMT is currently a competitive necessity within the primary industry of this business unit?

____ Yes

____ No

If no, do you believe AMT will be a competitive necessity within the primary industry of this business unit within the next five years?

____ Yes

____ No

To what extent have you evaluated the operational portions of your AMT? Circle the rating which applies.

1	2	3	4	5
Limited informal evaluation				Comprehensive formal evaluation

How would you characterize your overall AMT project to date? Circle the rating which applies.

1	2	3	4	5
A failure				Very successful

Indicate the way in which the AMT has caused changes in the following areas. For each item, circle the rating which applies.

	Significant negative change		No change	Significant positive change	
1. individual jobs	1	2	3	4	5
2. formal procedures	1	2	3	4	5
3. managerial responsibilities	1	2	3	4	5
4. other systems	1	2	3	4	5
5. interdepartmental relationships	1	2	3	4	5

6.	organizational structures	1	2	3	4	5
7.	power structures	1	2	3	4	5
8.	decision processes	1	2	3	4	5
9.	performance evaluations	1	2	3	4	5
10.	reward/incentive structure	1	2	3	4	5

Indicate the degree to which the newly installed AMT has affected any of the following:

	strong negative effect (1)	modest negative effect (2)	No effect (3)	modest positive effect (4)	strong positive effect (5)
1. decrease in product cost	--	--	--	--	--
2. increase in control of entire production process	--	--	--	--	--
3. increase in productivity of production operations	--	--	--	--	--
4. increase in productivity (utilization) of capital equipment	--	--	--	--	--
5. reduction in engineering design cost	--	--	--	--	--
6. increase in capability of engineers	--	--	--	--	--
7. reduction in engineering change costs	--	--	--	--	--
8. increase in product quality	--	--	--	--	--
9. reduction of work-in-process inventory	--	--	--	--	--
10. reduction in materials/ supplies costs	--	--	--	--	--
11. reduction of personnel costs	--	--	--	--	--

	strong negative effect (1)	modest negative effect (2)	No effect (3)	modest positive effect (4)	strong positive effect (5)
12. increase in ability to meet delivery dates	--	--	--	--	--
13. increase in order fill rate	--	--	--	--	--
14. decrease in overall lead time (development to market)	--	--	--	--	--
15. increase in product mix flexibility (simultaneous production of different products0	--	--	--	--	--
16. increase in component flexibility (capability to substitute new components)	--	--	--	--	--
17. increase in modification flexibility (incorporation of component design changes)	--	--	--	--	--
18. increase in rerouting flexibility (ability to change operation machine sequence)	--	--	--	--	--
19. increase in volume flexibility (ability to change operation, machine sequence)	--	--	--	--	--
20. increase in material flexibility (ability to handle variability in raw materials input)	--	--	--	--	--

For each of the following statements listed below, would you please indicate the degree of your agreement or disagreement. Use the following scale to circle the rating which applies.

Strongly Disagree	Mildly Disagree	No Opinion	Mildly Agree	Strongly Agree
1	2	3	4	5

1. The company provides an organized, comprehensive understanding of manufacturing productivity improvements.	1	2	3	4	5
2. Improving manufacturing productivity, is comprehended by the company's employees, as an organized goal which the company is pursuing.	1	2	3	4	5
3. Improving manufacturing productivity, is comprehended by the company's managers, as an organized goal which the company is pursuing.	1	2	3	4	5
4. Employee comprehension of the relationship between AMT and the company's organized goal of manufacturing improvements.	1	2	3	4	5
5. Managerial comprehension of the relationship between AMT and the company's organized goal of manufacturing improvements.	1	2	3	4	5
6. Employee acceptance of the company's commitment to the goal of productivity improvements.	1	2	3	4	5
7. Managerial acceptance of the company's commitment to the goal of productivity improvements.	1	2	3	4	5
8. The integration of the manufacturing strategy with the overall company's strategic planning process.	1	2	3	4	5
9. The company's inclusion of operations managers (engineering, manufacturing, materials, etc.) in the development of the overall strategic plan.	1	2	3	4	5
10. The marriage of AMT goals with the overall strategic plan.	1	2	3	4	5
11. Comprehension, and a working knowledge, of AMT by the most executive members of the company.	1	2	3	4	5
12. An understanding by middle management that AMT is necessary to each independent functional area as well as to the company as a whole.	1	2	3	4	5
13. Top management support (comprehension of, direct involvement in, and budgetary resolve) towards the full implementation of AMT.	1	2	3	4	5

14. A chain of command that is charged with the completion of tasks throughout each independent area of the company. This independent chain of command is followed by a hierarchical organization that reports to the executives.	1	2	3	4	5
15. The implementation of incentive programs, such as evaluations and compensation types, which focus business goals on the long run.	1	2	3	4	5
16. Organizational understanding of AMT at all levels of the company.	1	2	3	4	5
17. Human resource involvement, as it relates AMT skills training of the company's employees.	1	2	3	4	5
18. An organized goal oriented plan for specific AMT training/retraining of employees.	1	2	3	4	5
19. A formal policy of change to accommodate new technological advancement.	1	2	3	4	5
20. Managerial competence with computers.	1	2	3	4	5
21. Employee competence with computers.	1	2	3	4	5
22. A long term familiarization with computers in the company's business environment.	1	2	3	4	5
23. Previous interaction within the company of shared data bases.	1	2	3	4	5
24. Previous experience with computer applications.	1	2	3	4	5
25. Previous experience with closed loop control concepts.	1	2	3	4	5
26. Previous experience with components involved in the actual production processes (i.e. numerically controlled machines).	1	2	3	4	5
27. Availability of employees with AMT skills in the work force.	1	2	3	4	5
28. A process that determines what specific AMT components are needed by the company.	1	2	3	4	5
29. Corporate communication between branches as part of a needs analysis determining what type of AMT equipment is needed.	1	2	3	4	5
30. Corporate strategic analysis determining what type of AMT equipment is needed.	1	2	3	4	5

31. The development of an AMT design for the company to determine what type of equipment is needed.	1	2	3	4	5
32. The design should include target dates, budgets and other incentive packages.	1	2	3	4	5
33. Project and Operations Management techniques are employed to track target dates.	1	2	3	4	5
34. Project and Operations Management techniques are employed to tracks costs.	1	2	3	4	5
35. The employment of a project manager for AMT implementation.	1	2	3	4	5
36. The AMT project manager directly reports to the highest executive of the company.	1	2	3	4	5
37. A formal of informal team, derived from all aspects of the company, which implements AMT.	1	2	3	4	5
38. The long term employment of special participants from the implementation team.	1	2	3	4	5
39. Oversight groups composed of executives directing the AMT effort as it relates to the entire business strategy.	1	2	3	4	5
40. Include employees who will use the AMT components in the implementation effort.	1	2	3	4	5
41. Staff composed of engineers on hand to assist all employees.	1	2	3	4	5
42. AMT subsystems which will be compatible at selected versus the "island" of technology approach.	1	2	3	4	5
43. Specific components of the AMT system are prioritized over other components.	1	2	3	4	5
44. Manufacturing knowledge by the information systems personal who will participate in the implementation and integration of AMT subsystems.	1	2	3	4	5
45. Manufacturing knowledge and computer skills by employees who will participate in the implementation and integration of AMT subsystems.	1	2	3	4	5
46. Direct involvement by middle management in the implementation of AMT subsystems.	1	2	3	4	5
47. Employee involvement in the design of individual AMT subsystems.	1	2	3	4	5

48. Employee involvement in the selection of specific AMT components.	1	2	3	4	5
49. Employee involvement in a process which determines what specific AMT subsystems are installed.	1	2	3	4	5
50. Employee involvement in the implementation of installed subsystems.	1	2	3	4	5
51. A continuous evaluation after the installation and implementation of the AMT system.	1	2	3	4	5
52. Employee involvement in the evaluation process of individual AMT subsystems.	1	2	3	4	5

APPENDIX II

GLOSSARY

AUTOMATED GUIDE VEHICLE SYSTEM (AGVS):

An automated guide vehicle system is a material handling system that uses independent operated, self propelled vehicles that are guided along defined pathways on the floor. The vehicles are powered by means of on-board batteries that allow operation for several hours between recharges. The definition of the pathways is generally accomplished using wires embedded in the floor or reflective paint on the floor surface. Guidance is achieved by sensors on the vehicle that can follow the guide wires or paint.

There are a number of different types of AGUS all of which operate according to the preceding description:

1. **Driverless Trains** - This types consists of a towing vehicle (which is the AGV) that pulls one or more trailers to form a train. this was the first type of AGVS to be introduced and is still popular. It is useful in applications where heavy payloads must be moved large distances in warehouses or factories.

2. **AGVS pallet trucks** - Automated guided pallet trucks are used to move palletized loads along predetermined routes. In the typical application the vehicle is backed into the loaded pallet by human workers who steer the truck and use the forks to elevate the load slightly. Then the worker drives the pallet truck to the guidepath, programs its destination, and the vehicle proceeds automatically to the destination for unloading.

3. **AGVS unit load carriers** - This type of AGVS is used to move unit loads from one station to another station. They are often equipped for automatic loading and unloading by means of powered rollers, moving belts, mechanized lift platforms, or other devices. Variations of the unit load carrier include light load AGVSs and assembly line AGVs. Light loaded guided vehicle are designed to move small loads through plants of limited size engaged in light manufacturing. The assembly line AGVS is designed to carry a partially completed subassembly through a sequence of assembly workstations to build the product.

Automated guide vehicle are used in a growing number of applications. The applications tend to follow the type of vehicle named above, and have been divided into the following four categories:

1. Driverless Train operations
2. Storage/distribution systems
3. Assembly-line operations
4. Flexible Manufacturing systems

AUTOMATED STORAGE/RETRIEVAL SYSTEMS(AS/RS)

A automated storage and retrieval system handles, stores, and retrieves materials with precision, accuracy, and speed under a defined degree of automation. AS/RS consists of a series of storage aisles that are serviced by one or more storage retrieval machines, usually one S/R machine per aisle.
The aisles have storage racks for holding materials to be stored. The S/R machines are used to deliver materials to the storage racks and to retrieve material from the racks. The AS/RS has one or more input/output stations where materials are delivered for entry into storage and where materials are picked up from the system. The input/output stations are often referred to as pickup-and-deposit stations in the terminology of AS/R systems. Several important categories of the automated storage/retrieval system can be distinguished:

Unit load AS/RS- This is typically a large automated system designed to handle unit loads stored on pallets or other standard containers. The system is computer-controled and the S/R machines are automated and designed to handle the unit load containers. A unit load AS/RS is the fundamental building block of all AS/RS systems all other types are variations.

All automated storage/retrieval systems consist of certain basic elements. These components are:

1. Storage structure
2. Storage/retrieval (S/R) machine
3. Storage modules (e.g., pallets for unit loads)
4. Pickup-and deposit stations

The storage structure is the fabricated steel framework that supports the loads contained in the AS/RS. The structure must be designed to accept and hold the storage modules used to contain the stored materials.

The S/R machine is used to accomplish a storage transaction, delivering loads from the input station into storage, or retrieving loads from storage and delivering them to the output station. To perform these transaction the storage retrieval system must be capable of multi-dimensional movements.

The storage modules are the containers of the stored materials. Examples of storage modules include pallets, baskets, and special draws. These modules slide into the storage structure.

The pickup-and-deposit stations (P&D) are used to transfer loads to and from the AS/RS. They are generally located at the end of the aisles for access by the S/R machine and the external handling system that brings loads and takes loads away.

AUTOMATED ASSEMBLY EQUIPMENT (ASE):

The term automated assembly refers to the use of mechanized and automated devices to perform the various function in an assembly line or cell. This assembly line purpose is to produce a certain quantity of products. There a three types of production that automated assembly equipment is associated with:

1. Job Shop Production: (low volume)
2. Batch Production: (Medium volume of same product)
3. Mass Production: (Specialized manufacturing of identical products)

Much progress has been made in the technology of assembly automation in recent years. Some of this progress has been motivated by advances in the field of robotics. Assembly is a growing areas for industrial robots, which is a traditionally labor intensive activity in industry. Because of its economic important, automated methods have been applied to assembly operations.

The most appealing area for the application of industrial robots for assembly is in the production mixture of similar products or models in the same workcell or assembly line. The robot is useful in this application because of its ability to execute programmed variations in the work cycle to accommodate different assembly configurations. One example of this is the "Adaptable-Programable Assembly Station" (APAS).[1]

APAS involves the design of a flexible automated line for assembly of small electric motors. The APAS Project demonstrated the technological feasibility of the concept of flexible automated assembly. The importance of product design was also brought forward. Finally another lesson learned was that inspection of the product must be done periodically during assembly to ensure that components have been properly fastened.

AUTOMATED INSPECTION EQUIPMENT (AIE):

New approaches to the quality control function are emergin that are drastically altering the way inspection and testing are performed. These new approaches are based on advanced sensor technology often combined with computer based systems to interpret the sensor signal...Automated inspection is defined as the automation of one or more inspection steps. The full potential of automated inspection is best achieved when it is integrated into the manufacturing process with 100% inspection.

When Statistical Quality Control (SQC) inspection and testing are carried out manually, the sample size is often small compared to the size of the population. In principle the only way to achieve 100% good quality is to have 100% inspection. Theoretically only good parts will be allowed to pass through the inspection procedure. However when 100% manual inspection occurs expense increase prohibitively and inspectors become wary. Automated inspection offers an opportunity to overcome those two problems.

Modern automated inspection procedures are typically carried out by sensors that are controlled by and/or communicate to digital computers.

There are a variety of sensor technology available for automated inspection. Two broad categories are:

1. Contact Inspection methods
2. Noncontact inspection methods

Contact Inspection involves the use of a mechanically controlled probe or other device that makes contact with the object being inspected. The purpose of the probe is to measure or gage in some way. these methods are usually concerned with the physical dimensions of the part.

Noncontact inspection does not involve direct contact with the product. Instead a sensor located at a certain distance form the object to measure o gage the desired features. The potential advantages offered by noncontact inspection include lower inspection times and avoidance of damage to the part that might occur from contacting it.

There are numerous sensor technologies used in noncontact inspection. They can be classified as optical or nonoptical. Prominent among the optical inspection technologies is machine vision. Nonoptical techniques include electrical field techniques, radiation and ultrasonics.[2]

AUTOMATED MATERIAL TRACKING (AMT):

Identification systems play a fundamental role in the material handling function of manufacturing. The collection of data is mostly sensor based methods that provide a means of reading data that are coded on a product without the need for human interpretation. The technologies available for this use are: Bar Codes, Magnetic stripe, Optical Character Recognition. The material tracking function of identification systems involve optimizing accurate inventory status and routing of material from one location to another.

AUTOMATED TESTING EQUIPMENT (ATE):

Testing and inspection are similar in this instance, although there is one difference. Inspection is used to assess the quality of the product relative to the design specifications testing is a term in quality control that is generally used relative to the functional aspects of the product. Implicit in the automation aspect of this equipment is the electric and mechanic components of the equipment.

CAPACITY REQUIREMENTS PLANNING (CRP):

Capacity planning is concerned with determining what labor and equipment capacity is required to meet the current master production schedule as well as long term future production needs of the firm. Capacity planning also serves to identify the limitations of the production resources so that an unrealistic master schedule is not planned. A master schedule defines the production plan of the firm in terms of products, how many and when.

COMPUTER AIDED MANUFACTURING (CAD):

Computer - aided manufacturing is defied as the effective use of computer technology in the planning, management and control of the manufacturing function. CAM applications for manufacturing planning are those in which the computer is used indirectly to support the production function, but there is no direct connection between the computer and the process. The second category of CAM is concerned with developing computer systems for the implementation of the manufacturing control function. Manufacturing control is concerned with managing and controlling the physical operations in the factory.

COMPUTER AIDED PROCESS PLANNING CAPP):

Computer aided process planing represents the link between design and manufacturing an a CAD/CAM system. Process planning is concerned with determining the sequence of processing and assembly operations that must be accomplished to make a product. CAP is designed around two approaches:

1. Retrieval CAPP systems

2. Generative CAPP systems

Retrieval CAPP systems are based around the principles of group technology and parts classification. Generative CAPP on the other hand is an alternative approach to automated process planning. Instead of retrieving and editing; the computer creates the process plan using logical procedures a human planner would.

COMPUTER INTEGRATED MANUFACTURING (CIM):

The ideal CIM system applies computer technology to all operations functions and information processing functions in manufacturing from placing the order to designing the specifications through the actual manufacturing process. The CIM concept is that a firms operation related to the production function incorporate in an integrated computer system to assist and automate the operations.

COMPUTER NUMERICAL CONTROL (CNC):

Computer numerical control is an NC system using a dedicated microcomputer as a machine control unit. CNC has several benefits over its predecessors:

Storage of more than one part program

Use of diskettes

Program editing at the machine tool site

Compared to conventional NC machine; CNC offers greater flexibility and computational capability.

DIRECT NUMERICAL CONTROL (DNC):

Direct Numerical Control can be defined as a nanufacturing system in which a number of machines are controlled by a computer through direct connections. The part program is transmitted to the machine tool directly from computer memory. In principle one computer can be used to control over 1000 machines.

DISTRIBUTION REQUIREMENTS PLANNING (DRP):

An inventory scheduling and requirements planning system which calculates flow times for each product through the line; such that the end product reaches the distribution centers rather than the end of the assembly line. This system includes transportation times in its calculations.

FLEXIBLE MANUFACTURING SYSTEM (FMS):

A flexible manufacturing system consist of a group of processing stations interconnected by means of an automated material handling and storage system, and controlled by an integrated computer system. what gives FMS its name is that it is capable of processing a variety of different part simulations under NC program control at the various workstation.

GROUP TECHNOLOGY (GT):

Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design. Similar parts are arranged into families. Each family would possess similar designs and manufacturing characteristics. Part similarities are of types: design attributes and manufacturing attributes, in other words the geometry of shape and the sequence of processing steps respectively.

IMPLEMENTATION:

The process of taking sounds theory and putting into practice. In this specific case a computer system is placed into a business environment and accessed by a user. This user than interfaces with the system, inputs or outputs data accordingly and operates ore efficiently in the process.

INSTALLATION:

The physical installation of the computer system in the actual business environment. After the placement of the system; it is tested accordingly and the system is then implemented accordingly.

MANUFACTURING RESOURCE PLANNING (MRP):

Manufacturing resource planning is a computational technique that converts the master schedule for end products into a detailed schedule for the raw materials and components used in the end products. The detailed schedule identifies the quantities of each raw material and component item. It also indicates when each item must be ordered and delivered so as to meet the master schedule for production.

A "closed loop" MRP system incorporates actual resource capacity and production status at any time. If this system is integrated with the financial databases of the business a inclusive system known as MRP II is developed.

MANUFACTURING OPTIMIZATION SYSTEMS (MOS):

Computer oriented algorithims which determine the "best" decision under certain conditions or constrains. The manufacturing model is specified under a general usually simplified system where certain variables can be manipulated to achieve an optimal decision. Specific examples in the manufacturing realm of optimization include Line Balancing, Inventory Control, and Facility Layout.

MANUFACTURING SIMULATION SYSTEMS (MSS):

A computational oriented approach to model a manufacturing system usually to develop an optimized approach to some variable. These simulation of variables are usually a function of time. Simulations are usually performed as an alternative to the actual behavior. This occurs because of the finality involved in real systems or prohibitive costs associated with long term manipulation of variables.

1. Captor, N., B. Miller, B.D. Ottinger, A.J. Riggs, L.M. Tomko, and M.C. Culver, "Adaptable-Programable Assembly Research Technology Transfer to Industry," Final Report, NSF Grant ISP 78-18773, January 1983

2. All definitions based on:
Groover, M.P., and E.W. Zimmer, CADM: Computer-Aided Design and Manufacturing, Prentice-Hall, Inc., Englewood Cliffs, NJ 1984, Chapter 19.

Appendix III

Geographical Distribution for Major U.S. Corporations

State	City	Corporation	Telephone
Alabama	Cullman	Cullman Products Corp.	(205)734-4921
Alabama	Huntsville	Machine Craft, Inc.	(205)539-2221
Alabama	Montgomery	J.R. Smith Mfg. Co.	(205)277-8520
Arkansas	Fort Smith	Automotive, Inc.	(501)785-1461
California	Santa Ana	ATV Systems, Inc.	(714)261-2390
California	Cupertino	Apple Computer, Inc.	(408)996-1010
California	San Diego	Cubic Corp.	(619)277-6780
California	San Diego	Foodmaker, Inc.	(714)571-2121
California	Whittier	Fairchild Furniture, Inc.	(213)698-7988
California	Cupertino	Fairchild Semiconductor Corp.	(408)864-6250
California	San Diego	General Dynamics Corp.	(619)573-6111
California	Palo Alto	Hewlett Packard Co.	(415)857-1501
California	Cupertino	Intersil Inc. (Subs. General Electric)	(408)996-5000
California	Irvine	Kendall McGaw Lab	(714)660-2000
California	Beverly Hills	Litton Industries, Inc.	(213)859-5000
California	Paramount	Lackhart Industries, Inc.	(213)774-2981
California	Los Angeles	Northrop Corp.	(213)553-6262
California	El Segundo	North American Aircraft Operations	(213)647-1000
California	Downey	Space Transportation Systems Div. North American Space Operations	(213)922-2111
California	Canoga Park	Rocketdyne Division North American Space Operation	(213)710-6300
California	Anaheim	Autonetics Electronics Systems	(714)762-8111
California	Newport	Semiconductor Products Business	(714)833-4600
California	City of Commerce	Westelectric Castings, Inc.	(213)722-8000
California	Chatsworth	Waugh Controls Corp.	(818)948-8281
California	LaJolla	Henley Group, Inc.	(619)455-9494
California	Calabasas	Lackheed Corp.	(818)712-2000
California	Los Angeles	Northrop Corp.	(213)553-6262
Colorado	Ft. Collins	Apogee Robotics, Inc.	(303)221-1122
Connecticut	Stamford	Fag Bearings Corp.	(203)327-1960
Connecticut	Groton	Data Systems Division	(203)446-5960
Connecticut	Fairfield	General Electric Co.	(203)373-2211
Connecticut	Stamford	General Signal Corp.	(203)357-8800
Connecticut	Manchester	Gerber Scientific Products, Inc.	(203)643-1515

Connecticut	South Windsor	Gerber Systems Technology Inc.	(203)644-2581
Connecticut	East Norwalk	Harrel, Inc.	(203)866-2573
Connecticut	Westport	Metal Box America, Inc.	(203)226-8588
Connecticut	Danbury	Unimation, Inc.	(203)744-1800
Connecticut	Bloomfield	Kaman Corp.	(203)243-8311
Connecticut	Hartford	United Technologies	(203)728-7946
Florida	Orlando	American Machinery Corp.	(305)295-2581
Florida	Miami	American Metals Service	(305)592-7550
Georgia	Atlanta	Aaron Rents, Inc.	(404)231-001
Georgia	Americus	Metaluz Lighting	(912)924-8000
Georgia	Atlanta	Fugua Industries, Inc.	(404)658-9000
Georgia	Augusta	Roper Corporation	(404)724-0822
Illinois	Northbrook	American Metal Ware Co.	(312)498-6026
Illinois	Springfield	American Metals Supply Co., Inc.	(217)528-7553
Illinois	Park Ridge	American Machine & Science	(312)698-5420
Illinois	Chicago	American Name Plate & Manufacturing Co.	(312)376-1400
Illinois	Hinsdale	Automatic Screw Machine Products Co.	(312)654-1113
Illinois	Moline	Deere & Company	(309)752-8000
Illinois	Peoria	Dresser Haulpak Division (Dresser Industries, Inc)	(309)672-7000
Illinois	Rolling Meadows	Gould, Inc.	(312)640-4000
Illinois	Rockford	Ingersoll Engineers, Inc.	(815)987-6111
Illinois	Chicago	Litton Precision Gear	(312)847-4211
Illinois	Rolling Meadows	Methode Mfg. Corp.	(312)392-3500
Illinois	Chicago	Prater Industries, Inc.	(312)656-8500
Illinois	Aurora	Henry Pratt Company	(312)844-4000
Illinois	Chicago	Graphics Systems Division General Industries Businesses	(312)656-8600
Illinois	North Aurora	D.R. Sperry & Co.	(312)892-4361
Illinois	Algonguin	Wauconda Tool & Engr. Co.	(312)658-4588
Illinois	Chicago	Allied Products Corp.	(312)454-1020
Illinois	Skokie	Brunswick Corp.	(312)470-4700
Illinois	Peoria	Caterpillar, Inc.	(309)675-1000
Illinois	Itasca	The Boler Company	(312)773-9111
Illinois	Woukegan	Outboard Marine Corp.	(312)689-6200
Illinois	Rockford	Sundstrand Corporation	(815)226-6000
Indiana	Elkhart	Jessen Manufacturing Co., Inc.	(219)295-3836
Indiana	Indianapolis	Kennedy Tanks & Mfg. Co.	(317)787-1311
Indiana	Brookville	The Sperry Rubber & Plastics Co., Inc.	(317)647-4141
Indiana	Columbus	Cummins Engine Co., Inc.	(812)377-5000
Indiana	South Bend	Clark Equipment Co.	(219)239-0100
Indiana	Jasper	Kimball Int'l Inc.	(812)482-1600
Iowa	Cedar Rapids	Collins Defense Communications	(319)395-1000

Iowa	Muscatine	Hon Industries, Inc.	(319)264-7400
Kansas	Wichita	Coleman Co., Inc.	(316)261-3211
Kentucky	Hebron	Automated Systems Division	(606)334-2600
Kentucky	Florence	Litton Industrial Automation Systems	(606)283-2202
Maryland	Towson	Black & Decker Corp.	(301)583-3900
Maryland	Bethesda	Martin Marietta Corp.	(301)897-6000
Massachusetts	Billerica	Automatix, Inc.	(617)667-7900
Massachusetts	Worcester	Cincinnati Milacron Heald Corp.	(617)853-2121
Massachusetts	Beverly	Kenner Parker Toys, Inc.	(617)927-7600
Massachusetts	Westfield	H.B. Smith Co., Inc.	(413)562-9631
Massachusetts	Lexington	Rath & Strong, Inc.	(617)861-1700
Michigan	Southfield	American Motors Corp.	(313)827-1000
Michigan	Ann Arbor	Applicon	(313)995-6000
Michigan	Warren	Automotive Moulding Co.	(313)757-7800
Michigan	Highland Park	Crysler Corp.	(313)956-5741
Michigan	Dearborn	Ford Motor Co.	(313)322-3000
Michigan	Detroit	Forging Specialties, Inc.	(313)535-1784
Michigan	Roseville	Johnson Int'l Corp.	(313)775-2530
Michigan	Alma	Lobdell-Emery Mfg., Co.	(517)463-3151
Michigan	Kalamazoo	Prab Robots, Inc.	(616)329-0835
Michigan	Troy	Automotive Operations	(131)435-1000
Michigan	Detroit	The Smith Group, Inc.	(313)964-5554
Michigan	Troy	Ford New Holland, Inc.	(313)643-2000
Michigan	Taylor	Masco Corp.	(313)274-7400
Michigan	Tecumseh	Tecumseh Products Co.	(517)423-8411
Minnesota	St. Paul	Pentair Inc.	(612)636-7920
Minnesota	Minneapolis	The Toro Company	(612)888-8801
Missouri	Springfield	Aaron's Automotive Products, Inc.	(417)831-5257
Missouri	Kansas City	Automatic Systems, Inc.	(816)356-0660
Missouri	Kansas City	Automatique, Inc.	(816)561-6474
Missouri	St. Louis	Consolidated Aluminum Corp.	(314)878-6950
Missouri	St. Louis	General Dynamics Corp.	(314)889-8200
Missouri	Blue Springs	Harmon Industries, Inc.	(816)229-3345
Missouri	St. Louis	McDonnel Douglas Corp.	(314)232-0232
Nebraska	Gering	Lockwood Corporation	(308)436-5051
Nebraska	Lincoln	Lincoln Electric System	(402)475-4211
New Jersey	Berkeley	AT&T Technologies, Inc.	(201)771-2000
New Jersey	Edison	American Metal Molding Company	(201)284-4300
New Jersey	Mount Laurel	AW Computer Systems, Inc.	(609)234-3939
New Jersey	Parsippany	Artisian Electronics Corp.	(201)887-7100

New Jersey	Roseland	Automatic Data Processing Inc.	(201)994-5000
New Jersey	Ramsey	Bogen Communication, Inc.	(201)934-8500
New Jersey	Warren	The Chubb Corp.	(201)580-2000
New Jersey	Fairfield	Foremost Machine Builders Inc.	(201)227-0700
New Jersey	Whippany	Stephen Gould Corp.	(201)428-1500
New Jersey	Wychoff	International Wire Products	(201)891-5800
New Jersey	Woodcliff Lake	Intersoll-Rand Co.	(201)573-0123
New Jersey	Irvington	Jersey Plastic Molders Inc.	(201)926-1800
New Jersey	New Brunswick	Johnson & Johnson	(201)524-0400
New Jersey	Cherry Hill	Lincoln Graphics, Inc.	(609)662-3433
New Jersey	Parsippany	Machine Technology, Inc.	(201)386-0600
New Jersey	Elizabeth	Metalwash Machinery Corp.	(201)352-6876
New Jersey	Edison	Metex Corporation	(201)287-0800
New Jersey	Parsippany	Metem Corporation	(201)887-6635
New Jersey	Morristown	Westinghouse Elevator Co.	(201)984-9500
New Jersey	Morristown	Allied-Signal Inc.	(201)455-2000
New Jersey	Mountainside	Dresser Industries	(201)654-3300
New Jersey	Livingston	Foster Wheeler Corp.	(201)533-1100
New York	Plainview	ARX, Inc.	(516)694-6700
New York	White Plains	ASEA, Inc.	(914)428-6000
New York	Oceanside	American Medical Alert Corp.	(516)536-5850
New York	Port Jervis	A & W Products Co., Inc.	(914)856-5156
New York	Great Neck	AVX Corporation	(516)829-8500
New York	White Plains	A & W Brands, Inc.	(914)683-5890
New York	Brooklyn	ABBE Engineering Co.	(718)963-2824
New York	Jamestown	AARQUE Steel Corp.	(718)664-6014
New York	New York	Booz, Allen, & Hamilton Inc.	(212)697-1900
New York	Vernon	Del Electronics Corp.	(914)649-2000
New York	Buffalo	General-Electric Mechanical Corp.	(518)876-9685
New York	Latham	General Steel Fabricators Corp.	(518)785-3221
New York	Rochester	Genesee Brewing Co., Inc.	(518)546-1030
New York	Amityville	Goetel, Inc.	(516)842-2300
New York	New York	J. Gerber & Co., Inc.	(212)613-1100
New York	Bethpage	Grumman Corporation	(516)575-2464
New York	Armonk	IBM Corporation	(914)765-1900
New York	Bethpage	Grumman Electronics Systems Division	(516)575-0574
New York	Westbury	Metpar Steel Products Corp.	(516)333-2600
New York	New York	American Standard, Inc.	(212)703-5100
New York	New York	Colt Industgries	(212)940-0400
New York	New York	Crane Company	(212)415-7300
New York	New York	Dover Corporation	(212)826-7160
New York	New York	Sequa Corporation	(212)986-5500
North Carolina	Monroe	Keane Monroe Corporation	(704289-5581
North Carolina	Charolotte	Metric Construction, Inc.	(704)554-1415
Ohio	Perrysbury	Abbey Etna Machine Co.	(419)874-4301
Ohio	Cincinnati	Cincinnati Electronics Corp.	(513)733-6100
Ohio	Cincinnati	Cincinnati Milacron, Inc.	(513)841-8100
Ohio	Cincinnati	Cincinnati Time Recorder Co.	(513)241-5500
Ohio	Akron	Forge Industries, Inc.	(216)376-7414

Ohio	Cincinnati	General Tool Company	(513)733-5500
Ohio	Cleveland	Lincoln Electric Co.	(216)481-8100
Ohio	Cincinnati	Lodge & Shipley Co.	(513)541-4774
Ohio	Cleveland	Machinery Centers	(216)451-5588
Ohio	Cleveland	Smith & Harris Machine Co.	(216)267-3366
Ohio	Middletown	Crystal Tissue	(513)423-0731
Ohio	Cleveland	Parker Hannifin Corp.	(216)531-3000
Ohio	Canton	The Timken Company	(216)438-3000
Ohio	Maumee	Trinova Corporation	(419)891-2200
Oklahoma	Bartlesville	Applied Automation, Inc.	(918)661-4710
Oklahoma	Tulsa	North American Aircraft Operations	(918)835-3111
Oregon	Portland	A-T Industries, Inc.	(503)292-0224
Pennsylvania	Philadelphia	American Metal Works, Inc.	(215)338-9194
Pennsylvania	Royersford	American Machine & Tool Company, Inc.	(215)948-3800
Pennsylvania	Philadelphia	Jessee Jones Industries	(215)425-6600
Pennsylvania	Latrobe	Kennametal, Inc.	(415)539-5000
Pennsylvania	Oaks	Metalweld, Inc.	(215)666-9390
Pennsylvania	Pittsburgh	Rockwell Internatinal Corp.	(415)565-2000
Pennsylvania	Lenni	Westlake Plastic Co.	(215)459-1000
Pennsylvania	Pittsburgh	Westinghouse Electric Corp.	(412)642-2000
Pennsylvania	Zelienople	Herman Corporation	(414)452-7711
Pennsylvania	Pittsburgh	Joy Technologies, Inc.	(412)562-4500
Pennsylvania	York	York International Corp.	(717)771-7890
Rhode Island	Warwick	Kenney Manufacturing Co.	(401)739-2200
Rhode Island	Providence	Textron, Inc.	(401)421-2800
South Carolina	Marion	AVM Maremount Co.	(803)464-7823
South Carolina	Duncan	Cryovac Division (W.R. Grace & Co.)	(803)433-2000
South Carolina	Orangeburg	Stone Products Division	
Tennessee	Chattanooga	American Manufacturing Company	(615)624-1191
Tennessee	So. Pittsburgh	Lodge Manufacturing Co.	(615)837-7181
Texas	Euless	Del Norte Technology, Inc.	(817)267-3541
Texas	San Antonio	Fairchild Swearingen Corp.	(512)824-9421
Texas	Houston	Smith International	(713)443-3370
Texas	Dallas	Telecommunications Electronics Operation	(214)996-5000
Texas	Houston	Baker Hughes, Inc.	(713)439-8600
Texas	Houston	Cameron Iron Works, Inc.	(713)939-2211
Vermont	Arlington	Mack Molding Company	(802)375-2511
Virginia	Atrasburg	Automotive Industries Inc.	(703)465-3741
Virginia	Waynesboro	Genicom Corporation	(703)949-1000
Virginia	Bassetts	Bassetts Furniture Industries, Inc.	(703)629-7511

Virginia	Chantilly	Fairchild Industries, Inc.	(703)478-5800
Virginia	Richmond	Figgie International, Inc.	(804)264-5600
Virginia	Fairfax	Mohasco Corporation	(518)841-2211
Washington	Seattle	The Boeing Company	(206)655-2121
Washington	Everett	General Telephone Co. of the North West, Inc.	(206)258-5321
Wisconsin	New Berlin	Artos Engineering Co.	(414)782-3300
Wisconsin	Appleton	Appleton Mills	(414)734-9876
Wisconsin	Cudahy	Patrick Cudahy Inc.	(414)744-2000
Wisconsin	Brookfield	Harnischfeger Engineers, Inc.	(414)671-4400
Wisconsin	Mequon	Johnson Level & Tool Manufacturing Co., Inc.	(414)242-1161
Wisconsin	Racine	S.C. Johnson & Son, Inc.	(414)631-2000
Wisconsin	Milwaukee	Kearney & Trecker Corp.	(414)476-8300
Wisconsin	La Crosse	Machine Products Commpany	(608)782-2678
Wisconsin	Milwaukee	Allen-Bradley Company	(414)382-2000
Wisconsin	Manitowac	Rockwell Lime Company	(414)682-7771
Wisconsin	Milwaukee	Allis-Chalmers Corp.	(414)475-2000
Wisconsin	Wauwatosa	Briggs & Stratton Corp.	(414)259-5333

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