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**An empirical investigation of the impact of flexible automation  
on business strategy and organizational structure**

Parthasarthy, Raghavan, Ph.D.

City University of New York, 1991

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A

AN EMPIRICAL INVESTIGATION OF  
THE IMPACT OF FLEXIBLE AUTOMATION ON  
BUSINESS STRATEGY AND ORGANIZATIONAL STRUCTURE

by

RAGHAVAN PARTHASARTHY

A dissertation submitted to the Graduate  
Faculty in Business in partial fulfillment  
of the requirements for the Degree of  
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University of New York.

1991

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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

### AN EMPIRICAL INVESTIGATION OF THE IMPACT OF FLEXIBLE AUTOMATION ON BUSINESS STRATEGY AND ORGANIZATIONAL STRUCTURE

by

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Advisor: Professor S. Prakash Sethi

Various studies claim a causal role for flexible automation in business strategy management. Strategy literature, however, lacks a conceptual basis for analysis of this issue. A mechanistic view of automation has characterized strategy frameworks.

This study conceptually explains and tests the causal role of technology in strategy management. It views a firm's technology as adaptive to the industry's technological evolution to stay technically competitive. Such adaptations alter the firm's design/processing competences and create a misfit amongst manufacturing strengths, business strategy, and structure. Regaining "fit" requires complementary adjustments in strategy and structure. When adjustments reflect technology's changing competences, there should be an internal "fit" and higher performance. The thesis of this study is: the more a firm's strategy and structure match its technological

competences, the higher will be performance.

To test this thesis, this study analyzes questionnaire data of 82 flexible automation firms belonging to SIC groups 34-38 and operating in the U.S. Moderated regression analysis is used to test "fit" relationships. Results indicate technology positively interacts with quality, variety, innovation strategies and team structures that are complementary to flexible automation strengths. It negatively interacts with low cost strategies and standardized structures that are in conflict with flexible automation strengths. At the manufacturing level, technology is positively associated with worker skill diversity and team approaches that are congruent with flexible automation strengths. A sub-group analysis of the sample based upon high and low performers adds significant support to these findings.

For future research, the study suggests larger samples, a more refined measure for technology, and a longitudinal analysis. From a theoretical perspective, this study calls for a change in the current strategy formulation paradigm: from a market-based approach to an internal technical competency based approach that also considers external conditions. Towards that end, this study suggests redefining technology from an organic perspective: a system of evolutionary skills and competences that creates and executes ideas and products.

## PREFACE

In the process of completing a doctoral dissertation, a student invariably accumulates many debts of gratitude. I am no exception to that rule. Indeed, it is with pleasure that I acknowledge these debts here although it is but a meager recompense for the value received.

While I cannot possibly recognize every physical or inspirational help that I received, the more prominent sources of such help have to be acknowledged. At the top of the list are a handful of people who have been described by the pages of history as famous. Their claim to fame is not through any conventional means such as military prowess or material possession, oratorical eloquence or political ingenuity. Instead, it is through their philosophical writings that they have achieved a glory that has stood the test of time. To these philosophers and the ideas they espoused that I owe my conceptual knowledge and reasoning. My epistemic pursuits in general, and my theoretical ideas for this dissertation in particular, were especially influenced by the Kantian idealism, the Hegelian dialectics, and the Spencerian evolutionism. Some recent writings that I beg to include to this list are the Kuhnian radical thinking in science and the Weickian logic of enactment. Most of

all, I was greatly inspired (or, intrigued perhaps) by the ideas embodied in the "Upanishads", a collection of treatises on the Hindu philosophy, that I have avidly sought to incorporate them throughout this dissertation.

I am grateful to Professor S.Prakash Sethi for undertaking the onerous task of the dissertation committee chairmanship and for guiding me in completing this dissertation. His criticisms of my loose thinking were necessary for me to separate the chaff from the kernel, the critical from the merely existing, and the substance from the surrounding issues. I am especially fortunate to have him as my co-author in the publication of the theoretical part of this dissertation in the Academy of Management Review, January 1992.

I do sincerely thank the other members of my dissertation committee, Professors Jack Shapiro, David Dannenbring, and Mahmoud Wabha for their constructive criticisms of my work and for their kind words of encouragement. My thanks also go to Professor Donald Vredenburg for his comments and suggestions towards tightening the material in the abstract page.

Special thanks are extended herein to Professors Rajan Chandran and Raj Chaganti of Temple University, Vijay Govindarajan of Dartmouth College, Paul Swamidass of the University of Missouri, Todd Korol of the Fairleigh Dickinson University, and David Hagen, General

Manager of Ford's Engine Division for their help at the conceptual, data collection, or analysis stage of this dissertation. My appreciation also goes to a number of my colleagues and friends who helped me in various ways during the writing and typing stages of this dissertation.

I lost both my parents during the time I was writing this dissertation. It was they who instilled in me the faith that education is a suffering that must be undergone initially in order to reap its subsequent fruits: wisdom . To their loving memory, and to my dear wife Jan, whose love and smiles are a pleasure to experience, I dedicate this work.

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## CHAPTER 1

### ORGANIZATION OF THE THESIS

Yasca mudhatamo loke  
Yasca Buddheh param gatah;  
Tavubhau Sukhamedhete  
Klisyatyantarito janah

Srimad Bhagavatam (III.7:17)  
(Verses in Sanskrit)

Translation: Only two kinds of people are happy and free from tension: the utter fool and the one who has surpassed himself, gone beyond his mind. All people in between are in varying stages of tension.

Purport: A mind in a constant state of tension, as evidenced by inquisitiveness and an ardent desire to know things unknown, is a prelude to the path towards wisdom and all higher levels of understanding.

#### 1.1 Outline

This chapter develops the rationale for this dissertation. It draws attention to the speculative writings on manufacturing technology and business strategy that frequently appear in the popular press and points to the need for scholarly research in this area. The plan of this research and its expected contributions are described.

#### 1.2 General

Factory automation is a topic of significant contro-

versy in the socioeconomic literature. On the one hand, its role in efficient production of standardized products in large volume is readily acknowledged. On the other hand, it has also been criticized for causing alienation, anomie, agnosticism, and morbidity. Not surprisingly, factory automation issues have become a topic of significant concern to the moralist, the populist, and the social scientist. And with such diversity amongst those who are concerned about automation, writings on this subject cannot but be polemic and equivocal.

### 1.3 Factory Automation and Management

Until now, philosophical discussions pertaining to automation and management have concentrated largely on organizational and motivational issues stemming from automation of the production line. Discussions have confined themselves to hypothesizing an association between the level of manufacturing automation (i.e., small batch, large batch, continuous flow production) and some work and behavioral variables. Specifically, scientific enquiries here have dealt with the impact of the firm's technological choice on worker satisfaction (Blauner, 1964; Fullan, 1970), skill level (Bright, 1958), morale (Davis & Trist, 1974; Rice, 1958; Trist & Bamforth, 1951), work group behavior (Sayles, 1958;

Walker & Guest, 1952), and most of all, organizational structure (Harvey, 1968; Hickson, Pugh, & Pheysey, 1969; Perrow, 1967; Thompson, 1967; Woodward, 1965). Studies have implicitly assumed performance implications based upon an appropriateness of fit (determined normatively) between the firm's technological choice and the organizational variable studied. Explicit exposition of propositions pertaining to performance or empirical investigations to ascertain performance based upon the hypothesized fit are rare (Miner, 1982).

Current research knowledge on technology and management is thus restricted to a limited range of parochial issues involving manufacturing automation and some organizational variables. Suggestions have been made to investigate automation's impact on management from a global perspective, i.e., strategy formulation and implementation (See Gunn, 1987; Skinner, 1985). However, conceptual thinking that will provide a basis for undertaking such an investigation has been slow to develop.

#### 1.4 Statement of the Problem

For some time now, manufacturing literature has sought to extend the scope of discussions pertaining to technology and management to include business strategy

formulation issues. Arguments have been made that relate manufacturing technology and competitive choices at the strategy intent level (Hayes & Schmenner, 1978; Skinner, 1974, 1985; Wheelwright & Hayes, 1985). The rationale in these arguments is that a firm's ability to process a product according to a planned competitive criterion (e.g., cost, quality) or to meet unexpected market demands (e.g., fast delivery) is tied to its manufacturing technology strengths. Therefore, synchronizing technology decisions with business strategy formulation should have a positive impact upon performance.

A prolonged neglect of manufacturing technology issues in product/market and competitive choices and consequent deterioration in U.S. industrial competitiveness (Hayes & Abernathy, 1980) is apparently responsible for the "strategy-technology link" hypothesis. However, recent changes of a technical nature that are occurring in manufacturing automation (Bylinsky, 1983; Groover, 1987; Kusiak, 1986) demand a step further in this line of thinking: the integration of manufacturing technology itself as a variable in strategy formulation and implementation frameworks.

#### Alternative Automation Types and Competences

Historically, manufacturing automation was deemed to

improve process efficiencies for achieving lower costs and reliable production, i.e., conformity to standards. Achieving these advantages however required as a precondition, large production runs and a standard product design. With the production process thus dedicated (hence commonly referred to as fixed automation), automation's mission was described as executing planned operations efficiently rather than attempting to change them or provide new opportunities for the firm. In other words, automation was considered to be a downstream task implementation function only. Its role in product decisions such as improving quality (defined in this research in terms of features. See Garvin, 1987; Hayes & Wheelwright, 1979a & 1979b) or innovation was considered non-existent.

Introduction of computers in automation has altered this static and passive view of automation by endowing it with new competences in designing and processing products. By minimizing the changeover time from design to production, computerized automation has enabled the latter to constructively involve itself in product development and producibility decisions. By facilitating discrete production due to programming capabilities, it has made scope production possible at costs which were hitherto realizable only through long production runs of

standardized products. An implication of these developments for automation's mission is the larger degrees of freedom that automation now enjoys in product design and production: a) executing planned operations according to predetermined criteria (objective driven), or b) executing non-planned operations in emergent ways (opportunity driven). Automation can thus be a formative as well as an implemental tool.

Studies pursuant to these developments in automation (Adler, 1988; Bolwijn & Kumpe, 1986; Dean & Susman, 1989; Gerwin, 1989; Goldhar & Jelinek, 1983, 1985; Jelinek & Goldhar, 1984; Meredith, 1987a) suggest various changes to be made in business strategy and organizational structure for successfully implementing alternative automation types. The technology discussed in these studies is popularly known as flexible automation (FA) or advanced manufacturing technology. It typically comprises design and processing equipments such as design terminals and work stations, numerically controlled machine tools, robots, transfer lines, and storage systems which are computer controlled and further integrated by a supervisory computer. Individual tool programming and integration with other tools through a central system has enabled FA to offer the firm the flexibility advantages mentioned above.

### Implications for Strategic Management

In general, studies recommend for an FA user a technology-based approach, as opposed to the current marketing and finance-based approach, in the selection and implementation of business strategy. Such recommendations have been made normatively, using rational arguments (Goldhar & Jelinek, 1985; Hayes & Jaikumar, 1988), case studies (Meredith, 1987a), or by comparing the new technology to the old technology on processing competences (Nemetz & Fry, 1988). A considerable body of literature has since developed under the rubric of manufacturing strategy. The high frequency of these studies appearing in this literature and in some practitioner journals attests to the general importance of this topic for management. The relevance of these studies for strategic management stems from their implications to a firm's relative competitiveness.

### Need for a Scientific Investigation

In general, these studies have meaningfully elevated our attention to the impact of flexible automation on business strategy formulation and implementation. However, most writings on this topic are speculative, impressionistic, or anecdotal and lack scientific validity as a result. Moreover, most studies have

appeared in the popular press or practitioner journals and, as such, few provide any scholarly guideline or testable hypotheses for undertaking scientific research. Developing congruency in this area requires a systematic field investigation that will shed light on strategy formulation and implementation under alternative technology conditions. Unfortunately, however, no such investigation has been forthcoming and the journalistic writings on this important and timely topic flow unabated.

Problems with the current frameworks. One reason for the absence of scientific research on alternative automation types and their influence on business strategy is the lack of a conceptual grounding within which such research could be undertaken. Current strategic management frameworks, largely deliberate and sequential (Mintzberg, 1978), view the socioeconomic environment as the referent and starting point for making product/market and competitive choices. The basis for selection of choices at subsequent levels is a congruence criterion: the extent to which a choice is a corollary to the one that precedes it in the sequence. Hayes (1985) characterizes this as the "ends-ways-means" continuum. In this approach, the purpose of means is to maximize

performance on ends according to the predetermined ways but not to alter existing ways or suggest new ways. This market-based, top-down approach is clearly inappropriate for investigating the role of a firm's changing manufacturing competences on business strategy formulation and implementation. While interactive approaches which are more apt for the purpose have been discussed and emphasized in the generic strategic management literature (Burgelman, 1983; Quinn, 1980), conceptual schemes which will specifically explain the technology-business strategy relationship within a dynamic perspective are missing.

A second reason that is contributing to the problem here pertains to the manner in which automation has been perceived and treated in strategic management research and writings (Hayes & Wheelwright, 1984; Hayes, Wheelwright, & Clark, 1988; Wheelwright, 1985). A common notion on automation is that it is a perfunctory device whose competencies lie in maximizing efficiency and volume on current products. As such, it is presumed to have no role in the development of products/markets or criteria for competing in them. Explaining its role in business strategy formulation and implementation will require describing a firm's manufacturing technology as evolutionary and a conceptual basis which will support

this claim.

### 1.5 Purpose of This Research

The foregoing brings to light a gap in the literature: while historical accounts claim a significant relationship between alternative manufacturing types and strategic management decisions, field investigations which would validate these claims through systematic research are missing. To maintain continuity in the literature, this gap has to be filled. This research seeks to achieve this goal by providing a conceptual explanation of the interrelationships amongst the concerned variables and testing for their existence. The objectives of this research are thus as follows:

1. To develop an analytical framework which will explain the substantive relationships amongst the firm's environment, manufacturing technology, business strategy, organizational structure, and performance.
2. To use the framework to examine empirically:
  - a) the relationship between FA technology and specific business strategies (i.e., strategy content).
  - b) the impact of FA technology upon the

- firm's overall organizational structure.
- c) the impact of FA technology upon the firm's manufacturing structure.
  - d) the impact of FA technology upon the firm's strategic management process.
  - e) the association between FA technology and specific strategy choices as an indicator of firm performance.

#### 1.6 Expected Contribution of This Research

The research proposed here will have both theoretical and practical implications. From a theoretical perspective, this research should not only contribute to a better understanding of the relationship between business strategy and manufacturing technology but also serve as a benchmark for describing the role of alternative manufacturing technologies in strategy formulation and implementation. Specifically, this research should facilitate an understanding of business strategy and organizational structure choices that are appropriate for FA technology in terms of company performance. Further, the findings of this study should provide a basis for the creation of concepts which will explain competition based upon the FA competences in manufacturing. In general, this study should provide

the groundwork necessary for developing a formal manufacturing-based competition theory.

For a practitioner, the findings of this research will point out the business strategy and organizational structure choices that are appropriate for successfully implementing FA technologies. Various reports (Goldhar & Jelinek, 1983; Jaikumar, 1986) indicate that many firms lacked this knowledge and suffered significant financial losses as a result. By including manufacturing technology in the strategic management framework and testing for its effects upon strategic and organizational variables, this study will provide the empirical knowledge necessary for making informed choices on technology-driven competitive strategies. The importance of such a strategy for the U.S. firms can be understood within the context of their presently dwindling competitive strengths in world markets.

### 1.7 Scope of this Research

The scope of this research is restricted to manufacturing companies who are users of FA technology (FA to be defined and described later). The reason for restricting the sampling universe stems from the objectives of the dissertation itself: to understand what business strategy and organizational structure

choices are appropriate with FA technology in order to achieve superior company performance.

Only manufacturing companies that are operating within the frontiers of the United States are surveyed for this research. This geographical limitation was planned for two reasons: 1) to facilitate data collection in a timely manner, and 2) to enable an economical execution of any follow-ups in the data collection process such as, for example, telephone requests, mail reminders, personal visits, etc.

Owing to the specialized nature of this study, especially in regard to the propositions it makes, the scope of the universe for sampling was further restricted in terms of the company size and in terms of the company operations as classified by the Standard Industrial Classification (SIC) codes. These restrictions, and the manner by which they were executed, will be explained in detail in the methodology section of this dissertation.

### 1.8 Plan of this Dissertation

This dissertation has been divided into six chapters including this introductory chapter. Each chapter has been further divided into parts and sub-parts, using sectional headings, to facilitate easy reading and comprehension of the material presented. The following

briefly describes the contents of the remaining chapters.

Chapter 2 takes a historical look at manufacturing technology and its association with decisions made at the operative, administrative, and strategy formulation levels. The impact of technology upon manufacturing structure, overall organizational structure, and business strategy are chronologically reviewed and discussed. Specifically, extant theoretical literature pertaining to technology and business strategy are reviewed in light of the claims made in the practitioners' literature and anomalies are highlighted. Chapter Two discusses the shortcomings of the existing frameworks to deal with these anomalies and suggests an alternative model for explaining and resolving conflicts.

Chapter Three develops the framework for undertaking the research proposed in this dissertation. It first describes the previous theoretical works upon which the substantive relationships of the variables included in the framework would rest. It then introduces the elements of the framework, defines them by using extant literature as guidance, and relates them to each other by using the theoretical works described. Relevant hypotheses are drawn for testing the proposed framework.

Chapter Four discusses the methodology used to operationalize this research. It first describes the

sample and the process that was employed for constructing this sample. It then describes the instruments and measures that were used in data collection. Finally, it provides a broad overview of the statistical techniques that are appropriate for analysis and describes the method that was used in this dissertation.

Chapter Five describes the major findings of the research. The meaning of these findings for the hypotheses and the research framework in general are then discussed. The limitations of the research findings in regard to their generalizability are noted.

Chapter Six concludes with a discussion on the theoretical and practical implications of this research. Directions for future research are also provided.

## CHAPTER 2

### CURRENT STATE OF THE LITERATURE

Yasyamatam tasyamatam  
matam yasya na veda sah;  
Avijnatam vijanatam  
vijnatam avijanatam

Kena Upanishad, II.3  
(Verses in Sanskrit)

Translation: He who knows It, thinks he knows it not; and he who knows It not, claims he knows It. To the man of true knowledge, It is the "unknown"; to the ignorant, It is the "known".

Purport: True knowledge has no exemplars and, as such, it transcends all limitations. To assume it to be finite is the first sign of an indolent and stagnant mind.

#### 2.1 Outline

This chapter historically reviews the literature on the role of manufacturing automation in decisions relating to organizational systems and processes. The impact of automation on the firm's manufacturing structure and the overall organizational structure is chronologically reviewed and summarized. Later, current strategic decision frameworks are analyzed in light of automation's changing competences and resultant impact upon business strategy management. The disparity between conceptual thinking and empirical developments is

highlighted and the need for alternative models to describe business strategy formulation and implementation is emphasized.

## 2.2 General

Technical knowledge and business management have long remained as polarities. Engineers and men of machines generally loathe administrative procedures while business managers have an anathema for technicalities. Rationality and problem solving are the engineer's forte while politics and problem identification are those of the business manager. Engineers are pragmatic whereas business managers are visionary. The list goes on.

Paradigmatic differences between engineering and business management are obviously responsible for such chasmic differences in the attitudes of the respective group members. Homogenous and stable markets that prevailed until the sixties provided additional encouragement to these groups to maintain distinct identities. Businesses operating under these environmental conditions had to cultivate a functional differentiation within organizations (e.g., separating planning from execution, design from manufacturing) in order to realize the cost efficiencies required in competition. But environments have now become highly

fragmented and dynamic, and manufacturing is emerging as a critical competitive function due to programmable automation. A predominant strategic choice for most organizations today is design and volume flexibility, not standardization. Consequently, integration of functions as well as authority in strategic planning, policy-making, and strategy implementation has become necessary. The strategic issue for the organization today is: How to make every part of the organization think and act holistically, or as Van de Ven (1986) puts it: How to put the characteristics of the whole into each of the divided parts.

### 2.3 Factory Automation and Plant Management

Classical writings on management confined themselves to the area of decisions concerning how an enterprise was to do what it had set out to do. Inquiries on the fundamental choices governing which products or functions the firm was to engage in were considered to be irrelevant (Porter, 1978). Those latter mentioned entrepreneurial decisions, currently described as strategic, were assumed to be a one-time affair in the life of an organization. The objective of management was thus described as dealing with ways that would accomplish a given task efficiently rather than change the task itself or identify new tasks. Understanding the issues

involved within this restricted scope and identifying the principles that would resolve problems across all situations became the explicit premise for management research. A more or less stable environment that prevailed during the early periods of the study of management lent support to the assumptions underlying this premise.

With the study of management thus restricted to an analysis of tactical choices only, delineating the problem areas within the organization which would require research scrutiny became necessary. To the practitioner and to the researcher, an initial but significant concern was the factory automation and its implications for management. Rapidly expanding markets during the late years of last century were putting pressure upon firms for large volume supply of standardized products on a continuous basis. Conventional manufacturing technologies which would produce in a custom fashion or in small lots were obviously inappropriate for meeting this challenge. Further, the need to achieve a large market share in a fast growing market demanded a manufacturing technology which would contain production costs and facilitate competition based upon price. What emerged as a denouement was a sequential manufacturing technology, often referred to as fixed automation, mass production, or the

"American Way of Manufacturing" (Hayes, Wheelwright, & Clark, 1988). In this technology, by grouping large machines performing dedicated operations, volume production was achieved; by linking dedicated machines to other machines in the manufacturing sequence with the help of automatic transfer lines, cost efficiencies were achieved.

Prior to sequential automation, management problems largely involved solving operational uncertainties. Manufacturing was job shop in nature and used stand-alone machines which performed a variety of operations. Worker skills were primarily based upon individual artistry and a prolonged experience achieved through apprenticeship. Lacking process standardization, the competitive emphasis of the firm centered on technical ingenuity, the quality of its execution, product variety, and the ability to meet specific customer demands. As a result, critical management issues were by and large technical, involving direct supervision in design, production, and distribution of goods. A firm's success under these conditions depended upon the technical competence of the rank and file and an entrepreneurial attitude on the part of management (Hayes, Wheelwright, & Clark, 1988; Skinner, 1985).

The introduction of sequential manufacturing techno-

logy was bringing in its train certain administrative problems, heretofore unknown to management, such as: work and methods standardization, design and manufacturing coordination, division of responsibility and authority between operations and administration, and finance and accounting controls. It was to these task implementation problems arising as a consequence of factory automation that early management scholars were keen to find solutions for. Analysis and recommendations in these areas were done by keeping in mind the previously mentioned caveat, namely, that the study of management was restricted to finding ways for maximizing the firm's performance on planned operations.

America's initial understanding of the principles involved in managing a large scale manufacturing enterprise is largely attributed to the works of a single man: Frederick Winslow Taylor. Central to Taylor's (1947) inquiry was the need to understand the ways by which the human and mechanical activities could be coordinated. Large, dedicated machines were performing standardized operations in the backdrop of human activities which were largely fluctuating and unpredictable. There was thus a mismatch between the demands made by machines on the one hand and human actions on the other which inhibited the total realization of benefits associated with fixed

automation: volume production and cost efficiency. It was thought that these latter mentioned organizational objectives could be achieved by regulating human motions and actions to suit the needs of the machines. Managing the variation in human behavior using mechanical principles thus forms the corner stone of Taylolean philosophy. Standardization of work procedures and tools, separation of planning (product design) from doing (manufacturing), and supervisory control of worker activities and output through rules and procedures were some obvious recommendations stemming from this philosophy.

When these recommendations were translated into practice, worker skill and artistry became irrelevant for operations, production got separated from product design, and work methods and cost accounting became critical top management functions (See Hayes, Wheelwright, & Clark, 1988; Reich, 1983).

#### Summary

Managerial implications of the mass production technology and the scientific management movement that followed to rationalize it can be summarized as follows:

1. Technology and manufacturing issues should be delinked from top management's decision portfolio (Chandler, 1977; Skinner, 1985).
2. The responsibility for planning and control

ling the firm's manufacturing task should be entrusted to technical personnel consisting of engineers and production foremen.

3. The mission of manufacturing is to maximize performance according to planned criteria. The objective of manufacturing is thus task implementation only (Wheelwright, 1985).
4. Any addition or alteration to existing manufacturing technology should be considered and implemented only in light of increasing scale and efficiency on current operations.

#### 2.4 Factory Automation and Organization Management

Concern for the impact of factory automation on the overall organization could possibly have arisen with the emergence of large scale enterprises pursuant to the use of mass production technologies. Organizations now comprised, besides the factory, an administrative unit that emerged as a result of the need to control and coordinate manufacturing activities with market demands. Initial revelation on the existence of a general relationship between technology and organization came from research conducted in coal mines in England (Trist & Bamforth, 1951). However, details of a correspondence between specific technological characteristics and

organizational structure characteristics had to await for research which would use the manufacturing sector as the population.

Early discovery of a possible relationship in this area came by chance. Data collected from 100 manufacturing companies in England to test whether the use of classical management principles led to performance showed no significant pattern (Woodward, 1958, 1965). However, a post hoc interpretation of the data revealed that structural variations in these firms were possibly due to the differences in the manufacturing technology they used. In essence, the argument made was that "different technologies imposed different kinds of demands on individuals and organizations and these demands had to be met through an appropriate form of organization" (Woodward, 1958:9). Testing this argument required a definition of technology.

Woodward conceptualized technology based upon the level of technical complexity, defined as the extent to which the production process was controllable. The higher the level of technical complexity, the more the production process was deemed to be controllable. The measurement scale, which also corresponded to the chronology of historical development in production, ran from unit and small batch production, such as prototypes

or custom manufacturing of suits; to large batch and mass production, such as automobile manufacturing; and further to continuous flow production, such as the manufacture of petroleum or chemicals. Low levels of technical complexity represented a low control over the production process thus indicating a high need for flexible methods of work coordination. In high levels of technical complexity, control over the production process was high and hence more formal coordination mechanisms were needed.

Using control as an intervening variable, the effects of technology on structure were described as follows:

1. Increase in technical complexity resulted in corresponding increases in the length of the line of command, span of control of the chief executive, ratio of managers to non-managers, etc. In other words, the higher the technical complexity, the higher was the control over the production process and the more formalized (or bureaucratic) was the organization as a result.
2. There was an inverse (U-shaped) relationship between technical complexity and the span of control of first-line supervisors and the style of management. Unit and process techno-

logies needed a smaller span and an organic management style at the operations level. In mass production, there was a need for a large span and a mechanistic management style.

3. There tended to be an optimal structure for each technology type based upon performance.

Replication of the Woodward study by Harvey (1968) and Zwerman (1970) generally corroborated her findings. It is however worth noting here the refinement that Harvey proposed to Woodward's scale: a continuum ranging from "diffuseness" to "specificity". Diffuse technologies (Woodward's batch technology) were characterized by variety, high innovation, and frequent technical changes. Specific technologies were exemplified by the production of standardized products and minimal changes of volume and variety. Diffuse technologies showed organic structural characteristics while specific technologies (Woodward's mass production technology) showed mechanistic structural characteristics.

A concern subsequent to Woodward's research has been: To what extent would the techniques or technical complexity used in the manufacturing process affect the overall organization which also includes the administrative sector? A series of studies relating to this concern was initiated in the early sixties at what was to

become the University of Aston in Birmingham, England (Pugh & Hickson, 1976). The original Aston study (Hickson, Pugh, & Pheysey, 1969) classified technology into an operations technology (techniques used in the production work flow), materials technology (characteristics of the materials used in the transformation process), and knowledge technology (characteristics of the knowledge used in the organization). However, scales were constructed to measure only operations technology by developing a composite measure called "work flow integration". Work flow integration was measured as follows:

1. Automation of equipment. The extent to which the production process is automated or self-performing.
2. Workflow rigidity. The extent to which operational knowledge, skills, and equipment are rigid rather than adaptable in their uses.
3. Specificity of evaluations. The extent to which operational activities can be measured against formal and planned criteria.

Organizational structure was measured using the following characteristics:

1. Structuring of activities. The extent to which jobs were specified in detail and

rules and procedures were formalized.

2. Concentration of authority. The extent to which decisions in the organization were centralized.
3. Line control of workflow. The degree to which the production hierarchy ( rather than procedures and impersonal rules) controlled the work flow.

Using the above measures, the Aston group found that manufacturing technology influenced only those structural variables that were centered on the production work flow. Its impact upon the overall organizational structure, however, was found to depend upon the size of the organization. The explanation offered in support of this proposition was that in larger organizations, managers were buffered from the effects of technology by specialists and by standard procedures that went with the firm's size. Consequently, the structural framework of management was not significantly affected by the firm's production technology.

#### Summary

To summarize, research relating to factory automation and organizational structure has produced equivocal results. The issue that has emerged out of these conflicting findings is not whether manufacturing

automation has impact over organizational structure or not. Instead, it pertains to the question: at what level of the organization is the effect of automation more pronounced. While the lack of methodological rigor has often been cited as the cause for confusion in this area (see, e.g., Ford & Slocum, 1977; Gerwin, 1979; Rousseau, 1979; Stanfield, 1976), one significant reason seems to be due to a narrow conceptualization of automation by previous research: variations in automation levels have been defined by authors using a unidimensional scale of increasing specificity. In this definition, since a highly specific technology (i.e., highly automated) is more controllable, it implies that its influence will be restricted to production operations only. However, alternative automation types (i.e., flexible automation) are of the diffuse type. Higher levels of automation in these technologies are associated with higher variety and discrete production as opposed to specific production. The uncertainties arising in production as a consequence should have significant implications for both the operations and the strategy formulation areas of the organization.

#### 2.5. Factory Automation and Task Management

At the job level, the effects of automation on job

design, job specifications, and worker autonomy have been studied by conceptualizing technology as the knowledge used in problem solving (Perrow, 1967) and based upon the coordination requirements it places amongst various functions (Thompson, 1967). The problem solving approach visualized two dimensions along which technologies can vary: input variation (i.e., the number of exceptions encountered due to differences in the raw material) and knowledge variation (i.e., whether exceptions can be solved by logical analysis or by exercising judgment). Four different technology types were derived using these two dimensions. However, data collection and analysis led to the compression of four into two technology types, namely, routine and non-routine, since it was found to be more realistic to do so (Perrow, 1970:82).

The coordination approach classified technology into three types based upon the interdependence needs they posed for jobs (low, medium, and high) and whether such needs could be met through standardized mechanisms. Clearly, the emphasis here is upon the ability to standardize the interdependence needs than upon the number and extent of such needs. Thus, in the interest of parsimony, technologies can be broadly classified in this approach as routine or non-routine types; in the former, coordination needs can be standard-

ized whereas in the latter, they have to be left to worker discretion.

There have not been many empirical studies of technology and structure at the job level. Of the sparse number of investigations, service organizations (e.g., hospitals, health care organizations) predominate as the unit of analysis while research on manufacturing organizations are few and far between. The general understanding of relationships in this area is that specific or routine technologies are associated with precise job description, standardization of work and rules (Hage & Aiken, 1969; Hrebiniak, 1974), semi or unskilled operations personnel (Woodward, 1965), and planned coordination mechanisms (Mahoney & Frost, 1974) whereas diffuse or non-routine technologies are associated with broad job descriptions, worker autonomy, worker discretion, and coordination of organizational activities through mutual adjustment (Mahoney & Frost, 1974; Mohr, 1971; Van de Ven et al, 1976).

## 2.6 Factory Automation and Strategic Management

The definition of what falls within the purview of the analysis of management has steadily expanded over the years to include decisions relating to product/market and competitive choices. Complex, atomized, and dynamic

environments within which businesses currently operate have forced scholars to include strategy content and process as a critical area of investigation in the study of management. A large body of literature under the rubric of what is now known as strategic management has been accumulated to stand as a referent in discussions relating to formulation and implementation of strategic choices. This section briefly describes this literature, the place that automated technology currently occupies in this literature, and the need for change in its conceptual thinking due to the changes occurring in automation's characteristics.

#### The Strategic Management Framework

The concept of change and consequent need for congruence amongst organizational components on the one part and between the organization and the environment on the other (Andrews, 1971; Hofer & Schendel, 1978) is a central theme in strategic management thinking. Change impacts an organization in one of two ways: by providing it with new growth opportunities or by bringing in threats to its existing business. Exploring the sources of change and experimenting for internal competences that will enable a firm to exploit change (or control it, as the case may be) forms the basis for strategy formulation models (Hofer & Schendel, 1978). Change, however, produces

intrafirm and firm-environment disequilibrium resulting in organizational ineffectiveness. The concept of "fit" (Miles & Snow, 1984) thus receives a parallel importance in strategic management conceptualizations.

Strategy Formulation: Current Approaches. Two different perspectives of how strategies are formulated and fitted with other choices are described in the literature. A synoptic perspective (see Lorange & Vancil, 1977; Paine & Naumes, 1978) describes strategy formulation as "deliberate" (Mintzberg, 1978) and sequential. It starts at the top management level with a systematic assessment of the firm's socioeconomic environment to identify opportunities/threats and arrive at broad strategy choices. This is followed by the selection/ modification of choices at the operational and administrative levels that lend support to the chosen strategy by serving as effective implementation mechanisms. The sequence here can be briefly characterized as an "outside-in and to-down" process. In this process, each lower level component is deemed to function more as a vehicle for implementing the choices made at higher levels than as a catalyst for making new choices. In other words, the direction of influence of each component is assumed to move down towards a lower level component along the logical sequence than towards those

at the top (see, e.g., Hrebiniak & Joyce, (1984:90). Threats to an existing configuration are met either by defending it through planned manipulations (Thompson, 1967), modifying the implementation mechanisms to suit the needs of strategy, or by creating a new configuration through sequential adjustment, starting from strategy.

Consistent with the logic that management occurs within a dynamic context (Lindbloom, 1959), an incremental approach (Quinn, 1980) has also been proposed in the literature as a plausible model for strategy-making or for regaining "fit" conditions. This can briefly be described as a "bottom-up and inside-out" process. Strategy formulation in this approach occurs in an evolutionary manner based upon a confluence of internal decisions and external events. An implication of this approach is that a firm's existing operational and administrative mechanisms, namely, its technology and structure, will have significant influence over the selection of future strategic choices. Research using this approach thus far has been sparse and studies have only dealt with the influence of structure on strategy (Bower, 1970, 1974; Burgelman, 1983). Also, both structure and technology have been viewed more as constraints than as facilitators in the strategy formulation process (see, e.g., Hrebiniak & Joyce,

1984:90; Szilagyi & Wallace, 1983:495).

Summary. In summary, the "outside-in and top-down" approach appears to be the predominant view at present to explain strategy formulation. Current views largely hold the socioeconomic environment as the referent in strategymaking since change, the very basis of strategic management, is assumed to be due to market and economic imperatives. In this approach, the internal components of an organization are considered as static constraints that should be matched with dynamic elements (identified through environmental search) in a selective manner. The idea that internal components of a firm could be evolutionary and consequently serve as a spring board for strategy creation is still nascent in strategic management research and writings.

#### Business Strategy Choices

Whether a firm uses a synoptic approach or an incremental approach, it must select a strategy for competing within its business segment. The business strategy literature discusses the bases upon which such strategy choices rest such as, for example, a firm's market share vis-a-vis the market growth rate (Hedley, 1977; Hofer, 1977), the life cycle stage of the product (Anderson & Zeithaml, 1984; Hambrick & Lei, 1985; Hofer, 1975), and top management beliefs and values (Miles &

Snow, 1978). However, several generic strategies have been identified as appropriate for firms operating across various industry conditions. The underlying assumption in these generic strategies is that while the superficial characteristics of industries may differ, their deep structure is sufficiently similar that certain ways of competing, if effectively implemented, can lead to competitive advantage in many industries.

A generic typology that has become significantly popular in business strategy research is Porter's (1980) competitive strategy framework. The framework is academically well accepted and is considered internally consistent (Dess & Davis, 1984; Hambrick, 1983). It involves two distinct strategic choices applied industry-wide or in segmented markets thus adding to four separate ways of competing:

1. Industry-wide Cost Leadership refers to competing in the entire market on the basis of low price.
2. Industry-wide Differentiation refers to competing in the entire market by being different than the other firms in the industry on some dimension that is valued by the market. Differentiation can be based upon product quality (perceived or real), reliability, delivery,

service, etc.

3. A Segmented Cost Focus refers to competing in a segmented market on the basis of low price.
4. A segmented Differentiation Focus refers to competing in a segmented market by providing customers with some added value relative to nonspecialized firms.

Porter views the above strategies as trade-offs. That is, a firm must make a sustained commitment to only one of the strategies in order to achieve competitive success. A firm that fails to do so runs the risk of being "stuck in the middle" - with higher costs while pursuing a low cost strategy or less differentiation while pursuing a differentiation strategy.

Strategy and Technology. Manufacturing technology has not been an issue of concern in conceptualizations relating to strategy content or process. While its place in strategic management has been recognized (Andrews, 1971; Ansoff, 1965), its role is assumed to be confined to strategy implementation activities only. As Skinner (1985) laments, manufacturing technology is viewed both by scholars and practitioners as essentially a "good soldier" that dutifully implements the various business strategies formulated by top management from time to time. The implication is that product/market and

strategic choices are often made without concern for manufacturing capabilities. A general criticism in the current manufacturing literature is that strategic management theory and practice have for long neglected to take note of the importance of manufacturing technology for competitive strategy formulation (Gunn, 1987; Skinner, 1985). The present American competitive malaise in international markets is attributed to this anomaly.

Reasons for Disregarding Technology. An important reason for disregarding technology in strategy formulation pertains to the manner in which the manufacturing function is perceived and treated in strategic management (Hayes & Wheelwright, 1984; Hayes, Wheelwright, & Clark, 1988; Wheelwright, 1985). For long, manufacturing has been the repertoire of the engineering discipline where the emphasis is on devising mechanisms for accomplishing tasks in an orderly manner. Rationality and logical algorithms have formed the basis for achieving this end. By dividing the task into sub-tasks and integrating them sequentially, engineering has introduced standardization in manufacturing in order to ensure predicatability. A predictable task is not obviously a basis upon which the competitive strategy of the firm would rest. On the other hand, it is a constant around which other less predictable tasks could be built. In line with this

thinking, manufacturing has been viewed as neutral to product/market and business strategy choices: its responsibility is not to get involved in strategy-making but only to execute the chosen strategy efficiently. These narrow assumptions have kept manufacturing out of strategy formulation, creating in the process a mismatch between the firm's new strategy and its manufacturing emphasis.

Recent Trends: Flexible Automation (FA). In recent times, changes occurring in the general environment and industry's technological environment are thrusting manufacturing technology to the forefront in competitive strategy management. To elaborate, socioeconomic trends leading to fragmented and atomized markets have shifted the competitive emphasis from high volume, standardized production to differentiated production. Further, a fast changing, global market framework has forged a new type of competition that is based upon product innovation, speed, and offering more value to customers (e.g., quality or flexible volume at no extra cost). Clearly, traditional competitive philosophies that recommend a "select and defend" approach in strategy formulation have become especially inappropriate for manufacturing companies operating in complex and dynamic environments.

To effectively meet segmented and changing markets, firms have been reformulating some of their manufacturing operations by using the computer. Depending upon the area and level of computer application, various sub-technologies have developed and are often classified within the umbrella of FA. While these sub-technologies have their individual merits in their respective area of application, their capabilities are considered to be far greater when integrated and controlled by a central computer. The following is a brief description of some of the more popular sub-technologies forming part of FA, the strategic advantages they provide to the firm, and how they have altered the trade-offs that manufacturing firms have traditionally faced in the selection of competitive choices (For more details on these technologies, see Groover, 1987; Meredith, 1987b):

1. A computer-aided Design System (CAD) which develops designs, displays them, and stores them for future reference or modification. CAD reduces the time and effort required to develop new product designs, custom designs, or make quick modifications to improve product producibility.
2. A computer-aided Engineering System (CAE) which enables the product's design to be

tested graphically without building expensive prototypes. CAE thus reduces the lead time and cost in developing and marketing new products.

3. A computer-aided manufacturing system (CAM) that translates CAD information for manufacturing the product according to design instructions. It prepares the route sheets by listing the sequence of operations and controls machine tools, robots, material flow and testing equipments to achieve production according to plan. Scope production (i.e., variety production) and high machine utilization are the advantages provided by CAM. Integrating CAD and CAM minimizes the "design to production" changeover time thus enhancing product quality and producibility.
4. An automatic storage and retrieval system (AS/RS) which delivers a batch of parts to a location or picks up a part from a location for storage. Significant advantages of AS/RS are in saving labor costs and in efficient use of inventory storage space.
5. A supervisory computer that controls and integrates all of the above.

Implementing FA. Successfully implementing a technological choice requires an assessment of its impact over the firm's business strategy. In the case of traditional automation (i.e., fixed automation), its repertoire was confined to low cost production of a standard product. Firms attempting to use differentiation strategies with a standard technology found themselves in a competitively ineffective position. Thus, in decisions relating to manufacturing technology, a firm had to make a choice between low levels of automation for achieving a high processing flexibility and high levels of automation for achieving a low processing cost. In the former, a firm had to trade off high volume and low cost for custom and variety production; in the latter, it was the reverse. As to what choice a firm would make depended upon its business strategy. The mission of manufacturing technology thus followed as a natural corollary to the firm's preselected market goals.

In the case of FA, computerization has significantly widened the repertoire of an automated technology: from efficiency competences only to a combination of efficiency, quality, and variety competences. That is, firms using FA can now employ more than one generic strategy at the same time without getting stuck in the middle (See Dean & Susman, 1989). Further, due to its implications

for both product design and processing operations, FA can facilitate the effective execution of a planned product or the development of a new product in an exploitative manner. Successfully implementing FA requires that its competences be taken into account at the business strategy formulation stage. Firms that have disregarded this logic, are reported to have incurred significant financial losses (Goldhar & Jelinek, 1983; Jaikumar, 1986; Skinner, 1985).

#### Linking Strategy and Technology: Current Approaches

Increasing competitive intensity for manufactured products and reports of serious problems that firms have encountered in implementing FA had generated a spate of speculative and journalistic writing on technology-strategy relationship. There is, at the same time, a small body of scholarly qualitative studies that have sought to conceptually link business strategy and manufacturing technology.

The Focused Factory Model: Skinner (1969, 1974) proposed a match between business strategy and technology by narrowly focusing the factory's processing characteristics towards the firm's competitive choice. Simply stated, the manufacturing objective of the firm, as evidenced by its technological characteristics, should be directed towards achieving one task in a specialized

manner, that is, consistent with the firm's business strategy. The factory's focus is thus derived from the firm's business strategy. The underlying assumptions in this model are:

- a) There are a number of choices that a firm can choose from to compete in an industry (e.g., cost, quality, delivery).
- b) The manufacturing operation of a firm can not excel in performance across all of them.
- c) By focusing on one choice only and repeatedly striving at it, performance excellence can be achieved.
- d) The choice for manufacturing should logically flow from the firm's business strategy.

The logic behind the 'focus model' is thus analogous to that of Porter (1980): a firm that does not concentrate on a single competitive objective gets stuck in the middle. By pursuing several missions at the same time, manufacturing achieves none successfully, thus becoming a millstone rather than a competitive weapon for the firm.

The Product-Process Life Cycle Model: Following the focused factory logic and borrowing from Abernathy & Utterback's (1978) model of evolutionary innovation, Hayes & Wheelwright (1979a & 1979b) proposed a life cycle

framework for linking strategy and technology. The framework suggests that processes evolve and go through a cycle just as products do. Successful performance therefore depends upon the extent to which a firm fits its process structure with its product structure. The authors recommend that to avoid a product-process mismatch, a firm should incorporate both product/market and process technology decisions in its strategy formulation. This should enable a firm to plan creatively for processing capabilities that would match the needs of a product across successive stages of the cycle.

Similar ideas have been expressed by Buffa (1984) who suggests that business performance depends upon the extent to which a firm is able to position its production system to match the market requirements.

System's Approach: Conceptualizing the patterning of activities in the processing function as a production administrative structure (PAS), Jelinek & Burstein (1982) proposed a system's approach to link technological choices with the firm's business strategy and organizational structure choices. The argument made was that the PAS is a subsystem of the total organization and, as such, "should be shaped to reflect elements of the firm's strategy (...defined as market choice, consequent process technology choices, and organizational design choices)"

(see p.250). In a nutshell, the firm's market and technology choices along with organizational design and PAS must be in a fit stage. Performance implications of this fit, though implied, have not been expressly specified in the framework.

#### Summary: Problems with the Current Approaches

Current business strategy literature (both content and process) can be broadly divided into two parts: a) the contingency-based and b) the generic type. In the former, competitive choices are described to be a function of market contingencies (e.g. product life cycle, market growth rate). Success of a firm in this approach depends upon its ability to correctly identify market trends and adopt appropriate marketing strategies. Other functions within the firm such as manufacturing and distribution are expected to lend support to these marketing strategies. Evidently, strategy content and process here are reactive. In the second approach, a firm may choose a generic strategy (cost, differentiation) for adoption, based upon the strengths it may possess in a functional area (e.g., manufacturing, distribution). To be effective in this approach, a firm should be able to successfully defend the strength on which its competitive strategy is based, through periodic refinements. Apparently, strategic decisions here are defensive.

Both these approaches are based upon the "outside-in and top-down" logic. Recent changes in markets and technologies are, however, demanding a dynamic thinking in competitive strategy conceptualizations. Developments in computer automation have made process technology evolutionary, causing it a significant source of inter-firm variation in competitive capabilities. At the same time, markets have become fragmented and highly dynamic indicating that firms should now compete on more than one criterion in a single market (e.g., quality at a lower cost) or on several criteria in multiple markets. To meet these new empirical developments, a business strategy framework which will conceptualize and describe competitive strategy as the result of a dynamic technical competency of the firm is needed. Models that have been proposed in this area as described above seem inadequate to meet this demand and can be faulted on one significant ground. They all assume a top-down approach in strategy-technology relationship. That is, the technological choice of a firm is considered as a natural corollary to the firm's strategic choice. An implication of this assumption is that manufacturing technology is a static device that cannot create products and markets or new criteria for competing in them.

This dissertation proposes a research framework

within which the role of technology as an independent variable in strategy formulation and implementation can be explained and investigated. The framework describes a firm's technology as an endogenous variable that continuously changes to remain in alignment with the industry's technological developments. Such changes however alter technology's design and processing capabilities. The framework explains the impact of a firm's technology in strategy formulation and implementation based upon its changing competences. That is, changes in a firm's technological competences alter its fit relationship with business strategy and organizational structure. Regaining fit would require adjustments in these areas which are in the direction of the firm's new technological strengths.

The concept of technological evolution as a dominant industry variable (Porter, 1988; Rosenberg, 1982; Sahal, 1981) provides the framework with the basic foundation for linking a firm's technology directly to its external environment. The concept of "fit" (Andrews, 1971; Miles & Snow, 1984) provides the underpinning for linking business strategy and organizational structure to the firm's evolving manufacturing competences.

## CHAPTER 3

### THE CONCEPTUAL FRAMEWORK

Purnamadah purnamidam  
purnat purnamudacyate;  
Purnasya purnamadaya  
purnamevavasisyate.

Isa Upanishad  
(Peace Invocation-  
Verses in Sanskrit)

Translation: The invisible (Supreme Being) is the Full; the visible (the universe) too is the Full. From the Full (Supreme Being), the Full (the visible universe) has come. The Full (Supreme Being) remains the same, even after the Full (the visible universe) has come out of the Full (Supreme Being).

Purport: Cause and effect, beginning and end, substance and attribute are relational terms. Truth knows no such distinction since it is an abstract concept. As such, truth can be understood only by using a metaphysical framework.

#### 3.1 Outline

This chapter develops the conceptual framework for undertaking the research proposed in this dissertation. It first describes the previous theoretical works upon which the substantive relationships of the variables included in the proposed framework would rest. It then introduces the elements of the framework, defines them by using extant literature as guidance, and relates them to each other with the help of the theoretical works

described. Relevant hypotheses are drawn for testing the proposed framework.

### 3.2 General

Hypothesizing relationships amongst variables and verifying their existence is an accepted goal of science. Kuhn (1970) describes two ways by which scientific knowledge evolves within a discipline: cumulatively and through revolutionary ways. In the former, accumulation of data leads to a more refined picture of the way things are. Kuhn calls this the "normal science" or paradigm-based studies in which the problems are stated and solved esoterically, using existing scientific traditions. In the latter, alternative theoretical schemes are proposed as explanations for the reality being encountered. Kuhn argues for the latter indicating the importance in science for the emergence of new ways to examine the nature of reality.

The history of science is indeed a history of competing views for conceptualizing, explaining, and verifying phenomena. Normal science studies are constrictive since they do not offer opportunities for an informed awareness of alternative viewpoints. Given the dialectical nature of things in the social world, antithetical ideas which promote diversity and encourage

eclecticism are necessary for progress in a social science discipline.

### 3.3 Conceptual Foundations for the Framework

#### The Concept of Change

The concept of change occupies a central place in strategic management conceptualizations (Andrews, 1971; Hofer & Schendel, 1978). Underlying this concept is the notion that a firm which has a better knowledge of the sources of change and which further has appropriate internal mechanisms to deal with them will survive and grow. The emphasis here is thus upon identifying, developing, and holding certain distinctive competences which are necessary for the firm to create a competitive difference within the industry. Simply stated, superior performance is assumed to be a function of the exclusivity that the firm possesses in critical areas of a business. Inferentially, anything which is generic and universally held does not provide a strategic advantage to the firm.

Technological Change. In recent times, changes occurring in the organization's environment are described to be of an evolutionary nature, caused by the innovation trends occurring in product and process technologies (David, 1985, 1987; Hughes, 1983, 1987; Rosenberg, 1982;

Sahal, 1981). That is, changes in technology do not culminate and stop at a predetermined goal but they continuously progress towards higher and more complex levels. Sahal (1981) views technology as a self-organizing system that evolves through experimental learning. The dominant design or technological guidepost that emerges due to this learning acts as a basis or stimulus for further technological change in a step-wise fashion. Sahal cites the successive growth witnessed in the computer technology over a short period of twenty five years as an example of this step-wise, continuous change. Similar observations have been made using the food, chemicals, and pharmaceutical industries as examples (De Bresson & Townsend, 1981).

The technological evolution model is described to be different from its precursor, the biological evolution framework, in one significant manner. Whereas distinct biological species cannot interbreed, step-wise technological change is described to frequently occur through a creative symbiosis (Rosenberg, 1982; Sahal, 1981) of two or more previously unrelated technologies. Martin (1984) provides some examples of technological change through symbiosis: use of nuclear power in marine propulsion; solid state electronics in numerical control systems. Similarly, Schroeder (1990) cites instances from the work

of Silverman & Bailey (1961) which indicates that the simultaneous innovations in corn, seed, fertilization, and planting techniques were required in order to generate the full potential of each.

The evolutionary approach to technological change has the following implications for the proposed framework:

1. Technology should be viewed as more than a mere set of tools and equipments. It should be treated as a body of competences, skills, and know-how that continuously evolves in human minds for conceiving, developing, and executing products.
2. To remain competitive, a firm's product and process technical know-how should be in congruence with the industry's technological trends. A firm's technological choice and competences are thus directly affected by its technological environment.
3. An industry's technological state can be described in terms of the technological sophistication achieved by the industry leader. A firm's technology (i.e., its technical advancement) therefore affects the industry's technological environment.

4. A firm can create a competitive superiority within the industry by using a combination of leading-edge technology (both hardware and software) and business choices which are internally consistent and externally opportunistic (i.e., timely and appropriate for the firm's products and markets).

#### The Concept of "Fit"

While change produces intrafirm and firm-environment disequilibrium, organizational effectiveness is often conceived as the result of a logical "fit" amongst the firm's internal elements (Child, 1975, 1977; Khandwalla, 1973) and between the firm and its environment (Anderson & Zeithaml, 1984; Hitt, Ireland, & Stadter, 1982; Venkatraman & Prescott, 1990). The concept of "fit" thus receives a parallel importance in strategic management thinking.

The concept of "fit", rooted in the contingency theory paradigm (Fiedler, 1967; Lawrence & Lorsch, 1967), is based upon the assumption that a logical relationship (i.e., the form of relationship) exists between variables across changing conditions which will contribute to performance. Central to the theoretical ideas here is the natural selection proposition (Aldrich & Pfeffer,

1976; Hannan & Freeman, 1977), namely, that the organizational characteristics must "fit" with their environmental context if the organization is to survive or be effective. Stated otherwise, the impact of organizational characteristics upon performance will be positive or negative depending upon their "fit" with the environmental characteristics. For example, an organic structure will have a positive influence over performance when the environment is dynamic since the characteristics of an organic structure and the characteristics of a dynamic environment are congruent. The underlying emphasis in a "fit" model is thus upon two issues: a) specifying the various contingencies that arise due to change, and b) specifying a "fit" relationship that will lead to higher performance.

The implications of the "fit" concept for the proposed framework are:

1. Changes in a firm's technology will affect its fit relationship with business strategy and organizational structure.
2. Lack of fit amongst technology, strategy and structure will affect performance.
3. Regaining fit amongst these variables to achieve performance will require a logical basis by which both strategy and structure

can be matched to the new technology.

Issues Relating to the "Fit" Concept: Over the years, studies have conceptualized and proposed "fit" relationships between strategy and structure (Chandler, 1962; Rumelt, 1974), technology and structure (Harvey, 1968; Perrow, 1967; Thompson, 1967; Woodward, 1965), environment and strategy (Anderson & Paine, 1975; Miles & Snow, 1978; White & Hamermesh, 1981), environment and technology (Lawrence & Lorsch, 1967), administrative systems and strategy (Galbraith & Nathanson, 1978), leader characteristics and strategy (Kerr, 1982; Szilagyi & Schweiger, 1984), leader traits and group characteristics (Fiedler, 1967) and reward systems and strategy (Kerr & Snow, 1980; Salter, 1973; Schellenberg, 1983).

While the popularity of "fit" as an important theory building tool in strategic management is thus evident, a significant problem in past studies is the nebulous manner by which "fit" has been conceptualized (see Fry & Smith, 1987; Schoonhoven, 1981; Van de Ven & Drazin, 1985; Venkatraman, 1989a). Abstruse and often a metaphorical definition of the "fit" relationship (e.g., "aligned with", "matched with", "congruent with") has led to the use of inappropriate statistical tests and consequent inconsistency of research results (Schoonhoven, 1981). Clarity in terms of verbalizing "fit" relationship and

specifying the statistical scheme for testing such relationship is therefore critical for formulating strategic management theories.

Two other issues in this area are worth noting here. Erstwhile studies have largely focused the use of "fit" paradigm to explain specific linkages only (e.g., strategy and structure or technology and structure) while global frameworks for examining strategic management relationships have been called for (Jemison, 1981; Waterman, Peters, & Phillips, 1980). Developing a congruent theory of strategic management requires that relationships amongst the various strategy formulation and implementation variables be explained and examined within a larger and integrative framework.

The second issue involves specifying the performance implications in the hypothesized fit relationships. Most previous research (for examples here, see Drazin & Van de Ven 1985) using the "fit" paradigm has excluded performance as a variable in their models possibly due to an implicit assumption that performance is inherent under "fit" conditions. As Fry & Smith (1987; See, also, Drazin & Van de Ven, 1985) note, theoretical models that specify linkages between variables will have no contributory value unless a predictive component (e.g., performance) to test the efficacy of the linkage is included in those

models. Specifying the nature of relationship amongst variables and further specifying how this relationship will affect performance under various system states is essential for developing comprehensive theories of strategic management.

### 3.4 The Framework

The technological change model and the "fit" paradigm provide the conceptual basis for the framework proposed here. Using the technological change model, the framework describes a firm's technology as an endogenous variable that undergoes frequent adaptive changes to remain competitive within the industry's technological environment (ITE). A firm's manufacturing technology choice is thus directly affected by the dynamics of the ITE. Using the "fit" paradigm, the framework suggests that changes in the firm's manufacturing technology will alter its competences and consequently its fit relationship with business strategy choices and organizational structure choices (both administrative and operational). Regaining "fit" would require adjustments in business strategy and organizational structure that complement the changing competences of the firm's manufacturing technology. Thus, the degree of complementarity amongst the firm's manufacturing technology, business strategy,

and organizational structure within the constraints posed by the ITE and the generic socioeconomic environment will determine the firm's performance on various dimensions.

#### Elements of the Framework

The following describes and defines the constructs used in the framework:

**SOCIOECONOMIC ENVIRONMENT.** This environment, external to the organization, comprises macro level forces operating in the social, economic, cultural, technological, and political spheres. Some examples of such forces are consumers' life-style, family formations, population trends, government expenditures, political climate, and long term technological trends. Changes in these areas provide new product opportunities to a firm or constrain its activities in an existing business. Such changes also influence the selection of competitive choices for the firm such as product price, quality, etc.

**INDUSTRY'S TECHNOLOGICAL ENVIRONMENT (ITE).** The evolutionary nature of technology posited here suggests that a firm's technological advantage is not absolute but relative to the state of technological development prevailing in the industry and especially as it pertains to the technological resources available to other firms viewed as primary competitors. Evidently, this environ-

ment, external to the organization, refers to the trends occurring within the industry in new technology development and eventual adoption by firms to achieve competitive capabilities in the areas of product design, processing, testing, storage and retrieval, etc.

MANUFACTURING TECHNOLOGY CHOICES. Currently, manufacturing technology is broadly classified based upon the type of automation, i.e., fixed or flexible, used in the production function (Buffa & Sarin, 1987:471). In general, automation involves controlling each machining activity and integrating it with other machining activities. Controls on machines can be set to perform single operations (e.g., cutting or drilling) repeatedly so as to achieve maximum volume, efficiency, and conformance to standards on a product. However, to achieve machine integration in this approach, the product must first be designed and the manufacturing sequence planned accordingly. As a result, the automated system becomes dedicated to the needs of a planned product and hence known as fixed automation. On the other hand, controls on machines can also be set to perform the specific operation needed by an incoming product in order that processing flexibility (i.e., producing variety) can be maximized. To achieve machine integration in this approach, each machine has to be first programmed to

perform several operations and the transfer of operations amongst machines has to be controlled by a central computer. The automated system thus becomes flexible to the processing needs of several operations and hence known as flexible automation.

The above describes the basic distinction between fixed and flexible automation in machining operations. However, firms are known to automate by using computers to link only some or several manufacturing activities (e.g., machining with design, or testing, or both). Manufacturing competences would depend upon such linkages. Further, automation invariably occurs in stages and in a piecemeal fashion. Besides, not all operations can possibly be linked by a computer. It is therefore more appropriate to describe a firm's technology as falling within a flexibility continuum, measured in terms of the intensity of flexibility.

Intensity of Flexible Automation (IFA) - This construct defines the extent to which a firm uses FA as an element of its manufacturing strategy. IFA is measured in either one of the following ways:

$$\text{IFA} = \frac{\text{Capital Outlay in Computer Automation (Replacement Value)}}{\text{Capital Outlay in Fixed Automation (Replacement Value)}}$$

$$\text{IFA} = \frac{\text{Capital Outlay in Computer Automation (Replacement Value)}}{\text{Total Manufacturing Outlay (Replacement Value)}}$$

A significant issue with the above measure is that it does not provide an understanding of the firm's competences in individual technologies comprising FA (i.e., CAD, CAM, etc.). Availability of measures that would capture a firm's flexibility strengths in distinct operational areas (i.e., design, processing, etc.) is a boon to researchers since they would facilitate sophisticated data analysis. While developing such separate measures is not at all difficult, this researcher feels that data collection using such scales should pose problems since most firms may not have a break-up of investments on various sub-technologies comprising FA. The best solution under the circumstances is to exercise control at the sampling stage: selectively surveying firms which have made investments in sub-technologies which are of interest to the researcher.

The rationale for using IFA as a proxy for manufacturing technology choices can be best understood in terms of: 1) the range of choices available to a firm between fixed and flexible automation, and 2) the evolutionary nature of manufacturing technology that is posited here.

The degree of IFA for a firm depends upon the imperatives that the industry poses to the firm to maintain its technological competitiveness. Other factors that determine the IFA level for a firm are that

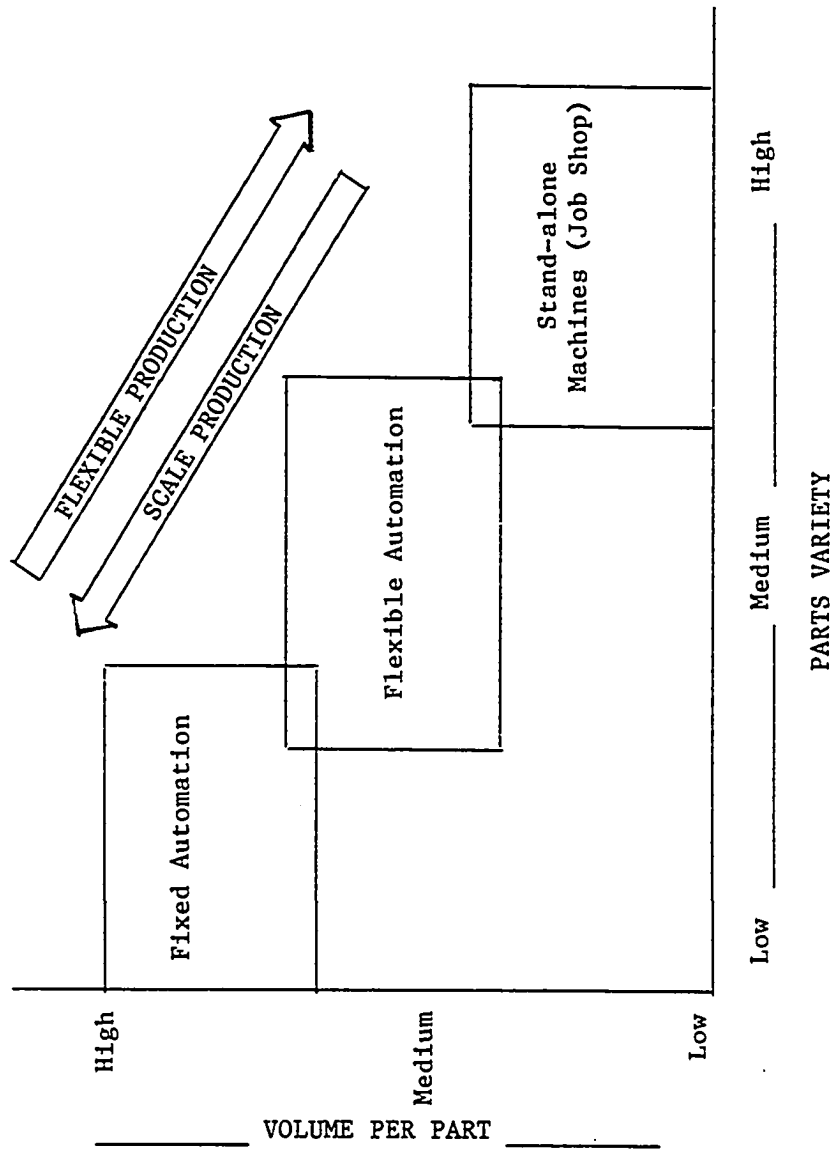
firm's competitive position vis-a-vis its competitors' both in terms of manufacturing costs and market positioning; rate of technological ossification occurring within the industry; strengths in technology, technical competence; availability of necessary capital and human resources; and preferred strategic choices.

FA Competences - Differences in machine control and integration techniques used by fixed and flexible automations support the notion that they will have opposing competences in production. At their extremes, fixed automation can maximize volume and cost efficiencies in a single operation (scale production competency) whereas flexible automation is strong in product or volume change, processing speed, and machine utilization (i.e., flexible production competency). Figure 3.1 explains these differences diagrammatically.

As is evident, FA is not conducive to maximizing volume just as fixed automation is not, in regard to variety. However, since the technology of a firm is described to be on a flexibility continuum, the issue of what is FA's processing competence would depend upon the the firm's IFA: the higher the IFA, the higher is its competency for processing variety and frequent product changes.

**BUSINESS STRATEGY CHOICES.** Business strategy answers

FIGURE 3.1  
 TYPES OF MANUFACTURING SYSTEMS AND COMPETENCES



Adapted from Hegland (1981)

the question: How will a firm compete in the markets it chooses to serve? Three strategic choices that have a direct bearing upon the manufacturing competences of a firm are considered here: cost leadership, quality leadership, and flexibility (Dean & Susman, 1989; Wheelwright, 1978). While these choices are specific in their connotation, they should be viewed as the logical offshoot of a firm's mission and long-term objectives which together form its overall strategy. Thus, any discussion of these choices would invariably subsume its relevance for the firm's overall business strategy.

1. Cost Leadership - refers to the firm's intentions to strive for the most efficient producer status in the industry. The manufacturing approach associated with this strategy is that of fixed automation: long production runs, limited product mix, and reasonable quality standards. While an acceptable level of product quality cannot be ignored here, cost minimization is the overriding priority. Hyundai exemplifies this strategy in automobiles. A firm which emphasizes volume sales, operating efficiency, process R&D, product selling price,

price, refining existing products, etc. as its competitive priorities would be considered to be pursuing this strategy.

2. Quality Leadership - refers to the firm's intentions to strive for leadership position in the industry based upon product performance, reliability, and features. Unlike the cost leadership strategy which emphasizes low cost per unit, quality strategy emphasizes high quality per unit and small production runs. While cost minimization is important here, maintaining and improving quality through multiple and unique product attributes is the overriding priority. Mercedes exemplifies this strategy in automobiles. A firm which emphasizes unique/advanced product design, product features, brand identification, etc. as its competitive priorities would be considered to be pursuing this strategy.
3. Flexibility - refers to the firm's intentions to compete in a single or several markets by satisfying market needs for product mix, volume mix, quality, and innovation in a cost effective manner. That

is, the firm attempts to maximize differentiation (Porter, 1980) without jeopardizing cost. Two types of flexibility are emphasized here: Scope Flexibility and Speed or Changeover Flexibility (See Gerwin, 1989; Meredith, 1987a). Currently, some of the automobile, aerospace, and consumer electronics companies are reported to be pursuing these strategic choices. Emphasis on product variety, volume flexibility, and custom production indicates scope flexibility. Speed in innovation, frequent new product introductions, and fast delivery are some indicators of speed flexibility.

A firm's choice of business strategy will depend upon its manufacturing competences, the constraints posed by the firm's internal mechanisms (i.e., its technology and organizational structure), and the demands of the external environment. Techniques that were used to measure business strategy choices are described in the methodology section of this dissertation.

ORGANIZATIONAL STRUCTURE CHOICES. Organizational structures have been classified based upon the division

of task and authority (horizontal and vertical differentiation), and the level of integration used. Using these criteria, structures have been variously classified as product, process, or combination and tall or flat types. A typology that subsumes most classifications is the bipolar mechanistic-organic continuum (Burns & Stalker, 1961). A structure is mechanistic when tasks are rigidly defined (i.e., highly specialized), authority is centralized, and planned mechanisms are used for integration. It is organic when tasks are loosely defined (i.e., highly generalized), authority is decentralized, and integration is based upon targets (Galbraith, 1974).

The framework includes in its analysis of organizational structure both the firm's overall structure and its operational structure. Some of the commonly discussed components of operational structure are division of task, operator skills, operator autonomy, and functional coordination (see Boddy & Buchanan, 1986; Majchrzak, 1988; Walton, 1989).

Organizational structures are considered to be a function of the firm's environment (Lawrence & Lorsch, 1967), strategy (Chandler, 1962), and manufacturing technology (Harvey, 1968; Woodward, 1965). Consistent empirical support exists for strategy as a determinant of the firm's structure (Rumult, 1974; Wrigley, 1970)

whereas mixed results have been obtained in research pertaining to the other two variables. However, the body of literature involving technology-structure and environment-structure investigations is significant enough to warrant serious consideration while discussing organizational structure. The framework proposed here therefore includes technology in explanations relating to the causes of structure. As regards the environment, while its impact upon structure is recognized, no attempt has been made here to include it in theoretical discussions.

Details regarding how organizational structure was measured are given in the methodology section of this dissertation.

PERFORMANCE. For the purposes of this dissertation, measures of performance should accomplish two things:

1. They should demonstrate the efficacy of the combined effect of all input variables and their interactive influence in maximally achieving the firm's long-term financial and competitive goals. These may be termed as "Output Efficiency Based Performance Measures" (OEBP). They include the conventional measures of a firm's performance (return on sales, return on investments, etc).

2. They should also demonstrate the efficient use of a specific input element which the firm considers to be the critical core of its competitive strategy. In economic terms, these are the scarce resources or a firm's unique attributes upon which it expects to build its foundation of success. These may be termed as "Input Efficiency Based Measures" (IEBP) and include general measures of customer satisfaction involving product quality, uniqueness, useful life, etc.

Both these measures would be used for assessing the performance impact of FA. The objective of OEBP measures is to understand the performance effects of FA in association with strategy and structure. IEBP measures seek to assess the independent and immediate effects of FA on performance.

These are, indeed, only approximate measures and may suffer from the contaminating effects of various internal and external factors. Under ideal conditions, one would like to isolate such contaminants so that one may measure the true impact of FA on performance. However, such ideal conditions are well nigh impossible. In the above measurement scheme, a firm may have a high IFA and a sound internal fit and yet perform poorly either because

of market conditions (e.g., recessionary economy) or because of an inefficient use of FA. A firm's overall performance may be positively or adversely affected by the general economic conditions, government's fiscal and taxation policies, industry structure and competitive environment, national and international political changes, to name a few.

Measures of IEBP pose similar problems. For example, customer satisfaction may be affected by relative changes in performance by a firm's competitors, general attitudes toward certain products or distribution channels. Also, firms are not known, in general, to compile qualitative data that would reveal the independent effects of manufacturing technology on the firm's financial or market performance.

Under the circumstances, one can offer only approximate measures and leave it to the researcher to employ additional measures of control during data collection. For example, in the case of OEBP measures, one may minimize the effect of exogenous variables by controlled sample design (i.e., using samples that experience the same environmental conditions). In IEBP measures, data may be derived from the perceptual observations of respondents.

Details regarding how performance was measured are

provided in the methodology section of this dissertation.

### Linking the Elements

A central proposition inherent in the proposed framework is that a firm's choices in manufacturing technology, business strategy, and organizational structure should be in a "fit" stage for superior performance to occur. But the firm's ITE is described to be evolutionary, causing the firm to modify/change its manufacturing technology in order to prevent its ossification and to maintain the firm's technological competitiveness within the industry (For some examples here, see Schroeder, 1990; Schroeder, Congden, & Gopinath, 1988). Such changes however alter the firm's design/ processing competences (or constraints) thereby creating a misfit amongst manufacturing capabilities, business strategies, and organizational structure. Regaining "fit" requires adjustments in the emphasis that the firm places in its business strategy (e.g., low cost, quality, flexibility or any combination) and in its organizational structure (e.g., processes or end-results). To the extent that such adjustments reflect the changing competences and constraints of the firm's manufacturing technology, there should be an internal "fit" and consequently performance. By implication, the higher that a firm's business strategy and organizational

structure choices complement the firm's manufacturing capabilities, the higher is performance.

Adjusting the firm's strategy and structure according to its manufacturing technology capabilities could cause a "firm-environment" misfit: between the firm's strategic intent and the demands of its external environment. It is suggested here that firms gain this "fit" proactively: by altering the rules of competition in the industry. This argument is consistent with the dematurity logic proposed by Abernathy, Clark, & Kantrow (1983). The changing nature of competition in the automobile industry due to changes in manufacturing technology is a good empirical example here (For some other examples, see Meredith, 1987a).

The above description is a "bottom-up and inside-out" approach in strategy formulation. It is indeed a narrow description of the strategy-making process, especially when viewed in the backdrop of the eclectic approaches that strategic management writings currently espouse. Yet, this limited description was chosen to facilitate an in-depth examination of strategy formulation and implementation that occurs within the narrow confines of manufacturing technology strengths. Indeed, this researcher recognizes and subscribes to the interactive propositions in this area, namely, that

strategy formulation is a combination of "outside-in/inside-out" and "top-down/ bottom-up" processes. That is, strategies result both through deliberate planning and through an experimental involvement between the firm's internal competences and external demands.

#### Dimensions of "Fit" in the Proposed Framework

"Fit" amongst manufacturing technology, business strategy, and organizational structure is conceptualized in the proposed framework using the "matching" perspective and the "moderating" perspective described in the strategic management literature (Venkatraman, 1989a; Venkatraman & Camillus, 1984). A classic example of fit as a match between variables is Chandler's (1962) thesis on strategy and structure relationship. The match between these two was logically derived in the form of propositions: a geographical expansion strategy and a field unit structure are congruent; or, a diversification strategy and a divisional structure are congruent. The critical requirement here is thus a theoretical specification of a congruence relationship between variables. The implications of this congruence relationship, though not verbalized, are implicitly assumed to be important (Drazin & Van de Ven, 1985; Fry & Schellenberg, 1984).

The moderating perspective describes relationship amongst variables in interactive terms. The theoretical

import here is that organizational variables interact with each other and produce an effect upon performance which is significantly different from their independent effects. Evidently, the emphasis is to identify variables that are associated with each other and further to specify the form and strength of this association on performance (Arnold, 1982). Thus, not only is a match or isomorphism amongst variables that is important here but a higher value for those matching variables is equally important since they would produce a higher performance due to their joint effects (Drazin & Van de Ven, 1985).

Using the matching perspective, the framework argues that a match amongst manufacturing technology, business strategy, and organizational structure will be necessary for achieving superior performance. The match here is specified based upon the competences and constraints of the firm's manufacturing technology. Thus, scope and change competences in manufacturing technology are congruent with quality/flexibility business strategies and an organic organizational structure in terms of superior performance. Scale and standardized production competences in manufacturing technology are congruent with cost leadership strategies and a mechanistic organizational structure in terms of superior performance.

Using the moderating perspective, it is hypothesized

here that the effects of manufacturing technology competences on performance will vary across different values of business strategy and organizational structure choices that are complementary to technology's strengths. Thus, quality/flexibility business strategies and an organic organizational structure complement scope and change competences in manufacturing technology. Therefore, the higher the importance attached to these choices when the manufacturing competency is scope and change, the higher will be performance. Likewise, cost leadership strategies and a mechanistic organizational structure do not complement scope and change competences in manufacturing technology. Therefore, the higher the importance attached to these choices when the manufacturing competency is scope and change, the lower will be performance.

The methodology section describes how fit amongst the concerned variables was measured.

### 3.5. Hypotheses

The framework proposed here is used to generate hypotheses for the user of FA technology. The unit of analysis here is a manufacturing entity that uses FA as defined and described earlier in this dissertation. It may be either a company or an SBU. If it is a company, it

is a large, single product firm with a functional organization. If it is an SBU, it is a product group or division of a diversified firm with a separate manufacturing and marketing set up. Ideally, the unit of analysis is a business that determines its own manufacturing and marketing strategies.

An important caveat here is that the technology used by the unit of analysis should have investments in both CAD and CAM. The reason for this caveat is that the hypotheses offered here are applicable only to a firm that has a flexible technology in both its design and processing operations. For analytical purposes and for inter-firm comparison, however, the criterion used is the IFA.

The hypotheses proposed here pertain to the two distinct areas of strategic management: strategy formulation and strategy implementation. They are derived from the thesis developed in this dissertation and they make suggestions regarding what business strategy and organizational structure choices will be appropriate for an FA user in order to achieve superior performance.

### Strategy Formulation

Strategy formulation comprises the articulation of a mission for the firm by way of products and markets in

which it would compete, a set of long-term objectives to be achieved within the stated mission, and a strategic plan specifying how the mission and objectives will be realized. The framework proposed here suggested that under evolving technological conditions, strategy formulation be based upon the competences and constraints of the firm's manufacturing technology as measured by its IFA. The competences of flexible automation involve both scope and speed flexibility. Its strengths are in the economical production of variety, frequent design changeovers, and rapid processing of engineering and market information. Its constraints are its unsuitability for economically producing in large volume a standardized product. Translated in terms of tasks and objectives, the mission for a user of flexible automation should specify a broad scope for its products/markets and include product and process innovation as a critical theme for the business. Long-term objectives should emphasize growth/profitability through diversity and change rather than through market share in a single product/market segment. Typically, objectives should underscore a process orientation (variety, innovation, custom production) rather than a product orientation (efficiency, high volume) in the selection of market-related choices. Some examples of objectives which

emphasize growth/profitability through product/market scope and change are: a) seeking new markets for existing products; b) developing new products for existing markets; c) developing new products for new markets. Some examples of objectives which emphasize growth/profitability through scale and standardized production are: a) maintaining market share for existing products; b) increasing market share for existing products. Stated as a proposition, the performance of a flexible automation firm will be high when its market objectives are derived from the strengths of its technology, namely, scope (i.e., product/market diversity) and change (i.e., innovation). By implication, the higher the flexibility component in an FA firm's technology and the higher that its market objectives reflect scope and change, the higher will be performance; the higher that they reflect scale and standardized production, the lower will be performance.

**Hypothesis 1a: Other things remaining equal, the higher the IFA in a firm's technology, and the higher that the market objectives emphasize scope and change, the higher will be performance.**

**Hypothesis 1b: Other things remaining equal, the**

higher the IFA in a firm's technology, and the higher that the market objectives emphasize scale and standardized production, the lower will be performance.

To fully realize a firm's market directions, and to achieve a competitive differential advantage within the industry, the competency on which a firm's strategy is based should be thoroughly exploited. With scope production a crucial FA strength, this would mean the creation of a "product-market strategy portfolio" for the firm comprising such choices as product mix, size/volume mix, custom production, etc. That is, a firm's business strategy choices should be such that they fully complement the firm's core competency strengths by directing their attention towards diversified product/market segments. Thus, an FA user's performance will be high when it places a high emphasis on scope flexibility strategy (competing in different products and markets on several scope criteria); the higher the firm's IFA and the higher the emphasis on scope flexibility strategy, the higher will be performance. This hypothesis is consistent with the arguments made by other authors (e.g., Dean & Susman, 1989; Susman & Dean, 1989), namely, FA firms should pursue a multi-product/market, multi-

competitive choice strategy in order to be effective.

**Hypothesis 2: Other things remaining equal, the higher the IFA in a firm's technology, and the higher that the competitive priorities emphasize scope flexibility strategy, the higher will be performance.**

Besides scope, speed is a crucial FA trait. Flexible systems can thrive only under conditions of instability (Reich, 1983); they are engines of change. Their strength lies in quickly manufacturing small/medium lot sizes of a product mix for diversified markets. They can rapidly and efficiently substitute new products for those that are currently manufactured and distributed. Since the markets in which they can survive are fragmented and short-lived, frequent changes in product features or new product introductions are crucial for the firm's success. Competitive choices which do not seek such changes but which mainly concentrate on defending an existing market (e.g., through pricing or promotion) would be inconsistent with this technology. Inferentially, an FA user's performance will be high under speed flexibility/quality strategy conditions but low under low cost strategy conditions. This hypothesis is consistent with some

previous research findings (See Richardson, Taylor, & Gordon, 1985; Tombak, 1986).

**Hypothesis 3a:** Other things remaining equal, the higher the IFA in a firm's technology, and the higher that the competitive priorities emphasize speed flexibility/quality strategies, the higher will be performance.

**Hypothesis 3b:** Other things remaining equal, the higher the IFA in a firm's technology, and the higher that the competitive priorities emphasize low cost leadership strategy, the lower will be performance.

The ability of FA technology to rapidly process engineering and market information indicates its usefulness in the areas of frequent product changes. However, to fully capitalize on this strength, a firm's correspondence with its environment should facilitate an active involvement between its internal technical/business elements (i.e., R&D, manufacturing, marketing) and external constituencies relevant to product/process development (i.e., suppliers, distributors, equipment vendors, and scientific/engineering community).

Organizations using FA technologies are reported to have directly linked their scheduling systems with those of their suppliers so as to rapidly respond to market demands (see Ettlíe, 1983; Hayes, Wheelwright, & Clark, 1988: 191-202). Similar on-line links with customers are reported to be in use at some FA firms to enable the customers to make any last minute design modifications on their products (Meredith, 1987a; Zygmont, 1987). In essence, the greater the importance attached to maintaining direct links between the firm and its external constituencies that are relevant to new product/process development, the greater will be the firm's operational flexibility, and higher will be company performance as a consequence.

**Hypothesis 4: Other things remaining equal, the higher the IFA and the higher that the firm emphasizes direct automated links between its operations and its environmental constituencies such as suppliers, distributors, equipment vendors, and engineering/ scientific community, the higher will be performance.**

#### Strategy Implementation

Strategy implementation occurs through organization-

al structure which involves decisions relating to division of task, authority, and a set of coordination mechanisms that will integrate these two within and across the divided tasks. While strategy largely specifies the task, and technology its coordination, both strategy and technology determine how the task and authority will be divided.

Generally speaking, flexibility involves managing variety rather than volume, change rather than the routine, and judgment rather than the standard procedures. A flexibility strategy calls for a synthesis of competitive choices which, until now, have been treated as polarities. A flexible technology calls for an integration of product planning and execution which had hitherto been considered as separate and sequential. A complex and dynamic environment in which flexible strategies and technologies are used, demands a highly integrated organizational structure in which each differentiated part can think and act in a holistic manner. Clearly, the underlying theme that is common to these three contingencies is integration as opposed to differentiation. Evidently, traditional structures which emphasize a high level of differentiation in task and authority would be inappropriate for these conditions. Instead, an integrative structure which

incorporates diverse disciplines under one banner by using task forces and committees and which makes product, market, and technology decisions based upon expert knowledge rather than the traditional managerial authority will be needed. The resulting arrangement is an organic structure, variously classified as competitive adhocracy or team structure (Mintzberg, 1979), matrix structure (Galbraith, 1971), or dynamic network (Miles, 1989).

Theoretical arguments (Mintzberg, 1979:434-435) and empirical findings (Finein, 1988; Johne & Snelson, 1988; Veraldi, 1988) support the thesis that an organic structure is most appropriate for firms which manufacture and market diverse but interrelated technological products; have broad market interests; and, face an environment of rapid change punctuated by strong competition. Some case study examples that relate organic structures to flexible automation can be seen in Boddy & Buchanan (1986), Hayes & Jaikumar (1988), and Walton (1989).

**Hypothesis 5a: Other things remaining equal, the higher the IFA in a firm's technology, and the higher that the organizational structure characteristics are organic, the higher will be performance.**

Hypothesis 5b: Other things remaining equal, the higher the IFA in a firm's technology, and the higher that the organizational structure characteristics are mechanistic, the lower will be performance.

The correspondence between technology and structure is relatively more pronounced at the operational level (Child, 1972; Child & Mansfield, 1972; Hickson et al., 1969). Different technologies place different emphases in the production and marketing of goods and influence operational level choices relating to personnel selection, control of work, and coordination methods. Fixed automation focuses on controlling the transformation of tangible inputs into outputs. Depending upon the degree of automation used (i.e., small or large batch), employee skills in this arrangement range from direct product or process knowledge to monitoring the machines engaged in production. Flexible automation, on the other hand, focuses on a higher level of abstraction: controlling the information used in the input-output transformation activity. As a result, employee skills should include knowledge relating to product design in addition to those necessary for the physical transformation of inputs into outputs (see, e.g., Adler, 1988;

Majchrzak, 1988:132-135). Further, since the complexity of the information and the speed at which it must be handled are both high for flexible automation, there is a need at the shopfloor level for workers to possess diversified operational skills and act swiftly by exercising judgment. Consequently, the competitive success of a flexible automation firm will depend upon the use of multiskilled operations personnel who possess complementary capabilities in product design and manufacturing.

**Hypothesis 6a:** Other things remaining equal, the higher the IFA in a firm's technology, and the higher is the degree of diversified skills that its shopfloor personnel possess, the higher will be performance.

**Hypothesis 6b:** Other things remaining equal, the higher the IFA in a firm's technology, and the higher is the degree of specialized skills that its shopfloor personnel possess, the lower will be performance.

Integration of activities at the operational level requires a basis by which the flow of work between

product design and production can be organized. Fixed automation, built on rational principles, relies upon the logical sequence of the workflow to determine the order of linkages (Chapple & Sayles, 1961). The sequence is planned "off-line" (Schonberger, 1982) and, depending upon market uncertainties, runs either from marketing to design to manufacturing or from design to manufacturing to marketing (Woodward, 1965). Specific techniques used to achieve integration amongst operational activities include rules, hierarchical referrals, or emphasizing the goal itself (Galbraith, 1974).

Flexible automation is based upon discrete processing concepts. The hallmark of FA lies in its ability to plan and start execution in real time. Almost instantaneously, product design and manufacturing cycle can be set in motion to meet changing market needs. Since these activities are undertaken 'on-line', a pre-planned workflow sequence is hard to construct. As a result, an operational structure that differentiates product engineering from manufacturing and subsequently integrates them using the logical flow (i.e., from planning to executing), is inappropriate here. Instead, it calls for a parallel approach where both the product design and manufacturing needs (e.g., tooling) are undertaken side-by-side. The workflow between design and

manufacturing thus becomes iterative and occurs in real time.

**Hypothesis 7a:** Other things remaining equal, the higher the IFA in a firm's technology, and the higher is the degree of parallel integration between design and manufacturing, the higher will be performance.

**Hypothesis 7b:** Other things remaining equal, the higher the IFA in a firm's technology, and the higher is the degree of sequential integration between design and manufacturing, the lower will be performance.

Besides planning for the sequencing of activities, specific methods must be designed to achieve coordination amongst diverse functions at the operational level. Fixed automation relies upon prespecified rules owing to its rational logic and sequential flow of activities. For flexible automation, since the task contingencies cannot be anticipated in advance, rules are not an appropriate technique for achieving interfunctional coordination. The diverse nature of the tasks at the operational level and the speed at which they should be planned and executed

suggests that project teams will be a comparatively effective technique for the purpose (see Ettlíe & Reifeis, 1987).

**Hypothesis 8: Other things remaining equal, the higher the IFA in a firm's technology, and the more frequently it uses project teams at the operational level, the higher will be performance.**

## CHAPTER 4

### RESEARCH DESIGN AND METHODOLOGY

Samkhyayogau prthag balah  
pravadanti na panditah;  
Ekam apy asthitah samyag  
ubhayor vindate phalam.

Bhagavad Gita (Ch.5)  
(Verses in Sanskrit)

Translation: Of reason-method and discipline method as separate, fools speak, not the wise. Resorting to even one of them, completely Man wins the fruit of both.

Purport: Epistemic knowledge is conceptually derived through philosophical reasoning or empirically gathered through experimental learning. No matter what method is used, the ultimate goal should be pursuit of knowledge.

Methodology - a hotchpotch of crude contrivances to fathom the unfathomable

#### 4.1. Outline

This chapter starts with a description of the sample and the process that was used for constructing this sample. It then describes the instruments and measures that were used in data collection. Finally, it broadly discusses the statistical schemes that are available for data analysis and describes the method that was used in this research.

#### 4.2. The Sample

The universe from which a sample would be constructed for this research was defined to be manufacturing companies using flexible automation technologies. The population was further restricted to those companies which were in operation within the geographical confines of the United States. This additional restriction was planned in order that data could be collected in a timely and economical manner.

A significant initial problem encountered in sample construction was that no exclusive directory or source material that would list the users of FA technology was available. A population had, therefore, to be derived through a careful process of narrowing down to likely users of this technology. An empirical investigation by the United States Department of Commerce (Manufacturing Technology: 1988, Publication # SMT 88-1) indicated that FA technology was most prevalent in companies operating within the Standard Industrial Classification (SIC), major group codes 34 through 38. Several other articles and research reports on FA (e.g., see "A Competitive Assessment of the U.S. Flexible Manufacturing Systems Industry", U.S. Department of Commerce, July 1985; Tombak, 1988) had made similar observations. These reports and observations provided a convenient threshold

for constructing a viable research sample.

Two other critical issues needed attention in the selection of an appropriate sample: 1) What should be the size of the company or SBU to be chosen as a sample point? and 2) Who should be the individual within the sample company to whom the survey instrument would be addressed for response?

In regard to the size issue, the hypotheses to be tested in this dissertation were such that they could apply only to medium and large size firms. Based upon this student's reading and understanding of organizational size, a medium size company was defined as one which had an employee strength of over 150 and a large size company, over 500. The employee strength of 150 thus became the cut-off point to be used in constituting a sample.

In regard to the second question, the nature of information sought decided the issue. It could be provided only by those managers who had strategic decision-making responsibilities and who further possessed knowledge about the technologies used by the company. Managers having such titles as president, executive vice president, chief operating officer, manufacturing vice president, or general manager of an SBU or product division were regarded as belonging to

this group.

Two directories were chosen as the primary source for constructing the sample: 1) Ward's Industrial Directory, Volume IV (1990 edition) and 2) Directory of Corporate Affiliations, Volume I (1990 edition). Ward's directory listed companies according to the four-digit SIC code and arranged them within each code according to sales data. The Directory of Corporate Affiliations provided, besides SIC code and sales data, the names of strategic managers, products of the company, and employee strength. The sample generated using the company size and SIC code criteria mentioned above, contained 349 (three hundred and forty nine ) companies, of which, 290 (two hundred and ninety) were U.S. companies and 59 (fifty nine) were foreign subsidiaries.

Questionnaires were sent by first class mail along with a personally addressed letter to the respondent, explaining the goals of the research. To elicit an objective response, the letter suggested to the respondents that they could remain anonymous if they wished to. At the same time, however, they were encouraged to furnish their name and address in order that a summary of the research findings could be mailed to them.

The questionnaire mailing was done in three

instalments. Fifty-seven completed questionnaires were received during the first month, representing a return of 16.3 percent. While this is indeed a low percentage response by conventional standards, a priori reasoning that this could have happened because of the lack of an advance knowledge about the FA user population proved to be consolatory. In other words, the FA user population, within the previously mentioned size constraint (i.e., 150 employees or more), could have been a much smaller number than what was targeted. If this were to be the true state of nature, it would increase the returned responses to an acceptable proportion. Nonetheless, an attempt was made to explore whether the response rate could be increased. Calls were made to all the nonrespondents to enquire whether they were FA users, the reason for their nonresponse, and whether they could now respond. Duplicate questionnaire mailings, phone reminders and requests that followed, produced 27 more responses. Of the total of 84 responses, 82 were usable, representing an effective response rate of 24 percent.

An attempt was made to statistically compare the performance (i.e., company performance) of the second batch of respondents with that of the first batch in order to ascertain whether they belonged to the same

population group. An assessment of the homogeneity of the sample was necessary to ensure the validity of the research results. Accordingly, a random sample of 10 responses were drawn from each category and an analysis of variance was performed. Results indicated at a .05 significance level that the two categories of respondents belonged to the same population group.

#### Sample Characteristics

Characteristics of the total sample and its subgroups are shown in tables 4.1 and 4.2. A quick glance at these tables indicates the breadth of variation in IFA, sales, and sales growth thus attesting to the representativeness of the sample.

While the table data are self-explanatory, a significant point of interest here is that the average sales growth for non-U.S. firms is twice that of U.S. firms even though their IFA level is the same. A critical comparison of these groups in regard to their strategy process, content, and implementation could provide the answer for this vast difference in performance. Unfortunately, such an exercise could not be undertaken here since it fell beyond the frame of reference of this dissertation.

TABLE 4.1

CHARACTERISTICS OF THE SAMPLE  
(N=82)

BY NATIONALITY

U.S. Firms	83.0%
Non U.S.Firms	17.0%

BY INDUSTRY

Machinery (Light/Heavy)	17.1%
Motor Vehicles/Parts	30.5%
Aircraft/Parts	20.7%
Electronic Equipments	17.1%
Other	14.6%

BY IFA

Less than 10%	14.3%
11-25%	26.0%
Over 25%	59.7%

BY SALES

Less than \$ 50 million	25.3%
\$ 51-200 million	42.3%
\$ 201-500 million	14.1%
Over \$ 500 million	18.3%

BY SALES GROWTH

Less than 5%	29.3%
6-10%	28.0%
11-15%	17.1%
16-20%	17.1%
Over 20%	8.5%

TABLE 4.2

CHARACTERISTICS OF SUBGROUPS  
(N = 82)

<u>INDUSTRY</u>	<u>MEAN SALES</u> (millions)	<u>MEAN SALES</u> <u>GROWTH (%)</u>	<u>ROI</u> (%)	<u>ROS</u> (%)	<u>IFA</u> (%)
Machinery	396.00	8.0	10.8	8.9	26.00
Motor Vehicles/Parts	701.00	13.2	9.5	7.7	31.00
Aircraft/Parts	968.00	10.9	10.6	8.4	46.00
Electronic Equipment	183.00	4.75	8.5	6.2	40.00
Other	202.00	14.10	11.1	8.8	33.00
<u>NATIONALITY</u>					
U.S	640.00	8.5	10.2	7.8	36.00
Non U.S.	122.00	19.6	9.2	8.0	34.00

### 4.3. Instruments and Measures

#### The Instrument

The primary and singular instrument used for data collection was a questionnaire. Questionnaire items were developed by borrowing them from previously validated research (Dess & Davis, 1984; Govindarajan, 1988; Swamidass & Newell, 1987). Three additional strategies were undertaken to ensure item clarity and relevance: 1) discussion of the draft questionnaire with scholars in the field; 2) soliciting comments on the questionnaire items from managers; and 3) a pilot test. The questionnaire thus refined was further polished through prolonged discussions with members of the dissertation committee.

The questionnaire contained 80 questions and almost all of them were core questions that used numerically anchored 5-point, multi-item, rating scales. Where necessary and appropriate, ranking scales were also used. Questions were closed-ended so as to provide for stricter control at the data collection stage and to facilitate validity in statistical comparisons.

#### Reliability Assessments

Descriptive statistics (means, standard deviations), zero order correlations, and the cronbach alpha values (reliability indices) for the variables measured are

shown in Table 4.3. The Cronbach alpha values for the strategy and structure measures range from 0.38 to 0.82. Three of them exceed Nunnally's (1978) suggested threshold value of 0.70, four have moderate-to-high reliability scores and one is weak. However, all the item-to-total scale correlations except two were statistically significant at p-levels better than 0.01.

### Measures

The hypotheses offered in this research called for the measurement of the following variables:

#### I Independent Variable

Flexible Automation: Intensity of Flexible Automation (IFA).

#### II Moderator Variables

- 1) Market Objectives: Scope, Change, Scale, Standardized Production.
- 2) Business Strategies: Low Cost, Quality, Scope Flexibility, Speed Flexibility.
- 3) Organization-Environment Interface: High, Low.
- 4) Organizational Structure: Organic, Mechanistic.
- 5) Manufacturing Structure: a) Shopfloor Pers-

**TABLE 4.3**  
**DESCRIPTIVE STATISTICS AND ZERO ORDER CORRELATIONS**

Dimension	Mean	SD	Correlation Matrix																
			1	2	3	4	5	6	7	8	9	10	11						
1. Growth	10.61	11.60																	
2. IFA	0.36	0.24	.16																
3. Low Cost	3.52	0.54	-.41 <sup>c</sup>	-.11	(0.50)														
4. Quality	4.06	0.64	.45 <sup>c</sup>	.24 <sup>b</sup>	-.13	(0.55)													
5. ScopeFlex	3.23	0.68	.22 <sup>b</sup>	.08	-.11	.39 <sup>c</sup>	(0.38)												
6. SpeedFlex	3.63	0.69	.32 <sup>b</sup>	.06	-.10	.52 <sup>c</sup>	.37 <sup>c</sup>	(0.68)											
7. OrgEnv	3.15	0.80	.08	.10	.09	.28 <sup>c</sup>	.21 <sup>b</sup>	.55 <sup>c</sup>	(0.72)										
8. Org St.	3.10	0.63	.47 <sup>c</sup>	.21 <sup>b</sup>	-.32 <sup>c</sup>	.33 <sup>c</sup>	.28 <sup>c</sup>	.27 <sup>c</sup>	.30 <sup>c</sup>	(0.82)									
9. DMI	3.05	1.14	.25 <sup>b</sup>	.23 <sup>b</sup>	-.14 <sup>a</sup>	.28 <sup>c</sup>	.26 <sup>c</sup>	.30 <sup>c</sup>	.21 <sup>b</sup>	.55 <sup>c</sup>									
10. OpSkills	3.59	1.11	.22 <sup>b</sup>	.17 <sup>a</sup>	-.22 <sup>b</sup>	.17 <sup>b</sup>	.25 <sup>b</sup>	.19 <sup>b</sup>	.10	.67 <sup>c</sup>	.44 <sup>c</sup>	(0.76)							
11. PrTeam	3.33	1.03	.44 <sup>c</sup>	.18 <sup>a</sup>	-.22 <sup>b</sup>	.43 <sup>c</sup>	.24 <sup>b</sup>	.51 <sup>c</sup>	.38 <sup>c</sup>	.52 <sup>c</sup>	.56 <sup>c</sup>	.54 <sup>c</sup>	(0.53)						

Cronbach alpha in the diagonals. a p .10 b p .05 c p .01 N = 82

ScopeFlex = Scope Flexibility. SpeedFlex = Speed Flexibility. OrgEnv = Organization-Environment Relationship. OrgSt = Organizational Structure. DMI = Design-Manufacturing Integration. OpSkills = Operator Skills. PrTeam = Project Team.

onnel Skills: Specialized, Diversified.

b) Design-Manufacturing Integration: Planned and Sequential, On-line and Parallel.

c) Project Teams: Frequency of Use.

### III Dependent Variable

Performance (ROI, Sales Growth, Customer Satisfaction for Product Quality, Product Innovativeness).

The following sections define these variables and describe the schemes that were used in measuring them. Specific items and scales used for measuring them are provided in the Appendix. (See also Table 4.4 for a summary of definitions and measurements).

Intensity of Flexible Automation (IFA). Intensity of Flexible Automation was earlier defined in proportional terms: 1) computer automation to fixed automation, or 2) computer automation to total manufacturing outlay. To operationalize IFA, respondents were asked to estimate the value of investments (replacement cost terms) in fixed automation, computer automation, and in total machinery and manufacturing equipment. Most respondents provided data on computer automation and total manufacturing outlay only. As a

TABLE 4.4

## DEFINITION OF VARIABLES AND MEASUREMENT

VARIABLE	DEFINITION/MEASUREMENT
<b><u>Independent</u></b>	
IFA	Intensity of Flexibility in the firm's automation defined as the ratio of investment (replacement cost) in computer automation to total manufacturing outlay.
<b><u>Dependent</u></b>	
Sales	Average percentage sales growth for 1986-88.
Profitability	Average percentage ROI for 1986-88.
Customer perception for product quality, innovation	Perceptual information provided by respondents on a 5-point rating scale with values ranging from "Superior to Competition" to "Worse than Competition".
<b><u>Moderators</u></b>	
Scale Objectives	Growth/Profitability by concentrating on current products/markets.
Scope Objectives	Growth/Profitability by seeking new markets for current products.
Change Objectives	Growth/Profitability by innovating products for current market or new market.
	Measured using ranking and rating scales. Relative importance attached to items such as maintaining market share for current products seek new markets for current products, or new products for existing or new markets were used to infer the firm's business objectives.
Low Cost Strategy	Competing industry-wide on the basis of lowest cost to the consumer.
Quality Strategy	Competing industry-wide by providing product uniqueness in terms of superior design and features.
Scope Flexibility	Competing in single or several markets on the basis of product variety.

VARIABLE	DEFINITION/MEASUREMENT
Speed Flexibility	<p>Competing in single/several markets based upon speedy and frequent innovation, fast delivery.</p> <p>Measured using ranking and rating scales. Relative importance attached to various competitive methods such as product selling price, variety, frequent innovation were used to infer the firm's business strategy.</p>
Org-Environment Interface	<p>A rating scale was used to measure the importance the firm attached to interface with suppliers, customers, vendors, etc.</p>
Organic-Mechanistic Structure	<p>A semantic differential scale measured the structural dimensions on task grouping (formal-informal), decision making (centralized-decentralized), etc. A total of eleven items were used and scores were summated. High scores indicated organicness whereas low scores indicated a mechanistic structure.</p>
Shopfloor Personnel skills (Specialized, Diversified)	<p>A semantic differential scale was used to measure the dimensions on job design (narrow job scope-multiple roles), job description (formal-informal), and operator skills (specialized-diversified). Of the summed scores, low value indicated specialized skills whereas high value indicated diversified skills.</p>
Design-Mfg. Integration (Sequential, Parallel)	<p>A semantic differential scale was used to measure this dimension. Low score indicated sequential integration and high scores indicated parallel integration.</p>
Project Teams (Frequency of use)	<p>A semantic differential scale was used to measure the frequency of use (Rarely used-Often used). Low scores indicated low frequency whereas high scores indicated high frequency.</p>
"FIT"	<p>"Fit" amongst independent and the moderator variables was conceptualized using a matching and a moderating perspective. Moderated regression and correlation analyses were used to determine the existence of "fit".</p>

result, IFA was calculated for this research using these data only. Comparatively high proportions indicated a high IFA and comparatively low proportions indicated a low IFA.

Two other types of information on technology were found to be necessary in operationalizing IFA: 1) What sub-technologies within the umbrella of FA (i.e., CAD, CAM, AS/RS, etc.) were being used by the firm and which of these technologies were centrally linked? 2) How long have each of these technologies been in use? The first question was necessary to understand the extent of computer integration in manufacturing and, specifically, whether the firm used a CAD/CAM integration. The second question was designed to understand whether the technology and the appropriate business strategy choices were in place long enough to produce an impact upon performance.

Market Objectives. Market objectives of a firm are the marketing directions that it wishes to follow to achieve growth/profitability. Such directions are specified in terms of the firm's products and markets. A firm may choose to achieve growth or profitability by:

1. Concentrating on its current product and market;

2. Seeking a new market for its current product through product modification; or
3. Developing a new product either for its current market or a new market.

These directions are variously described as concentrated growth, market development, and product development (see Higgins, 1983: 86-87; Pearce & Robinson, 1991:227-234). Concentrated growth would suggest "scale" and "standardized production" objectives, market development would indicate "scope" objectives, and product development would indicate "change" objectives.

To infer the company's (or SBU's) market objectives, respondents were asked to indicate the relative importance their firm attached to the following five market directions by rank ordering them:

1. Maintain market share for existing products.
2. Increase market share for existing products.
3. Seek new markets for existing products.
4. Develop new products for existing markets.
5. Develop new products for new markets.

Clearly, 1 and 2 above would measure scale/standardized production objectives whereas 3, 4, and 5 would measure scope and change objectives.

To test for the convergent validity of the above measure, respondents were asked to rate on a 5-point

Likert type scale the importance their firm attached to cost, market share, quality, and product innovation. The values of the scale ranged from "least important" to "highly important". A high score on cost and market share would indicate a scale/standardized production objective whereas a high score on quality and innovation would indicate a scope/change objective. This measure helped, at the same time, to capture the "within group" differences. Such data are obviously necessary to examine theoretical claims which are of "the more is better" type (e.g., the greater the importance attached to scope objectives, the higher is performance).

Business Strategies: A firm's stated priorities for competing in its product/market segment(s) should indicate the business strategy choice(s) it has adopted for itself. Two sets of scales were used to measure the firm's competitive priorities. The first scale asked respondents to rank order the importance of cost leadership, quality leadership, and flexibility strategy for their business unit. The exact meaning of these constructs together with an example of a company that follows each of these strategies was provided. Respondents were further asked to indicate the importance their firm attached to these choices three years ago.

The objective was to facilitate a longitudinal analysis of technology, strategy, and performance relationship.

A second scale that was used to measure a firm's competitive priorities contained a list of competitive methods (e.g., product selling price, refining existing products) which would collectively indicate the business strategy construct of importance to the firm (see Dess & Davis, 1984; Porter, 1980). Using a 5-point Likert scale, respondents were asked to indicate the importance their firm attached to specific competitive methods in "comparison to their direct competition". Five items measured cost leadership, four measured quality leadership, four measured scope flexibility, five measured speed flexibility. All these items were drawn from previous research (Dess & Davis, 1984; Govindarajan, 1988; Swamidass & Newell, 1987).

Several reasons were responsible for including this second scale. First, strategy measurement has, of late, moved from a categorization approach to a dimension-based approach: that is, measuring the construct through a set of characteristics that collectively describe it (Venkatraman, 1989b). The attractiveness of this approach is in its ability to decompose the variation that is seen across different strategy classifications into a more 'fine-grained' difference along each

underlying trait or dimension (Venkatraman, 1989b). The attractiveness of this approach is in its ability to decompose the variation that is seen across different strategy classifications into a more 'fine-grained' difference along each underlying trait or dimension (Venkatraman, 1989b). Precisely, it facilitated a "within group" analysis. Second, it provided a basis for assessing the convergent validity of the responses obtained through the first question. Third, it enabled the assessment of a firm's strategy in relation to its direct competition. This latter issue sought to fulfill Hambrick's (1980) argument, namely, the strategy of a firm is essentially its choice of operating in a product/market segment in relation to its competition.

Organization-Environment Interface: Four items on a 5-point Likert scale measured the importance the firm attached to maintaining an active relationship with the environmental constituencies relevant to operations. They were: 1) On-line supplier interface for product design/development; 2) On-line customer interface to accommodate design/delivery changes; 3) Interface with equipment vendors for process improvements; and 4) Interface with scientific/engineering community for product/process innovation.

Organizational Structure. Organic or mechanistic-ness in a firm's structure has been described and researched based upon the task and authority dimensions such as centralization, formalization, specialization, standardization, and the coordination mechanisms used for integration such as rules and procedures, task forces, committees, etc. (e.g., see Gresov, 1989; Mintzberg, 1979:84-86).

Following previous research in this area (e.g., Child, 1972; Miller & Droge, 1986; Van de Ven and Ferry, 1979), a semantic differential scale was constructed using the bi-polar dimensions on task grouping, decision-making, coordination, control systems, hierarchy, reward criteria, communication system, etc. (For dimensions here, see Appendix). The scale was numerically anchored from 1 to 5 such that extremes in these items represented mechanistic or organic traits. The overall characteristics of the structure was based upon the summed scores on all these dimensions.

Manufacturing Structure. Using a semantic differential scale, characteristics of the firm's manufacturing structure were measured. Six traits were used to measure three elements of the structure: shopfloor personnel skills, design-manufacturing coordination, and use of

project teams. The traits measured were job design, operator job description, operator skills, design-manufacturing integration, project teams, and worker autonomy (For dimensions here, see Appendix). The scale was numerically anchored and a composite score was used to describe variations.

Performance. Measuring organizational performance is a thorny issue (Hrebiniak, Joyce, & Snow, 1989; Venkatraman & Ramanujam, 1987). Return on investment (ROI) is the most preferred measure of business performance (Hofer, 1983). The reasons for this preference are obvious: it is accurate, consistent (Hrebiniak, Joyce, & Snow, 1989), and makes inter-firm comparisons easy. However, obtaining an objective data on profitability is difficult especially when the unit of analysis is an SBU. To overcome this difficulty, suggestions have been made in the literature to obtain a subjective assessments of profitability (Dess & Robinson, 1984). Such assessments have been found to correspond closely with externally obtained secondary data (i.e., published data. See Venkatraman & Ramanujam, 1987).

This research, sought to obtain performance data based upon managerial assessments. Two types of data were sought: 1) those that were sales and profitability-oriented such as annual sales income for the last three

years, ROI, return on sales, and average sales growth; and 2) those that were customer-oriented such as product quality, innovativeness, and overall satisfaction. The latter data were obtained using a 5-point Likert scale in which respondents were asked to compare their firm with their direct competition. Values ranged from "superior to competition" to 'worse" than competition.

To assess convergent validity, questionnaire data on sales and profitability were cross-referenced against secondary data, wherever such data could be found. In all those cases where data could be externally located, there was a close agreement between the two.

#### 4.4. Analysis

The goal of analysis in this dissertation was to understand what specific business strategy and organizational structure choices were congruent with FA technology and whether they modified the FA technology-performance relationship. For methodological purposes, fit amongst technology, strategy, and structure was described in terms of a matching as well as a moderating perspective. The matching perspective would indicate the strength (i.e., magnitude) of the association amongst the fit variables in terms of performance. The moderating perspective would indicate whether the fit variables

interacted with each other to produce a positive or negative impact upon performance.

### Matching Perspective

Three somewhat related analytical schemes have been used by researchers to examine the existence of a fit relationship when it is described in "matching" terms: the deviation score analysis, the residual analysis, and the analysis of variance (ANOVA) (see Venkatraman, 1989a).

Deviation Score Analysis . The deviation score analysis is based upon the assumption that an absolute difference in the standardized score of two variables would indicate a lack of fit (Alexander & Randolph, 1985). The statistical model for analysis is as follows:

$$Y = b_0 + b_1X + b_2Z + b_3 ( X-Z ) + e$$

where

Y is performance,

X is the independent variable

Z is the moderator variable

If the coefficient  $b_3$  is statistically significant,

then a hypothesis of performance effects of fit is supported.

Deviation score analysis has merits inasmuch as it avoids the problems of multicollinearity associated with interaction models or linear notions of fit associated with residual analysis. Nevertheless, as Johns (1981) notes, there are problems peculiar to this model as well such as: a) subtraction can lead to biased estimates because of ceiling effects of the two variables involved; b) the reliability of the X-Z difference score is less than the average reliability of its component parts (X and Z) which makes the fit measure unreliable; and c) there is the possibility of a spurious association with an external variable.

Residual Analysis. In this method, the fit score is constructed out of the residuals of regressing one variable on the other (Dewar & Werbel, 1979). The residuals intuitively operationalize the actual degree of fit. If they are large, there is a lack of fit whereas if they are small, a good fit is assumed to exist.

Deawar & Werbel discuss the advantages and disadvantages of the residual analysis. Some advantages are: 1) it is possible to simultaneously test both universalistic and contingency predictions; 2) one can gauge the magnitude of the different effects by comparing

the coefficients. Some disadvantages are: 1) it can operationalize only linear notions of fit; 2) the residuals contain measurement and specification error.

Analysis of Variance (ANOVA). This approach has generally been found to be ideal for testing the interaction effects of variables, but Joyce, Slocum, & Von Glinow (1982) used it to test fit described in matching or general congruency terms. Use of an ANOVA rather than a regression format was favored by these authors since it served as a common scheme for testing competing fit descriptions (see Joyce, Slocum, & Von Glinow, 1982:274).

#### Moderating Perspective

Two types of analytical schemes have been used by researchers to test fit relationship within a moderating perspective: subgroup analysis and moderated regression analysis (Arnold, 1982; Sharma, Durand, & Gur-Arie, 1981; Zedeck, 1971).

Subgroup Analysis. In this approach, the sample is dichotomized (or trichotomized) based upon a contextual variable (Z), the hypothesized moderator. Alternatively, the independent variable (X) is split to evaluate its moderating effects in the relationship between Z and Y. In both these cases, the analytical procedure is the same

though the underlying theoretical conceptualization may differ. After the subgrouping of the sample, regression analysis is used to examine the relationship between X and Y for each group. The presence of a moderator and its effect on performance is determined based upon the differences found in the value of correlation coefficients (Bennett & Harrell, 1975; Sample & Warland, 1973) or the regression coefficients (Becherer & Richard, 1978). The difference is tested using a t-statistic or chi-square statistic.

Gupta & Govindarajan (1991) note that the subgroup approach, combined with ANOVA, has been the predominant method with researchers seeking to examine fit within a moderation perspective. However, according to these authors, subgroup analysis results in an inherent wastage of considerable information contained in an intervally measured data. As a result, they advise contingency researchers to explore analytical schemes that would retain the continuity of the data.

Moderated Regression Analysis (MRA). In recent years, this approach has received currency amongst researchers in the field of both organization theory (e.g., Collins, Hage, & Hull, 1988; McKinley, 1987) and business policy (e.g., Gupta & Govindarajan, 1984, 1986; Hitt, Ireland, & Phalia, 1982; Prescott, 1986). In this

approach, a dependent variable is regressed on an independent variable, one or more moderator variables, and a cross-product between the independent and the moderators (Arnold, 1982; Sharma, Durand, & Gur-Arie, 1981; Stone & Hollenbeck, 1984). The following equations describe the logic for MRA:

$$y = a + b_1x \quad (1)$$

$$y = a + b_1x + b_2z \quad (2)$$

$$y = a + b_1x + b_2z + b_3xz \quad (3)$$

The moderation hypothesis is supported if the unstandardized coefficient,  $b_3$  differs significantly from zero.

Arnold (1982) drew a distinction between the "strength" (i.e., magnitude) and the "form" (i.e., direction) of relationship between X and Y to better understand the issues involved in conceptualizing and testing moderation effects. A proposition which suggests that the effects of X on Y are different with moderator E than with moderator F describes the strength of moderation. On the other hand, a proposition which suggests that the combined effects of X and E on Y are different from the combined effects of X and F on Y describes the form of relationship. The appropriate

analytical strategy for testing the "strength" of relationship between X and Y, given a moderating situation, is to examine the correlation coefficient or  $r_{xy}$ . The appropriate analytical strategy for testing the "form" of relationship between X and Y, given a moderating situation, is to examine the regression coefficient or  $b_{yx}$  since what is proposed are the joint effects of the predictor and the moderator.

The distinction that Cohen & Cohen (1975:66) make between correlation and regression enables to capture the difference between the strength and form of relationship:

"Comparisons of correlations answer the question: "does X account for as much of the variance in Y in group E as in group F?" Comparisons of regression coefficients answer the question "does a change in X make the same amount of score difference in Y in group E as in group F"

#### Analytical Schemes Used in This Dissertation

Validity of research results depends upon the extent to which there is a vertical correspondence between the claims of a theory and the statistical tools that are used to test them. Two theoretical claims were made in this dissertation regarding technology-performance relationship:

- 1) The impact of FA technology on performance is higher with one set of strategy/structure

conditions than with another; and

- 2) The impact of FA technology on performance is direct or positive with one set of strategy/structure) conditions and inverse or negative with another.

In testing for proposition 1, the objective is to investigate whether technology (X) has a greater impact upon performance (Y) under a quality/flexibility strategy (Z) (or organic structure) condition than under a cost strategy (or mechanistic structure) condition. In verbal terms, the issue is one of determining the "strength" of association between X and Y under different contexts and the appropriate statistical technique is correlation analysis. Specifically,  $R^2$  would indicate the strength of relationship.

In proposition 2, the objective is to investigate whether technology (X) has a positive influence over performance (Y) under quality/flexibility strategy (Z) (or organic structure) condition and a negative influence under cost strategy (or mechanistic structure) conditions. In verbal terms, the issue is one of determining the "form" of relationship between X and Y under different moderating conditions and the appropriate statistical technique is moderated regression analysis. Specifically, the beta coefficients would indicate the

form of relationship.

Researchers have used the moderated regression analysis (MRA) to test both the "strength" and "form" of relationship between X and Y, given a contextual variable Z. Collins, Hage, and Hull (1988) used MRA to test the strength or magnitude of change in automation (Y) caused by structure (X) under different manufacturing technology conditions (Z). McKinley (1987) used MRA to test the form or direction of relationship between technical and structural complexity (X) and administrative intensity (Y) as moderated by organizational decline (Z). Following these researchers, this dissertation used MRA to test the strength and the form of relationship between technology and performance under different business strategy and organizational structure conditions. An analysis of the strength of the relationship was used to verify the matching perspective. An analysis of the form of relationship was used to verify the moderating perspective.

In broad terms, three types of relationships were analyzed using MRA:

- 1) the independent effects of technology on performance;
- 2) the interactive effects of a) technology and strategy, and b) technology and structure

for the total sample;

- 3) the interactive effects of a) technology and strategy, and b) technology and structure for high and low performers.

Multicollinearity. When too many independent variables are entered in a regression model as a block, multicollinearity or joint correlation is at issue. Multicollinearity refers to the absence of orthogonality in a set of independent variables. While the problem is common to all multiple regression models, unless the independent variables are perfectly correlated, collinearity per se does not completely invalidate a regression analysis (Peterson, 1982:529-530).

To minimize this problem, one could compute the main effects and interaction effects for each variable separately (Hair, Anderson, & Tatham, 1987) as follows:

$$Y = X_1 + X_2 + (X_1X_2)$$

where

$X_1$  is the independent variable (IFA)

$X_2$  is any of the moderating variable

$Y$  is performance

However, the results in such an approach could be

misleading since they do not include the simultaneous effects of other variables hypothesized to be present in the theoretical framework. Apparently, the combined regression model and the shorter approach as shown above have their individual merits and demerits. For comparative purposes, and to facilitate a more thorough analysis, both these methods along with a subgroup analysis were used in this dissertation. These methods are described below.

Method 1: The Combined Regression Model. Table 4.5 describes the equations that were used for this method. The procedure here is based upon McKinley's (1987) approach. In this method, the variables were first introduced in a stepwise fashion to compute their main effects (see equation 1). This was followed by the interaction terms entered individually as shown in equations 2 through 10. After the equations were computed, linear equations were derived for each equation starting from 2 to 10. The idea was to arrive at regression equations that would predict performance as a function of IFA across different contexts. Using mean values for all predictors except for the independent variable, the contextual (i.e., moderating) variable, and their cross product, equations 2 through 10 were reduced. For example, in equation 2, means were substituted for all

**TABLE 4.5**

**EQUATIONS FOR MODERATED REGRESSION (COMBINED APPROACH)**

1.  $Y = b_1 IFA + b_2 LC + b_3 Q + b_4 ScF + b_5 SpF + b_6 Env + b_7 OS + b_8 SK + b_9 DMI + b_{10} T + A$
2.  $Y = b_1 IFA + b_2 LC + b_3 Q + b_4 ScF + b_5 SpF + b_6 Env + b_7 OS + b_8 SK + b_9 DMI + b_{10} T + b_{11} (IFA \times DMI) + A$
3.  $Y = b_1 IFA + b_2 LC + b_3 Q + b_4 ScF + b_5 SpF + b_6 Env + b_7 OS + b_8 SK + b_9 DMI + b_{10} T + b_{11} (IFA \times OS) + A$
4. ....  
(IFA x Env) + A
5. ....  
(IFA x Q) + A
6. ....  
(IFA x SK) + A
7. ....  
(IFA x ScF) + A
8. ....  
(IFA x T) + A
9. ....  
(IFA x LC) + A
10. ....  
(IFA x SpF) + A

where,

IFA = Intensity of Flexible Automation, Env = Organization-environment relations, LC = Low Cost Strategy, OS = Organizational Structure, Q = Quality Strategy, SK = Operations employee skills, ScF = Scope Flexibility Strategy, DMI = Design-Manufacturing Integration, SpF = Speed Flexibility Strategy, A = Constant (Y intercept), Y = Average Sales Growth (3-year average).

predictors except for IFA, DMI (Design-Manufacturing Integration), and IFA x DMI. In the resulting situation, the regression equation contained the beta coefficients for IFA, the contextual variable of interest, and their cross product along with a numerical constant that represented the main effects of other variables. Next, the standard deviation score for the contextual variable was selected and using two standard deviations over and below the mean, a high moderating situation and a low moderating situation was created. The standard deviation data for the contextual variable were used to further reduce the regression equation to be stated as a function of IFA. Two equations were derived for each moderator variable, one representing the impact of IFA on performance in the context of a high moderator situation and the second, a low moderator situation. The equations were then graphed to show the change in the slope of the relationship between IFA and performance under different moderating conditions.

In the above analysis, the hypotheses would be supported if the following criteria are met:

1. The regression coefficients for the cross product terms should be statistically significant indicating that the slope of the relationship between technology and

performance changes across different levels of the moderating variables.

2. The sign of the coefficient should support the hypothesized direction in technology-performance relationship. Thus, if technology's effect on performance is predicted to be inverse in the context of a high emphasis on low cost strategy, the beta coefficient for "technology-low cost cross product" (i.e., IFA x LC) should be negative and statistically significant.
3. The linear equations and the associated graphs should confirm the predictions.

Method 2: The Shorter Approach. Table 4.6 describes the equations that were used for method 2. In this method, the main effects and the interaction effects for each moderating variable was computed individually. Linear equations were then derived and graphed as described in method 1.

As in method 1, the regression coefficients and the linear equations were important indicators for confirming hypotheses. However, an additional indicator of relationship in this method was the  $R^2$ . The contribution that each strategic/organizational choice made to  $R^2$ ,

**TABLE 4.6**

EQUATIONS FOR MODERATED REGRESSION  
(Shorter Approach)

1.  $Y = b_1\text{IFA} + b_2\text{LC} + b_3(\text{IFA} \times \text{LC})$
2.  $Y = b_1\text{IFA} + b_2\text{Q} + b_3(\text{IFA} \times \text{Q})$
3.  $Y = b_1\text{IFA} + b_2\text{ScF} + b_3(\text{IFA} \times \text{ScF})$
4.  $Y = b_1\text{IFA} + b_2\text{SpF} + b_3(\text{IFA} \times \text{SpF})$
5.  $Y = b_1\text{IFA} + b_3\text{Env} + b_3(\text{IFA} \times \text{Env})$
6.  $Y = b_1\text{IFA} + b_2\text{OS} + b_3(\text{IFA} \times \text{OS})$
7.  $Y = b_1\text{IFA} + b_2\text{SK} + b_3(\text{IFA} \times \text{SK})$
8.  $Y = b_1\text{IFA} + b_2\text{DMI} + b_3(\text{IFA} \times \text{DMI})$
9.  $Y = b_1\text{IFA} + b_2\text{T} + b_3(\text{IFA} \times \text{T})$

where

- LC = Low Cost Strategy
- Q = Quality Strategy
- ScF = Scope Flexibility Strategy
- SpF = Speed Flexibility Strategy
- Env = Organization-environment Relations
- OS = Organizational Structure
- SK = Operations Employee Skills
- DMI = Design-Manufacturing Integration
- T = Project Teams
- Y = Average Sales Growth (3-year average)

independently and in association with technology, would indicate what strategy and structure choices were appropriate for FA technology in terms of performance.

Subgroup Analysis Using Method 2. If the predictions made in this dissertation were to be true, the regression coefficients for strategy and structure choices should significantly reflect it in the case of high performers than in the case of low performers (cf. Miller, 1988). To test this logic, the sample was divided into three parts by computing the cumulative distribution of ROI and sales growth. Companies falling in the upper third percentile were termed as the high performing group whereas those falling in the lower third percentile were termed as the low performing group. Moderated regression analysis was performed for each of these subgroups using method 2. In this approach, the hypotheses would be confirmed if the following criteria are met:

- 1) The beta coefficients for high performers are in the hypothesized direction.
- 2) The relationships are more significant in the high performing group than in the low performing group.

## CHAPTER 5

### FINDINGS

The great tragedy of science - the slaying  
of a beautiful hypothesis by an ugly fact

Thomas Huxley

#### 5.1. Outline

This research was designed to test the hypotheses stemming from a central proposition: the performance of an FA firm will be superior when it formulates and implements business strategies based upon flexible automation competences. The data collection and analytical techniques for this investigation were described in the previous chapter. Two separate regression methods (a combined approach and a shorter approach) were proposed for data analysis. This chapter reports the results obtained through these methods and interprets their meaning for the research hypotheses and for the central proposition. It concludes with a discussion of the study's findings in regard to their generalizability.

#### 5.2 Moderated Regression Analysis Results

##### FA Technology and Performance Measures

As mentioned in the previous chapter, three differ-

ent performance measures were selected as criteria for this research: 1) return on investment (ROI), 2) sales growth, and 3) customer perception of the firm's product for quality, innovativeness, and overall satisfaction. It was hypothesized that the latter would indicate technology's independent effects on performance whereas ROI and sales growth would indicate its inter-active effects in association with business strategy and organizational structure.

Regression analyses involving customer perception measures did not produce results of an acceptable level of statistical significance ( $b = .39$ ,  $p = .52$ ). The independent and immediate effects of FA technology on performance could not therefore be substantiated by this research. Various factors could have contaminated the data here thereby causing the problem, such as: 1) the firm's marketing and promotion techniques; 2) customer's loyalty for the firm's products; and 3) lack of objective data within the firm that would relate technology to product quality and customer satisfaction thereby inducing managers to make wild and imperfect guesswork.

Regression analyses performed with ROI as the criterion to test the fit amongst technology, strategy, and structure did not produce valid results as well. The interaction beta coefficients between technology and the

moderating variables (i.e., business strategy and organizational structure) were statistically insignificant in most instances, indicating that the calculated coefficients were largely invalid and ungeneralizable. One reason for the lack of statistical significance here could possibly be due to the fact that organizations have not yet developed robust schemes for measuring the cost-profit impact of FA (Kaplan, 1984, 1986). As Kaplan (1984) notes, the traditional hurdle rates that organizations employ in capital budgeting and profitability decisions are not perhaps an appropriate method for measuring the impact of FA whose benefits are more of the intangible types: quality, flexibility, etc. Apparently, until accounting systems that would capture FA technology's implications for profits and market-related intangibles are in place, research schemes that would use ROI and customer perception measures as dependent variables cannot possibly be undertaken successfully.

The performance implications of FA technology reported here thus pertain to sales growth only. Sales growth is the average growth in sales registered by the firm for a three-year period: 1987-89. Two reasons can be offered why sales data have turned out to be a significant performance indicator in this research

context: 1) they are objective (as opposed to the perceptual guesswork data), and 2) in today's manufacturing environment which demands product quality and flexibility as key success factors, sales performance is critically related to a firm's manufacturing competences (Buffa, 1984; Skinner, 1985).

#### FA and Market Objectives

Hypothesis 1a suggested that the higher the IFA and the higher that the market objectives emphasize scope and change, the higher will be performance. Table 5.1 provides the results of moderated regression analyses using scope and change objectives as moderators. The beta coefficient for the interaction terms is positive, high, and statistically significant ( $b = 2.76$ ), indicating that a higher IFA and a higher emphasis on scope and change objectives would lead to higher performance. Hypothesis 1a is therefore supported.

Hypothesis 1b claimed that the higher the IFA and the higher that the market objectives emphasize scale and standardized production, the lower will be performance. Table 5.1 indicates that the beta coefficient for the technology-scale objective interaction term is negative ( $b = -.63$ ), thus attesting to the inverse relationship between these two in terms of performance. However, the

results here are slightly over the acceptable level of significance ( $p = 11.6$ ) thus compounding generalizability to some extent. Market factors, such as market buoyancy and growth for the products of some sample firms could have been responsible for the unexpected results here.

Implications. The implications of the above findings for an FA firm's mission and long-term objectives are clear: they should incorporate product/market diversity and change as critical themes for the firm's business. Objectives which would underscore market share through volume production and process economies should be avoided. The findings here are especially critical for FA firms which seek growth through concentric diversification (i.e., diversification through internal technological strengths). Care is necessary in choosing products and markets which would permit scope and change based objectives. These interpretations are consistent with the evolutionary descriptions of product and process which suggest a fit between the product/market objectives and processing strengths as a necessary condition for achieving competitive success (e.g., Hayes & Wheelwright, 1979; Stobaugh & Telesio, 1983). Some case study findings (e.g., Goldhar & Jelinek, 1983; Jaikumar, 1986) also support these findings.

### FA and Flexibility Strategies

Hypotheses 2 and 3a stated that the higher the IFA and the higher the emphasis on scope and speed flexibility strategies, the higher will be performance. Tables 5.2 and 5.3 provide regression results obtained by using the combined and shorter approaches described in the previous chapter. The independent effects of scope and speed flexibility on performance are low ( $b = .01$  and  $.12$ . See Table 5.2) but their interaction effects are high, and statistically significant ( $.98$  and  $1.60$ ). By implication, scope and speed flexibility have a significant influence over performance only in association with FA thus attesting to their moderating effects. The positive sign of the interaction coefficient confirms their moderating influence in the hypothesized direction. The moderating hypothesis is further confirmed by the significant increase in  $R^2$  after the interaction terms were entered in the equation (see Tables 5.2 and 5.3).

Regression analysis performed on high and low performing subgroups lend additional support to the moderating effects of these variables in technology-performance relationship (see Table 5.6). The interaction beta coefficient for scope flexibility in the high performing group was  $6.10$  and statistically significant (for the low performing group,  $b = .11$ ) and for speed

flexibility, the coefficient is 2.47 and statistically significant (for the low performing group,  $b = .83$ ). The substantial increase in  $R^2$  after the interaction terms were introduced further confirms the moderating effects of these variables.

Table 5.4 provide the linear equations that were computed using Table 5.2 data. Based on these equations, graphs were drawn to diagrammatically show the performance impact of technology under a high and a low moderating situation. The graphs for scope and speed flexibility are presented in Figures 2 and 3. The graphs significantly attest to the moderator claims in regard to these variables. Precisely, they confirm "the more is better" hypothesis. That is: the higher the emphasis on scope/speed flexibility strategies, the higher will be the impact of FA technology on performance.

Implications. The findings here support the claims made by several authors (e.g., Adler, 1988; Gerwin, 1989; Goldhar & Jelinek, 1985), namely, flexible automation would require a flexible thinking in competitive strategy. According to the present findings, firms which attach significant importance to product design and volume flexibility in competitive strategy formulation should realize superior performance.

By definition, flexibility involves more adjustment

than confrontation with the environmental forces. To elaborate, a flexible business strategy would require the pursuit of a segmented approach in products and markets, frequent design changes, and a vertical "deintegration" to facilitate product/market flexibility. Since these strategies will be successful only in small niche markets, FA firms should be prepared to seek business alliances or collaborative ventures to minimize product development/marketing costs and realize profits. These recommendations are consistent with the current thinking in this area (Dean & Susman, 1989; Kanter, 1989).

But an issue here is: Of the two flexibility types, which one contributes more to sales growth? For the sample analyzed in this research, high growth (Table 5.6) was associated more with scope flexibility than with speed flexibility. This outcome is however understandable since most firms in the sample belong to the automotive industry in which the current competitive emphasis is volume/variety flexibility (See Gerwin, 1989). But, as more and more FA firms adopt scope strategies and neutralize the competitive difference caused by them, competition amongst FA firms should turn towards time-based approaches (i.e., frequent innovation, speedy delivery). This inference is consistent with the evolutionary model of competition (Bolwijn & Kumpe, 1990)

which suggests that competition has progressed sequentially from product price to quality to variety, with each stage adding one more dimension to the competitive strategy. The next stage according to this model is product innovation.

#### FA and Quality, Cost Leadership Strategies

Hypothesis 3a suggested that the higher the IFA and the higher the emphasis on quality strategy, the higher will be performance. Table 5.2 indicates that quality has a significant independent influence over performance and is the second highest predictor of performance in the combined model ( $R^2 = .098$ ,  $b = .21$ ). When the effects of the other variables are controlled, quality predicts 20 percent of performance (Table 5.3,  $R^2 = .206$ ,  $b = .44$ ).

But the moderator influence of quality in technology-performance relationship is more pronounced with the interaction beta high and statistically significant at 1.16 (or 1.49 in the shorter approach). The positive sign of the beta coefficient confirms its moderator effects in the hypothesized direction. Further support for the moderator hypothesis on quality is available from the high performing group ( $b = 4.41$  and statistically significant. For low performers,  $b = 0.45$ ).

Hypothesis 3b claimed that the higher the IFA and

the higher the emphasis on low cost leadership strategy, the lower will be performance. Table 5.2 data indicate that low cost leadership has a negative independent impact upon performance ( $b = -.20$  and significant). That is, all else remaining the same, pursuit of this strategy by FA firms will lead to low performance. But more important to note is the technology-cost leadership interaction coefficient which is highly significant at  $-1.52$ . The interpretation here is that a higher IFA and a higher emphasis on low cost leadership will lead to a lower performance. The inverse relationship here is further confirmed by the interaction beta for the high performers which is  $-2.55$  (For low performers,  $b = 0.19$ ).

The linear equations for quality and cost leadership strategies are provided in Tables 5.4 and 5.5. The graphs that were drawn with the help of Table 5.4 data can be seen in Figures 1 and 4. These graphs clearly support the claims made by hypotheses 3a and 3b.

Implications. In general, quality strategy has presently become a dominant competitive priority for U.S. manufacturers (Meyer, Nakane, Miller, & Ferdows, 1987). But two issues need clarification here before the current findings can be interpreted. First, quality strategy in this dissertation has been defined as involving a concern for periodic developmental changes on the product's

design as opposed to design replicability (cf. Hayes & Wheelwright, 1979). Second, pursuing quality is not trading off cost reduction since computerized manufacturing is described to permit design changes without an appreciable change in cost. Thus, the implication here is, that FA firms whose competitive efforts mainly rely upon successive cost reductions without adding value to the product's design or features will experience low performance. This interpretation is in conformity with the observations made by other authors (e.g., Meyer et al., 1987; Richardson, Taylor, & Gordon, 1985).

#### FA and Organization-Environment Interaction

Hypothesis 4 indicated that the higher the IFA and the higher the emphasis on direct links between the firm's operations and its environmental constituencies such as suppliers, distributors, equipment vendors, and engineering/scientific community, the higher will be performance. Table 5.2, which provides regression data using the combined approach, indicates that the IFA-environment interaction beta is  $-.25$  but statistically not significant. But Table 5.3, which provides data from the shorter analysis, indicates the interaction beta to be  $-.90$  and statistically significant. One reason for the

difference in results here is the multicollinearity problem in the combined regression analysis, caused by a high correlation amongst quality, scope flexibility, speed flexibility, and organization-environment interface (See Table 4.3).

The analysis of high-low growth firms further confirms the negative interaction between IFA and organization-environment interface (For high growth firms  $b = -1.44$  and statistically significant; for the low growth firms,  $b = -.59$  but statistically not significant). The graph in Figure 5 indicates that while a high interface with the environment does not lower performance for an FA firm, a low interface increases performance. In sum, data from the present research do not significantly support the claims of Hypothesis 4.

Implications. A negative cross product term for the IFA and environment interface suggests that a high IFA and a direct interface between the firm's operations and environmental constituencies relevant to operations such as suppliers, distributors, etc. will lead to low performance. Despite the soundness of the theoretical logic underlying the claims made in Hypothesis 4, and the currently observed trends towards business alliances and joint ventureships (Kanter, 1989), it is indeed surprising that data from this research did

not support the hypothesis. Several factors could have contributed to this unexpected result: 1) "Organization-environment Interface" and "Speed Flexibility" are highly correlated (Table 4.3); 2) High performing FA firms in the current sample have offsetting influences coming from the adoption of other flexible approaches relevant to the successful implementation of FA technology; 3) The competitive intensity in industries where FA is used has not yet reached the stage where cooperative strategies with suppliers, distributors, etc. will be a critical requirement for success.

It is hoped that a larger sample, a more sophisticated measurement scheme for the construct of interest here, and the evolution soon of a market environment that is conducive for cooperative strategies should produce valid results.

#### FA and Organizational Structure

Hypothesis 5a stated that the higher the IFA and the higher that the organizational structure characteristics are organic, the higher will be performance.

Hypothesis 5b stated that the higher the IFA and the higher that the organizational structure characteristics are mechanistic, the lower will be performance.

Table 5.2 shows that organizational structure has an

independent and significant influence over performance ( $b = .48$  in equation 1) indicating that an organic structure (since structure was measured unidimensionally with high values representing an organic structure) would lead to higher performance. In fact, organic structure holds an unconditional relationship with performance as is evidenced by the regression data for the independent effects of structure (See Table 5.2, equations 2 to 10 and also see Table 5.3). However, regression data do not support the IFA-organizational structure interaction claims. Firms with a high IFA and high organic traits do not seem to be performing significantly better than those with a lower component of such traits (See the graph in Figure 6). Also, the low performers in Table 5.6 have a high and positive interaction coefficient ( $b = 1.15$ ) indicating that they are using an organic structure. The interaction coefficient for high performers on the other hand is a  $- 1.21$  which suggests that high performance was obtained without an organic emphasis.

Briefly, the interaction terms for IFA and structure do not support the moderator claims of Hypotheses 5a. That is, the more or less of organic traits do not influence FA technology's impact upon performance. Additional confirmation to this effect is available from the meager contribution made to  $R^2$  after the interaction

terms were entered in the model (See Table 5.3). As regards, Hypothesis 5b, no independent confirmation for its claims is available from the current data.

Implications. The interpretation here is that different dimensions of technology (i.e., highly flexible or fixed) do not demand different traits in the organization's structure to produce higher performance. Previous research has indicated that an organic structure is what is needed for FA technology (e.g., Majchrzak, 1988; Zuboff, 1988). Data from this research indicate that irrespective of the technology type, a firm needs an organic structure to remain effective. One plausible reason for the universality of organic structure is that market conditions have presently become highly fluid and demand as a result a flexible organizational arrangement across all contexts. A second reason is the higher level of education that is generally found in today's workforce. Managing them effectively needs informal structures that will provide broader job scope and autonomous working relationships. But a generic explanation that could be offered for the lack of support for the hypotheses here is that manufacturing technology does not, perhaps, affect a firm's overall organizational structure (Hickson et al., 1969). In any event, more research is required in this area before any

categorical generalizations can be made.

### FA and Manufacturing Structure

Personnel Skills. Hypothesis 6a suggested that the higher the IFA and the higher the degree of diversified skills that shopfloor personnel possess, the higher will be performance. Hypothesis 6b suggested that when the skills are highly specialized, performance will be lower. Tables 5.2 and 5.3 indicate that the interaction beta for IFA-skills is positive and significant (.68 and .99, respectively) thereby supporting the claims of Hypothesis 6a (Skills were measured unidimensionally with higher scores indicating diversified skills). In the case of high performing firms (Table 5.6), the interaction beta coefficient is positive and significant at 2.57, indicating that diversified skills have led to higher performance (For low performers,  $b = -.41$ ). The graph in Figure 7 further confirms the moderator hypothesis relating to personnel skills. Hypotheses 6a and 6b are therefore supported.

Implications. The findings here are in congruence with the observations made by other authors (Majchrzak, 1988; Zuboff, 1988), namely, flexible automation demands a workforce with flexible (i.e., diversified) skills. Increasing the skill diversity of the workforce will

however have implications for worker selection/training strategies and for work coordination mechanisms. In regard to selection and training, the objectives would underscore conceptual issues rather than machine specific skills since the manufacturing environment is made up of dissimilar machines. Coordination amongst the diverse areas in operations would be based upon an emphasis on end-results (Galbraith, 1974) rather than on standard operating procedures since exceptions would be the rule. These interpretations are in tune with the ideas expressed by others on the same subject (Dean & Susman, 1989; Majchrzak, 1988).

Design-Manufacturing Integration. Hypothesis 7a claimed that the higher the IFA and the higher is the degree of parallel integration between design and manufacturing, the higher will be performance. Hypothesis 7b suggested that a sequential integration between these two functions will lead to lower performance.

Tables 5.2 and 5.3 indicate that the interaction terms for IFA and design-manufacturing integration are materially and statistically insignificant ( $b = .00$  and  $.11$  respectively) thereby indicating that the "more or less" emphasis on such integration does not affect performance. Additional confirmation to this effect is available from the meager contribution made to  $R^2$  after

the interaction terms were entered in the model (See Table 5.3). The interaction beta for high performing firms (Table 5.6) is -1.06 but it is not statistically significant. Most importantly, the graph in Figure 8 indicates that design-manufacturing integration does not moderate the FA-performance relationship. Hypotheses 7a and 7b do not therefore receive support from the current research.

Implications. The unexpected result here could be unique to the sample companies analyzed in this research and may not be generalizable. It is quite possible that the sample firms achieved the benefits associated with a "parallel integration" through other means (e.g., project teams, committees, and other liaison devices). This explanation receives support from the high correlation that was observed between design-manufacturing integration and project teams (See Table 4.3).

Furthermore, design-manufacturing integration was measured using a single item. Finer differences amongst the sample firms on this construct could not therefore be adequately captured. Problems relating to measurement, not of fact, thus seem to be part of the reason for the unexpected result here. More rigorous measurement schemes for this construct should validate Hypotheses 7a and 7b.

Project Teams. Hypothesis 8 suggested that the

higher the IFA and the more frequently that a firm uses project teams at the operational level, the higher will be performance.

Table 5.2 indicates that the independent and interaction effects of project teams are positive, high, and statistically significant ( $b = .31$  and  $1.01$ ) indicating the impact of this construct on performance. Table 5.3 similarly confirms the significant independent and interactive effects of project teams on performance ( $b = .43$  and  $1.52$ ). For high and low performers, the interaction beta is  $3.92$  and  $.87$  respectively. The graph in Figure 9 further confirms the interaction effects of project teams in technology-performance relationship.

Implications. The findings here are in conformity with the extant literature which indicate a team-based approach as more appropriate for the manufacturing structure of a flexible automation firm (Ettlie, 1983; Ettlie & Reifeis, 1987). The implications here, however, are both for the firm's operational arrangement and for the evaluation and rewarding of worker output. Until now, manufacturing activities occurred within a structured environment to ensure proper implementation of planned strategies. Use of a team approach will introduce informalities in manufacturing, forcing operations management to undertake both line and staff activities

**TABLE 5.1**

**MODERATED REGRESSION ANALYSIS RESULTS FOR  
SCALE AND SCOPE OBJECTIVES  
(Shorter Approach)**

	<u>R<sup>2</sup></u>	<u>Final b</u>	<u>F Change</u>	<u>Y-intercept</u>
IFA	.024	IFA: 0.66*		
IFA+Sc1	.193	Sc1: -0.13		
IFA+Sc1+(IFAxSc1)	.224	IFASc1: -0.63	2.54	13.35
IFA	.024	IFA: -2.32***		
IFA+Sc	.119	Sc: -0.53***		
IFA+Scot+(IFAxSc)	.387	IFASco: 2.76***	27.58***	26.71

\*P < .10    \*\* P < .05    \*\*\* P < .01

Final b's are standardized beta coefficients.

Sc1 = Scale Objectives  
Sc = Scope Objectives



TABLE 5.3

MODERATED REGRESSION ANALYSIS RESULTS  
(Shorter Approach)

	$R^2$	<u>Final b</u>	<u>Main Eff.</u>	$F^C$	<u>Constant</u>
IFA	.024	IFA: 1.62**	0.11		
IFA+LC	.178	LC: 0.02	-0.39***		
IFA+LC+(IFA x LC)	.231	IFALC: -1.54**		4.76**	7.52
IFA	.024	IFA: -1.34*	0.05		
IFA+Q	.206	Q: 0.17	0.44***		
IFA+Q+(IFAxQ)	.247	IFAQ: 1.49*		3.85*	0.64
IFA	.024	IFA: -0.81	0.14		
IFA+ScF	.066	ScF: -0.10	0.20*		
IFA+ScF+(IFAxScF)	.102	IFAScF: 1.03*		2.78*	12.85
IFA	.024	IFA: -1.57***	0.14		
IFA+SpF	.120	SpF: -0.28	0.31***		
IFA+SpF+(IFAxSpF)	.250	IFASpF: 1.88***		12.04***	19.04
IFA	.024	IFA: 0.93**	0.15		
IFA+Env	.028	Env: 0.39**	0.06		
IFA+Env+(IFAxEnv)	.074	IFAEnv: -0.90**		3.50*	-3.96
IFA	.024	IFA: -0.12	0.06		
IFA+OS	.226	OS: 0.40**	0.46***		
IFA+OS+(IFAxOS)	.227	IFAOS: 0.21		0.14	-7.04
IFA	.024	IFA: -0.69*	0.12		
IFA+SK	.060	SK: -0.18*	0.20*		
IFA+SK+(IFAxSK)	.127	IFASK: 0.99**		5.01**	14.23
IFA	.024	IFA: 0.18	0.10		
IFA+DMI	.071	DMI: 0.17	0.22*		
IFA+DMI+(IFAxDMI)	.072	IFADMI: 0.11		0.07	5.40
IFA	.024	IFA: -1.21***	0.08		
IFA+T	.199	T: -0.09	0.43***		
IFA+T+(IFAxT)	.313	IFAT: 1.52***		11.40***	12.60

Final b's are standardized beta coefficients.

Main Eff. = Main Effect.  $F^C$  = F Change.

\*  $P < .10$  \*\*  $P < .05$  \*\*\*  $P < .01$

**TABLE 5.4**

LINEAR EQUATIONS SHOWING THE RELATIONSHIP BETWEEN IFA AND SALES GROWTH AT TWO DIFFERENT MODERATOR SITUATIONS: A HIGH EMPHASIS IN STRATEGY (OR STRUCTURE) AND A LOW EMPHASIS IN STRATEGY (OR STRUCTURE) (Combined Approach)

<u>Moderator</u>	<u>High Emphasis</u>	<u>Low Emphasis</u>
SpF	$Y = 1.03 \text{ (IFA)} + 11.42$	$Y = -3.82 \text{ (IFA)} + 12.02$
ScF	$Y = 0.51 \text{ (IFA)} + 7.80$	$Y = -2.21 \text{ (IFA)} + 8.55$
Quality	$Y = 0.41 \text{ (IFA)} + 6.50$	$Y = -2.51 \text{ (IFA)} + 6.40$
Cost	$Y = 0.15 \text{ (IFA)} - 26.47$	$Y = 3.20 \text{ (IFA)} - 26.90$
Env	$Y = 0.20 \text{ (IFA)} - 5.50$	$Y = 0.64 \text{ (IFA)} - 4.05$
OrgSt	$Y = 0.10 \text{ (IFA)} - 4.2$ (Organic)	$Y = -0.36 \text{ (IFA)} - 5.30$ (Mechanistic)
OpSk	$Y = 0.70 \text{ (IFA)} + 3.23$ (Diversified)	$Y = -1.70 \text{ (IFA)} + 5.20$ (Specialized)
DMI	$Y = 0.03 \text{ (IFA)} - 5.02$ (Parallel)	$Y = 0.03 \text{ (IFA)} - 4.84$ (Sequential)
PrT	$Y = 0.97 \text{ (IFA)} + 3.80$	$Y = -2.65 \text{ (IFA)} + 3.60$

where

SpF	=	Speed Flexibility
ScF	=	Scope Flexibility
OrgEnv	=	Organization-Environment Relationship
OrgSt	=	Organizational Structure
OpSk	=	Operator Skills
DMI	=	Design Manufacturing Integration
PrT	=	Project Team
Y	=	Average Sales Growth (3-year average)

The first number in each equation is the beta coefficient (standardized) and the second number is the constant (Y intercept).

TABLE 5.5

LINEAR EQUATIONS SHOWING THE RELATIONSHIP BETWEEN  
IFA AND SALES GROWTH UNDER TWO DIFFERENT MODERATING CONDITIONS  
(Shorter Approach)

<u>Moderator</u>	<u>High Emphasis</u>	<u>Low Emphasis</u>
SpF	Y = 1.28 (IFA) + 18.50	Y = -4.42 (IFA) + 19.46
ScF	Y = 0.59 (IFA) + 12.99	Y = -2.21 (IFA) + 12.71
Quality	Y = 0.53 (IFA) + 0.83	Y = -3.21 (IFA) + 0.43
Cost	Y = -0.74 (IFA) + 7.74	Y = 3.31 (IFA) + 7.30
Env	Y = -0.52 (IFA) - 3.35	Y = 2.36 (IFA) - 4.57
OS	Y = 0.14 (IFA) - 6.52 (Organic)	Y = -0.38 (IFA) - 7.55 (Mechanistic)
OpSK	Y = 1.09 (IFA) + 13.90 (Diversified)	Y = -2.47 (IFA) + 14.55 (Specialized)
DMI	Y = 0.27 (IFA) + 5.80 (Parallel)	Y = 0.24 (IFA) + 5.04 (Sequential)
PrT	Y = 1.50 (IFA) + 12.76	Y = -3.90 (IFA) + 12.44

where

SpF = Speed Flexibility  
 ScF = Scope Flexibility  
 Env = Organization-environment Relationship  
 OS = Organizational Structure  
 OpSK = Operator skills  
 DMI = Design-Manufacturing Integration  
 PrT = Project Team  
 Y = Sales Growth (3 year average)

The first number in each equation is beta coefficient (standardized) and the second number is the Y intercept (constant).

**TABLE 5.6**

**MODERATED REGRESSION RESULTS FOR HIGH GROWTH  
AND LOW GROWTH FIRMS  
(Shorter Approach)**

<u>HIGH GROWTH FIRMS (N=24)</u>		<u>LOW GROWTH FIRMS (N=25)</u>	
	<u>R<sup>2</sup></u>	<u>Intercept</u>	<u>R<sup>2</sup></u>
			<u>Final b</u>
			<u>Intercept</u>
			<u>Intercept</u>
IFA	.000		IFA: 0.00
IFA+LC	.112		LC: 0.13
IFA+LC+(IFAxLC)	.286	4.86	IFALC: 0.19
IFA	.000		IFA: -0.24
IFA+Q	.018		Q: 0.31
IFA+Q+(IFAxQ)	.215	43.80	IFAQ: 0.45
IFA	.000		IFA: 0.11
IFA+ScF	.041		ScF: -0.10
IFA+ScF+(IFAxScF)	.463	67.37	IFAScF: 0.11
IFA	.000		IFA: -0.54
IFA+SpF	.000		SpF: 0.03
IFA+SpF+(IFAxSpF)	.187	42.36	IFASpF: 0.83
IFA	.000		IFA: 0.68
IFA+Env	.167		Env: 0.31
IFA+Env+(IFAxEnv)	.310	15.07	IFAEEnv: -0.59
IFA	.000		IFA: -1.01
IFA+OS	.028		OS: 0.27
IFA+OS+(IFAxOS)	.055	15.90	IFAOS: 1.15

**TABLE 5.6**  
(Cont'd).

<u>HIGH GROWTH FIRMS</u> (N = 24)		<u>LOW GROWTH FIRMS</u> (N = 25)	
	<u>R<sup>2</sup></u>	<u>Final b</u>	<u>Intercept</u>
IFA	.000	IFA: 0.79	
IFA+DMI	.005	DMI: 0.50	
IFA+DMI+(IFAxDMI)	.055	IFADMI: -1.06	12.38
IFA	.000	IFA: -2.04*	
IFA+SK	.022	SK: -0.77	
IFA+SK+(IFAxSK)	.149	IFASK: 2.57*	37.14
IFA	.000	IFA: -3.48**	
IFA+T	.023	T: -0.61*	
IFA+T+(IFAxT)	.285	IFAT: 3.92***	40.22
	<u>R<sup>2</sup></u>	<u>Final b</u>	<u>Intercept</u>
	.043	IFA: -0.22	
	.157	DMI: 0.14	
	.192	IFADMI: 0.57	0.77
	.043	IFA: 0.58	
	.072	SK: 0.38	
	.088	IFASK: -0.41	-1.92
	.043	IFA: -0.54	
	.162	T: 0.02	
	.230	IFAT: 0.87	0.61

\* P < .10    \*\* P < .05    \*\*\* P < .01  
Final b's are standardized beta coefficients.

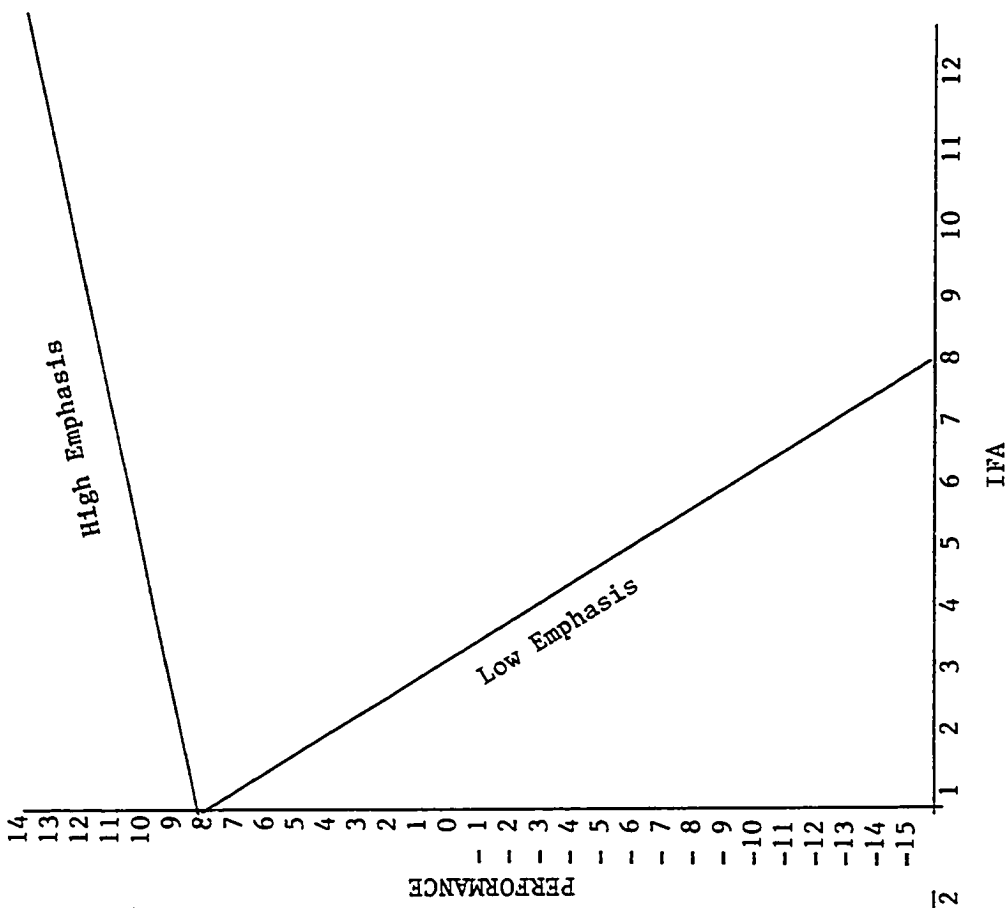


FIGURE 1 Quality Strategy

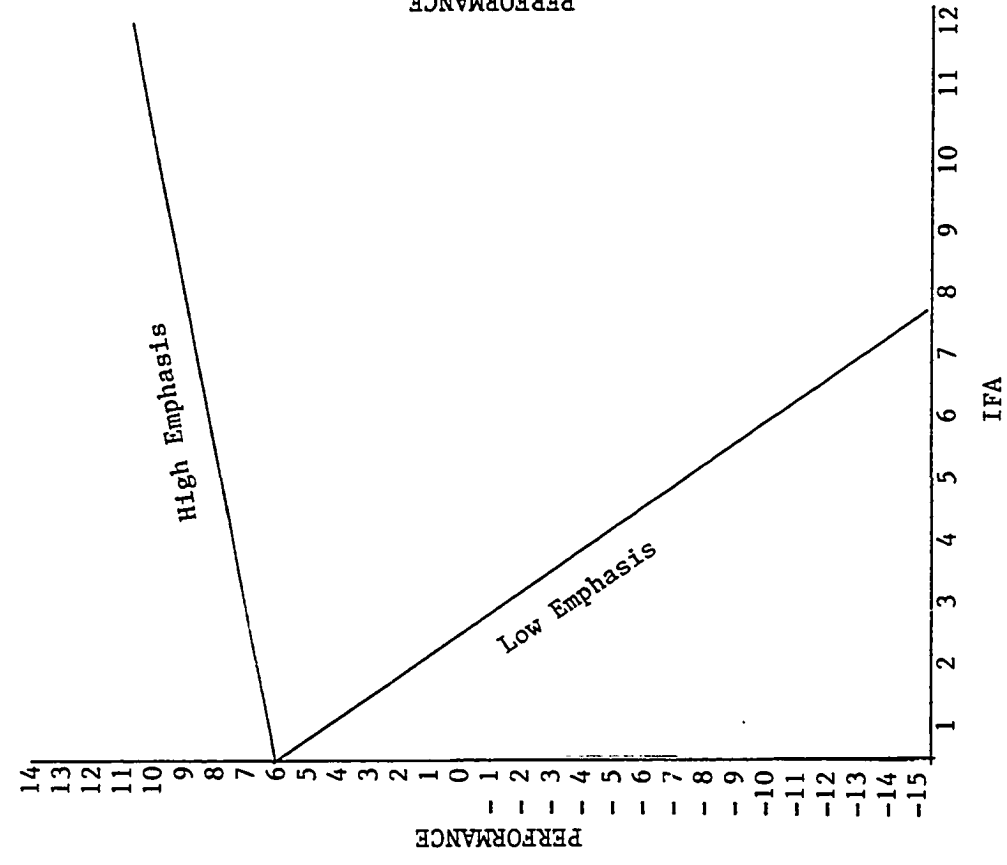


FIGURE 2 Scope Flexibility Strategy

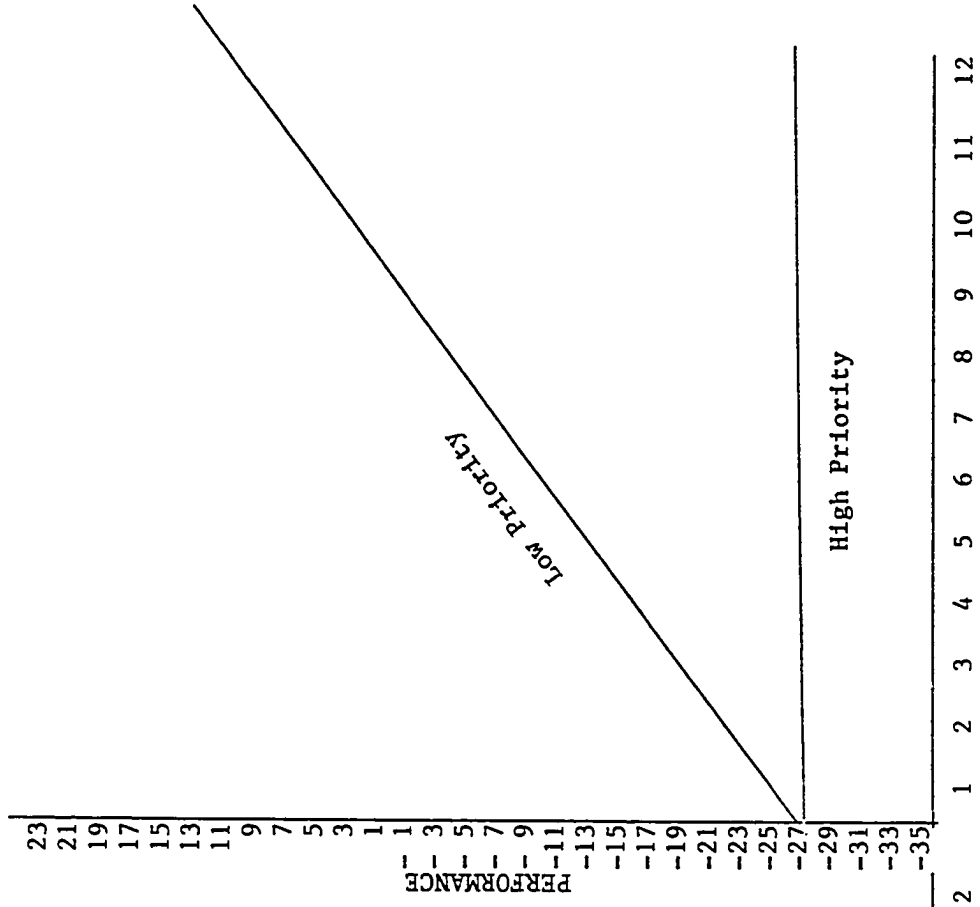


FIGURE 3 Speed Flexibility Strategy  
IFA

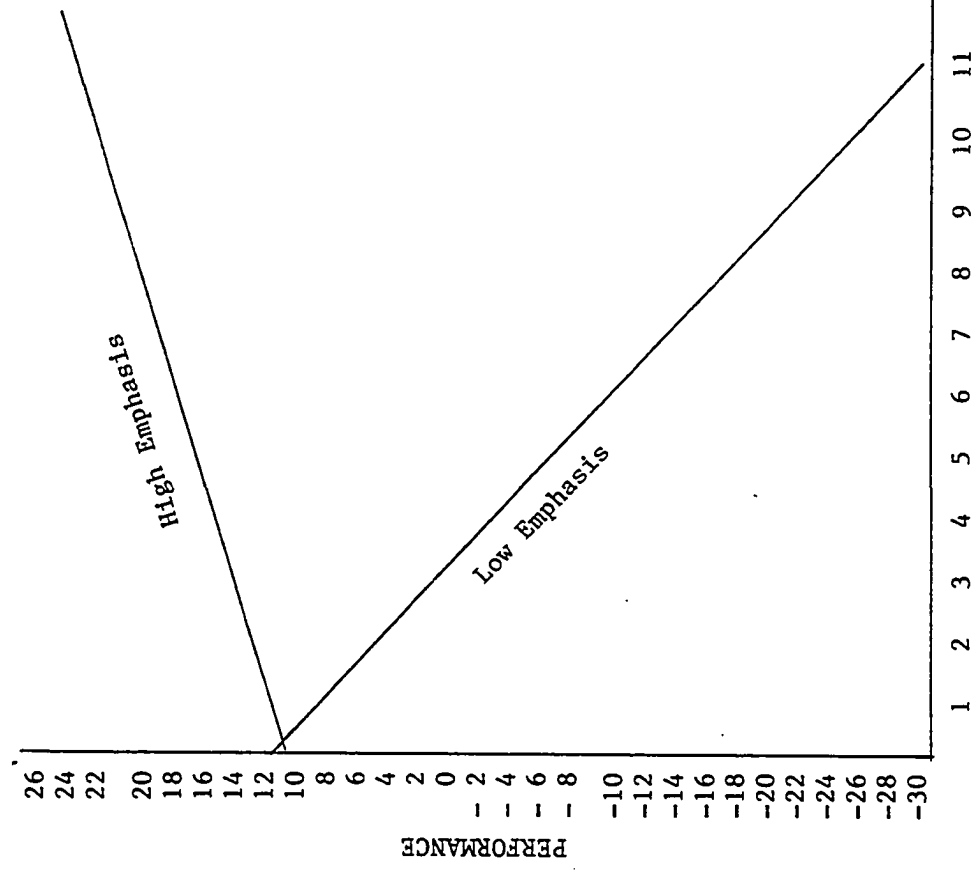


FIGURE 4 Low Cost Strategy  
IFA

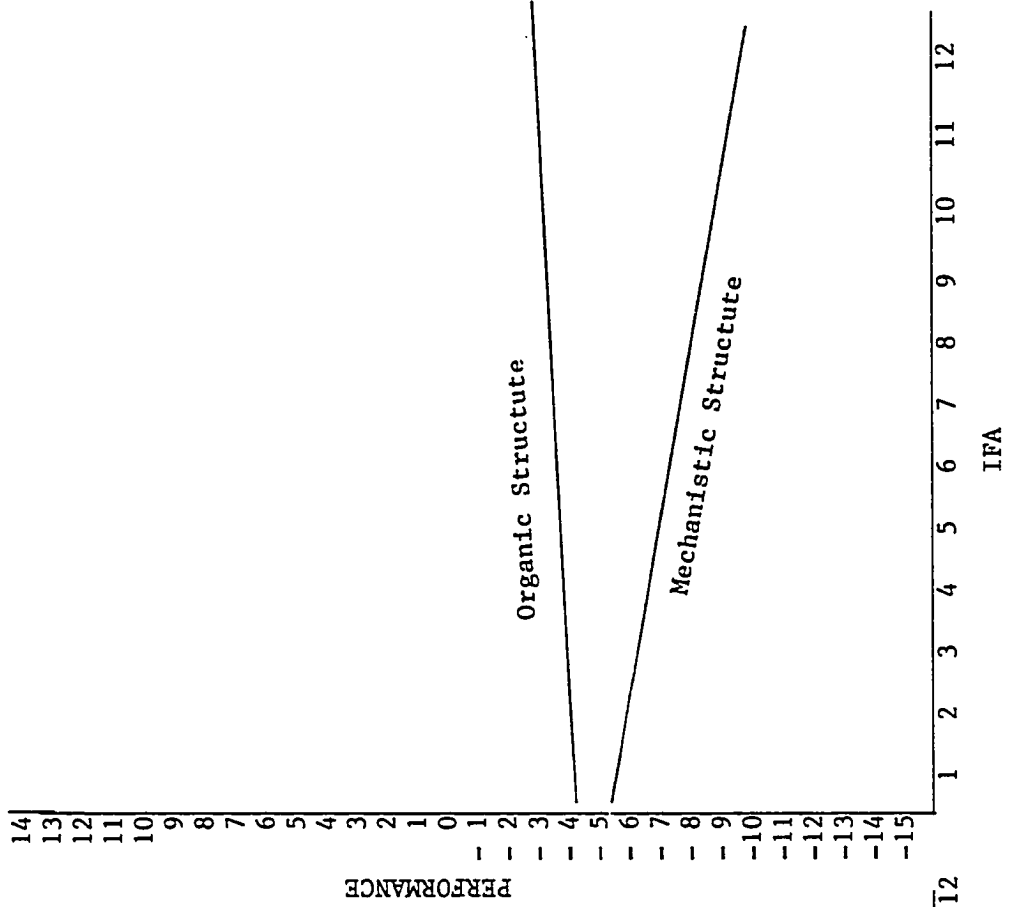


FIGURE 5 Org-Environment Interface

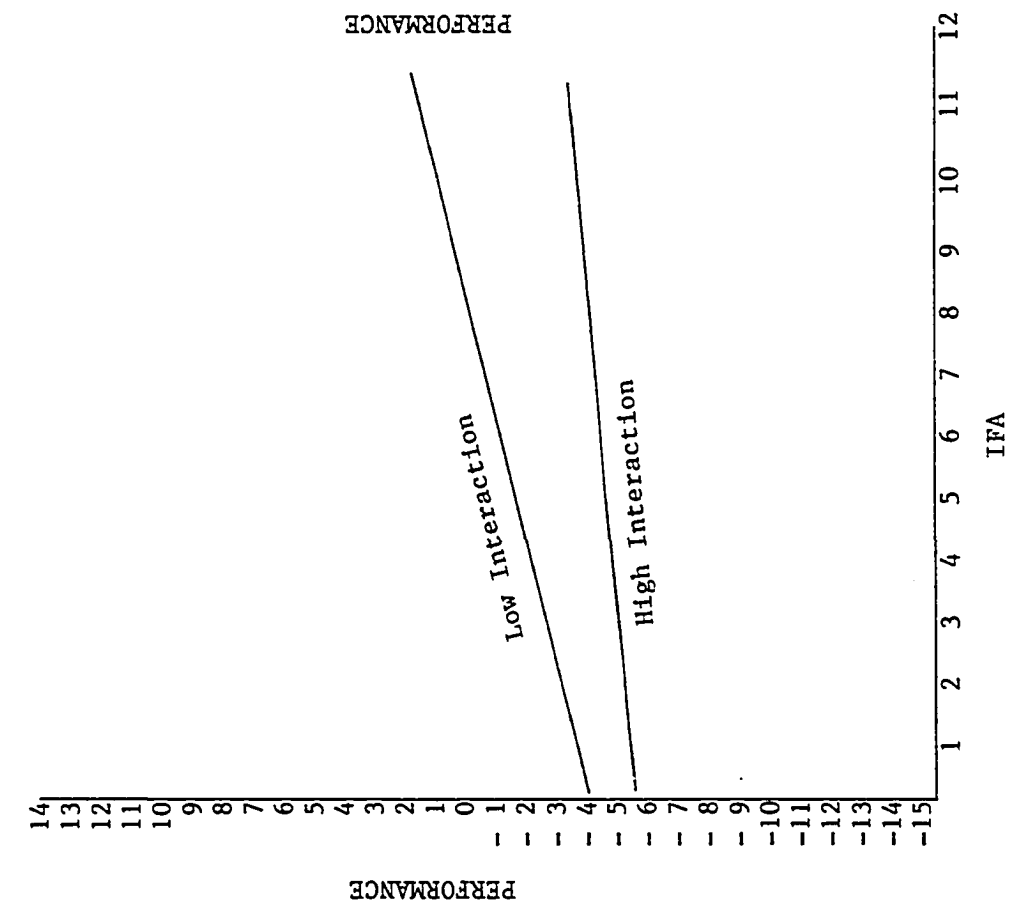


FIGURE 6 Organizational Structure

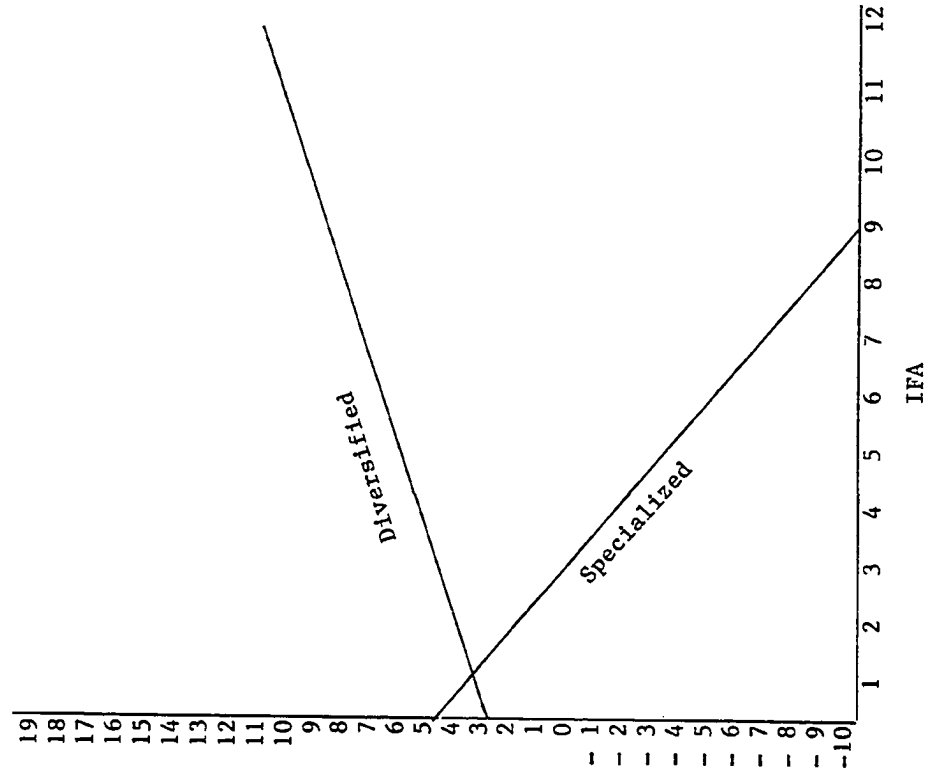


FIGURE 7 Operator Skills

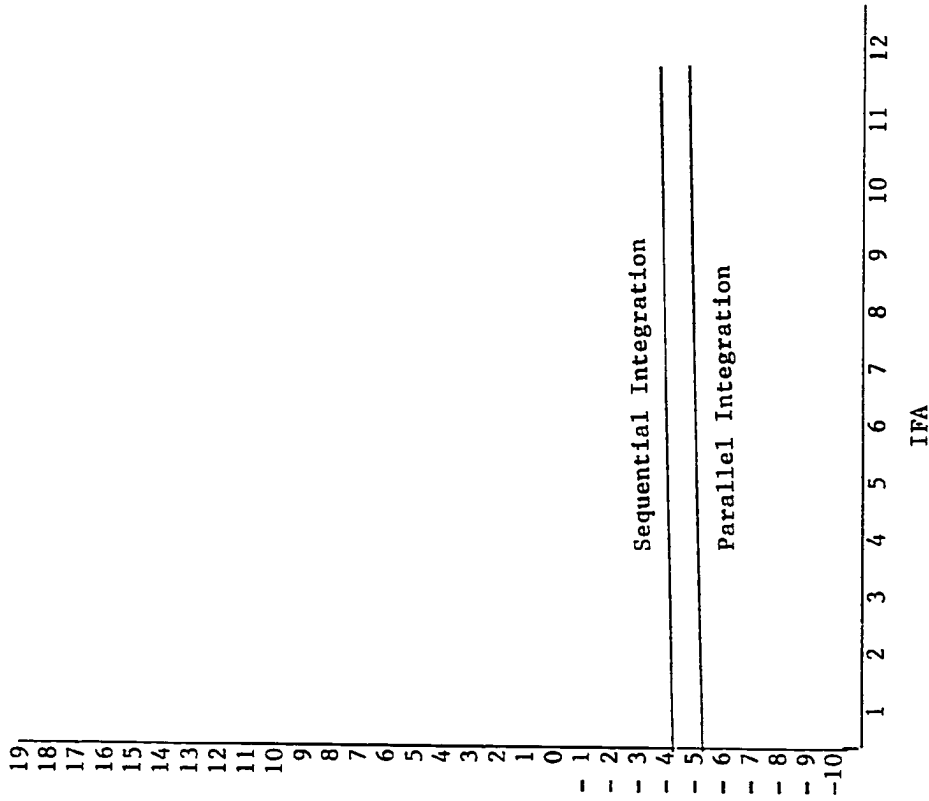


FIGURE 8 Design-Manufacturing Integrations

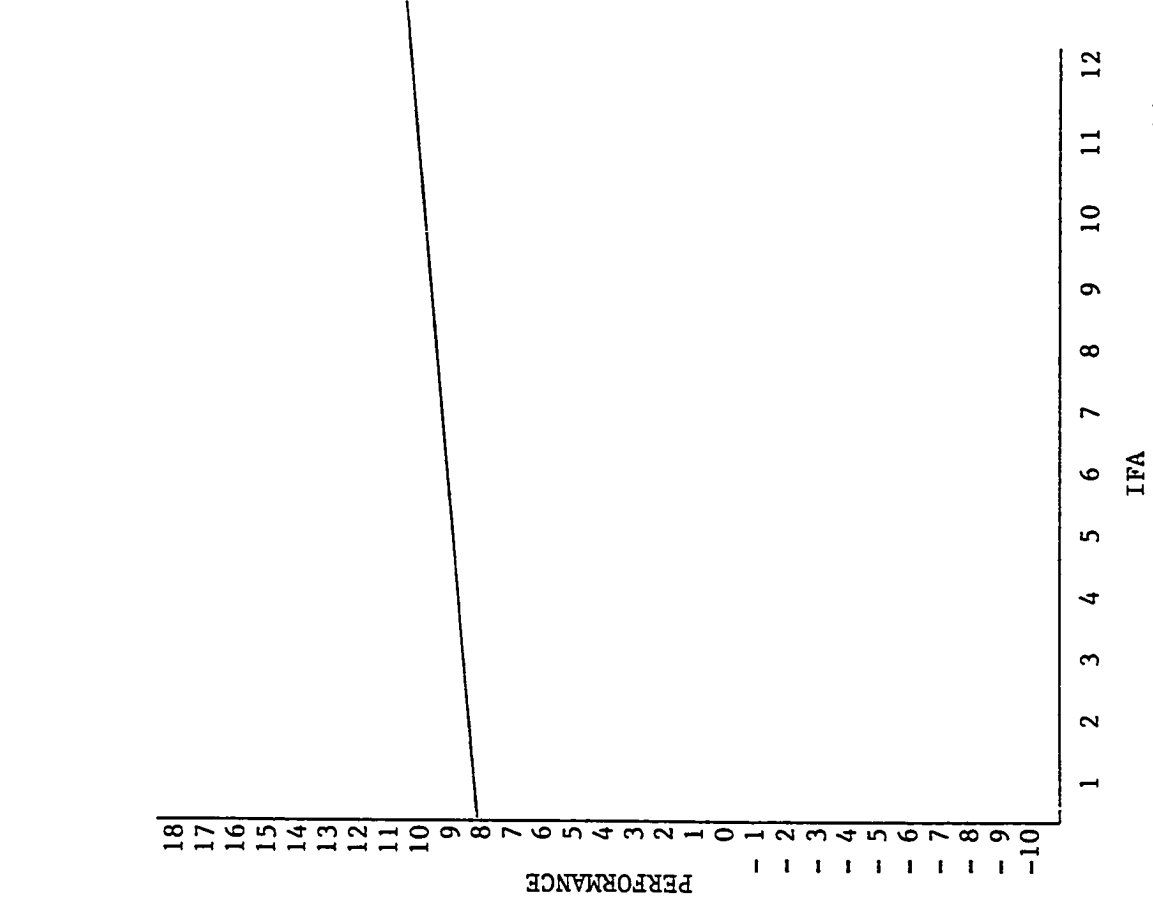


FIGURE 9 Project Teams

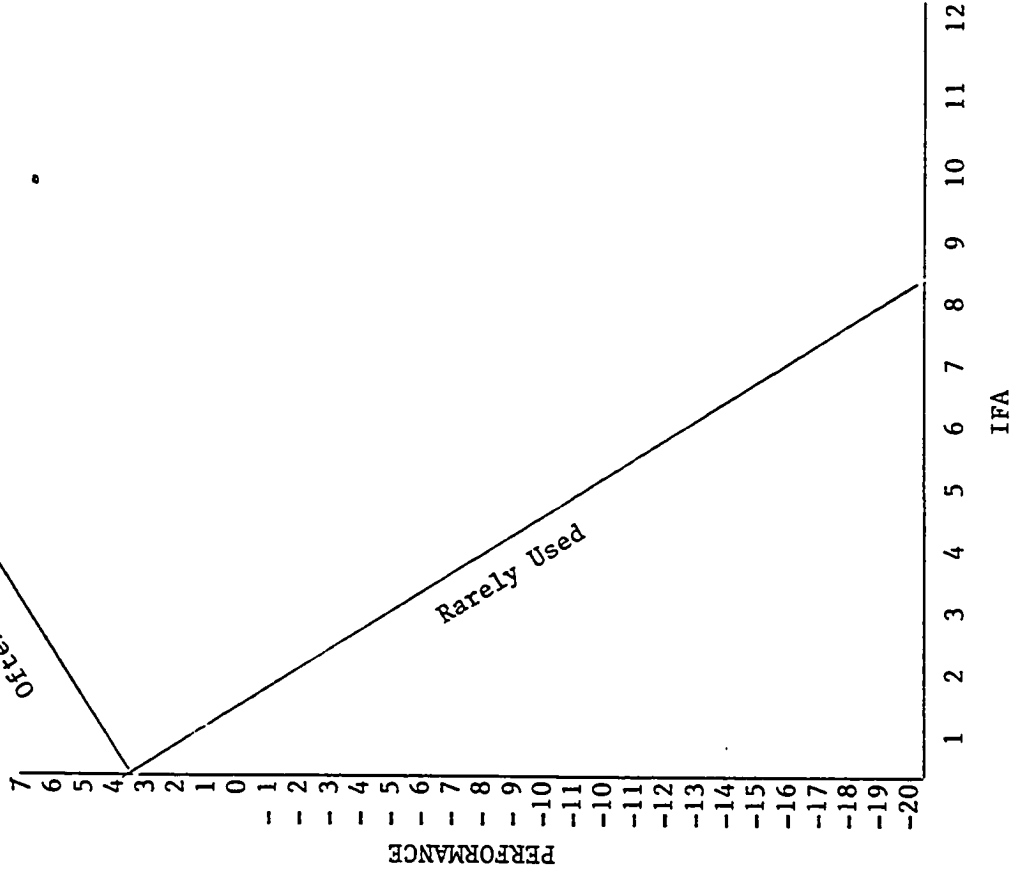


FIGURE 10 Main Effects of IFA

simultaneously. Informal coordination mechanisms have to be devised to supplement formal situations in order to manage residual interdependencies amongst operational units.

As regards evaluation of worker output, since tasks are interrelated in a team environment, it becomes impossible to measure them separately. As a result, performance evaluation should be based upon worker capabilities for problem solving and for the initiatives shown to function as a team member. Rewards should promote risk taking and solving novel problems as opposed to achieving efficiency by routinizing the solution to old problems.

### 5.3 Summary

The central thesis of this dissertation was that under evolving manufacturing technology conditions, business strategy and organizational structure choices of a firm should be based upon the competences and constraints of its manufacturing technology. The thesis was tested on a sample of firms using a newly evolving technology, popularly known as FA. The results of this testing supported most predicted relationships thus confirming the overall tenor of the thesis.

Using the technology-strategy-structure complement-

arity hypothesis, this study found that investments in FA technology without corresponding changes in the other two variables will have no impact upon performance. The strategies that were found to be congruent with FA technology in terms of superior performance are quality leadership, scope flexibility, and speed flexibility whereas low cost leadership was found to be negatively correlated. According to these findings, FA firms that compete on the basis of product quality (uniqueness in design and superior performance), product mix, frequent innovation, and speedy introduction of new products should register superior performance. On the other hand, those that emphasize volume production of a standardized product and product selling price as their competitive priorities should experience inferior performance. The extent of emphasis (or de-emphasis) that a firm would place on these methods would depend upon its IFA level.

These findings should not however be taken to mean that cost is an unimportant factor for an FA user. Rather, an increase in differentiation (i.e., quality, variety, etc.) without any addition to cost is interpreted as the key to success.

This study could not find supportive evidence to the flexibility hypothesis in the operations-environmental constituency relationship despite its theoretical logic

and the claims made to that effect by some authors (e.g., Kanter, 1989; Meredith, 1987a). As was mentioned earlier, extraneous factors in the organization's internal environment could have contaminated the results here. A more refined and a multi-item measurement scale should yield better results.

This research did not find higher levels of organic traits in an FA firm's overall structure to be correspondingly related to higher levels of performance. That is, an organic structure was found to be necessary for all FA firms, irrespective of their IFA level. Inferentially, high performing FA firms have achieved their performance superiority through an appropriate match of other variables: IFA, competitive strategies, and manufacturing structure.

At the factory level, diversified operator skills and frequent use of project teams were identified by this research as important for achieving superior company performance. FA firms whose shopfloor personnel have a broad job scope, are multiskilled, autonomous, and operate within a team environment should experience competitive success.

Parallel integration of design and manufacturing, a factor considered as critical for FA firm effectiveness (See Johne & Snelson, 1988) was not supported by this

research. Measurement problems are considered to be the reason for this unexpected result. A multi-item scale to measure design-manufacturing integration should validate the hypothesis here.

#### 5.4 Limitations

A major finding of this research was that business strategy and organizational structure choices of an FA firm should be congruent with its technology competencies to realize superior performance. Yet, in a benign or "rival free" environment, an internal mismatch may pose no significant threat to organizational performance (Franko, 1974). Market buoyance, governmental munificence, or monopoly conditions may enable a firm to disregard internal fit without any serious implications to performance. Thus, the findings of this study apply only to those firms who are operating in a competitive environment that can be characterized as highly complex (i.e., scope oriented) and highly dynamic (i.e., change and speed oriented).

The results of this research may not be generalizable in toto to small FA firms who have no formal organizational arrangements. Size of a firm is a significant factor in a firm's choice of mechanisms for internal coordination or firm-environment coordination.

Thus, a small firm may not have expert teams for product-process coordination and may not also afford any on-line link with external constituencies such as scientific or engineering community.

A significant limitation of this research in regard to the generalizability of its findings lies in the specialized nature of its sample. The scope of this research was confined to an investigation of manufacturing companies who are users of FA technology. For reasons mentioned in the methodology section of this dissertation, only those companies operating within the SIC major codes 34 through 38, who are users of FA, and who have investments in both CAD and CAM were surveyed and analyzed. The applicability of the study's findings is thus restricted to this specialized group only.

Flexibility, though widely discussed in today's management literature, is still a nebulous concept. Schemes for measuring it are only at a rudimentary stage. The schemes that have been used in this research for measuring flexible automation and flexible business strategies are only exploratory. As a result, they could have compromised the validity of this study's findings to some extent. Caution is therefore in order while interpreting them.

## CHAPTER 6

### CONCLUSION

In this chaotic milieu,  
claims of categorical relationships  
are epistemologically suspect.

A parody for social science research:  
All is not well when it ends well.

#### 6.1 Outline

This chapter briefly discusses the implications of this research from theoretical and managerial perspectives. Directions for future research are also a part of this chapter.

#### 6.2. Theoretical Implications

##### The Thesis in A Nutshell

This research started with a twin objective: 1) to conceptually explain the influential role of manufacturing technology on business strategy formulation and implementation, and 2) to empirically test for the effects of specific choices in this relationship on company performance. Towards this goal, a framework was proposed which described the relationship amongst manufacturing technology, business strategy, and

organizational structure as one that is governed by a strategic fit in terms of performance. The specific influence of technology on the other two variables was explained based upon the changing competences of technology and consequent need to create variations in business strategy and organizational structure in order to restore the balance. It was argued that the appropriate strategy and structure choices under the situation would be those that complement the firm's technological competences and constraints. The influence of technology in strategy formulation and implementation was suggested to occur in parallel with the socioeconomic imperatives.

#### Conceptual Implications of the Thesis

The substantive implications of the thesis presented in this dissertation are towards a reinterpretation of the strategic management paradigm. The paradigm for theory development and research in business strategy management centers around the notion that a strategic coalignment between the organization and the environment is a peremptory condition for achieving superior company performance (Andrews, 1971; Hofer & Schendel, 1978). Over the years, business policy researchers have sought to identify several correlates in the organization-environment relationship in order to develop various

models of strategic fit (e.g., Anderson & Zeithaml, 1984; Hofer, 1977; Miles & Snow, 1978). Such endeavors have invariably adhered to an "outside-in and top-down approach": analyzing the socioeconomic conditions of the environment and identifying organizational variables that would match the economic and market demands. The sequencing here is thus to understand the key competitive factors first and then to determine the internal competences that would translate market knowledge into organizational success. Precisely, the environment is the starting point for most strategy formulation frameworks that follow the "coalignment" tradition (cf. Mintzberg, 1990). While managerial choice models (Child, 1972) have been proposed here, ostensibly indicating the existence of flexibility in the selection of strategy alternatives, the primacy of the environment in the choice-making process is still the predominant view.

Yet, it is an axiom that an alignment between two variables can be achieved from either direction. Philosophically at least, one can have no quarrel with the logic underlying this axiom. Besides, in an environment where markets and economies are extremely volatile and unpredictable, an external orientation for selecting a firm's long term strategy is obviously a risky affair. Focusing on the firm's internal

capabilities should provide a more stable basis for this exercise. In this vein, this dissertation proposed a "bottom-up and inside-out" approach in strategy formulation. This approach seems closer to Mintzberg's (1978, 1990) emergent view of strategy formulation: strategies develop not only by design but also by default.

The theoretical implications of a technology-based strategy formulation model are varied. First, there is a need to describe as to when will strategy formulation be based upon manufacturing technology competences and when will it be a function of market influences. In other words, contingencies regarding when it will be the radical, "technology push" type and when it will be the reactive, "market pull" type have to be specified. Ideally, under a rapidly changing ITE condition, technology may demand predominance in strategy formulation since the competitive difference within the industry is created on the basis of the firm's technical strengths in product design, innovation, and cost efficient processing. On the other hand, under a rapidly changing socioeconomic condition that results in atomized markets, market research and market intelligence may hold the key to strategy formulation since the competitive difference is created on the basis

of an effective market segmentation and market positioning. Alternatively stated, dynamic environments may require technology-driven strategies whereas complex environments may require market-driven strategies. These are only crude inferences and are candidates for significant refinement and elaboration.

The dynamic model of strategy formulation proposed here also holds significant implications for the strategic management process currently portrayed as sequential: from strategy formulation to strategy implementation. Describing design and processing in this dissertation in almost instantaneous terms sharply contrasts with the well entrenched notions in strategic management thinking: "plan first and execute later"; "structure follows strategy"; "strategy formulation and implementation are consciously controlled, methodical activities". In fact, serious criticisms have already been levelled against the efficacy of such differentiated and linear assumptions in strategy formulation concepts and writings (Mintzberg, 1990; Quinn, 1980). Alternative models that would describe strategic management activities and components in an integrative manner are necessary to continue with the thinking proposed in this dissertation.

The theoretical issues brought out in this

dissertation implicitly underscore the need to redefine manufacturing technology. Technology can no longer be treated as a set of static tools and production equipments alone (Wheelwright, 1985). It should further be conceived of as a body of competences, skills and know-how that continuously evolves in human minds. As a tool, it executes current tasks according to plans. As a knowledge-base, it serves as a basis for improving current tasks and thereby provides opportunities for creating new tasks. Technology is thus a combination of physical as well as intangible assets. While the physical assets are generic, the intangible assets are the "exclusives" that create the cognitive and behavioral variations across organizations. Concisely put, technology should be thought of as a conceptual and a concrete system that executes ideas while at the same time creating new ideas.

### 6.3 Managerial Implications

Scientific inquiries seek to enlarge not only the theoretical knowledge but practical knowledge as well. Summarizing what was learned from this research for the practice of management is therefore in order.

A significant implication of the findings of this research is for top management skills and leadership

orientation. Most FA firms have failed to realize the benefits of this technology due to the top management belief in those firms that a mere investment in computer automation should automatically enhance sales and profitability (Goldhar & Jelinek, 1983). The findings of this research indicate that besides investing in them, there is a need to actively involve FA technology in strategic and organizational decisions. This would mean that the top managers have an informed understanding of FA technology, its competences, and how such competences influence product/markets and competitive choices. This would also mean that they adopt a management style that is conducive for a creative use of technology. Technically qualified top management personnel (Ettlie, 1990) and an inspirational leadership style that would foster and reward innovation are necessary for successfully implementing FA technology.

The findings also have implications for managerial training and development. An FA organization requires a horizontal and vertical aggregation of skills and authority. The emphasis in organizing is more on integration than on differentiation (Lawrence & Lorsch, 1967). Integration would be critically demanding at higher levels of coordination since line and staff distinctions become more pronounced at such levels.

Effectively managing an FA enterprise would require a team of generalists who have product/market planning, cost, profitability, and operational expertise. Managerial training and developmental schemes should take these requirements into account while planning for them.

#### 6.4 Future Research

This research makes no pretensions as regards to its exhaustiveness. Various issues of concern, both theoretical and methodological, still remain. For example, there is a serious need to widen the current knowledge pertaining to the functional areas where technology can create a competitive difference. At present, the areas impacted by technology are known to be product design, production, and distribution. The specific competitive choices associated with these areas are product quality, variety, innovativeness, cost, timely delivery, and speedy delivery. Yet, manufacturing technology can also be conceptually related to sales (e.g., after sales service) and packaging (e.g., in different packaging sizes to suit the customer's use or storage capacity). Apparently, studies that would theoretically relate manufacturing to various business functions and thereby develop a wider set of strategy taxonomies are needed.

Methodologically, there is a need to develop a more

robust measure of IFA. The measure used in this dissertation may have inherent biases. For example, the extent of investment in computer automation depends, inter alia, upon product characteristics, production volume, company size, and the industry's technological evolution. Additionally, a firm may have more than compensated its comparatively lower investments in computer automation through structural flexibility or employee skill diversification. These are significant issues that require recognition while refining the IFA measure.

It is also important that future research first classifies manufacturing firms along the value chain. In this research, unfortunately, no such classification could be made. For example, automobile firms included in this research are those that are either part manufacturers only, assemblers only, or both. Clearly, the nature of investment in FA would differ amongst companies based upon their task. Part manufacturers may be expected to have invested in both CAD and CAM in somewhat equal proportions whereas assemblers may have less investment in CAD than in CAM. For those engaged in both parts manufacturing and assembling, the investments in CAD and CAM could be comparatively higher. These "within industry group" differences have to be recognized in order to make meaningful IFA comparisons and analyze its

impact upon strategy formulation and implementation.

Finally, the impact of technology over the firm's strategy formulation, implementation, and performance occurs longitudinally. As a result, a longitudinal analysis, using a case study approach, should prove to be ideal for future research in this area.

**APPENDIX**

**I MEASURING BUSINESS STRATEGY**

Two sets of scales were used to measure business strategy: A) a rank order scale of competitive choices, and B) a Likert scale of competitive methods which would collectively indicate the strategy of importance to the firm. "Scale B" data were used for regression analysis. "Scale A" data were used for assessing the convergent validity of "Scale B" data.

A) Please rank order the importance of the following competitive strategies for your business unit (1 = Most Important, 2 = Next Important, and so on).

	<u>Today</u>	<u>3 Years Ago</u>
<u>Cost Leadership</u> (Cost minimization is the overriding priority. E.g., Hyundai in automobiles)	( )	( )
<u>Quality Leadership</u> (Improving features, reliability, are most important. E.g., Mercedes in automobiles)	( )	( )
<u>Flexibility</u> (Competing in several markets through product mix, frequent innovation)	( )	( )

B) In competing in your chosen market segment, please indicate how important the following competitive choices are for your business unit in relation to your most direct competition.

	<u>Least</u>	<u>Somewhat</u>	<u>Highly</u>	<u>Important</u>	
1. Operating efficiency	1	2	3	4	5
2. Product selling price	1	2	3	4	5

	<u>Least</u> <u>Important</u>		<u>Somewhat</u> <u>Important</u>		<u>Highly</u> <u>Important</u>
3. Innovation in manufacturing processes	1	2	3	4	5
4. Refining existing products	1	2	3	4	5
5. Stocking finished products for off-shelf availability	1	2	3	4	5
6. Unique/advanced product design	1	2	3	4	5
7. Product features	1	2	3	4	5
8. Brand identification	1	2	3	4	5
9. Product Quality	1	2	3	4	5
10. Product variety	1	2	3	4	5
11. Volume flexibility	1	2	3	4	5
12. Custom production	1	2	3	4	5
13. Entering new markets	1	2	3	4	5
14. Speed in innovation	1	2	3	4	5
15. Fast delivery	1	2	3	4	5
16. Frequent new product introductions	1	2	3	4	5
17. Product R&D	1	2	3	4	5
18. Just-in-time manufacturing	1	2	3	4	5

In the above scale, 1 to 5 measure low cost strategy, 6 to 9 measure quality strategy, 10 to 13 measure scope flexibility strategy, and 14 to 18 measure speed flexibility strategy.

## II MEASURING ORGANIZATIONAL STRUCTURE

Organizational structure was measured using a semantic differential scale consisting of eleven items. The scores on these eleven items were summed and averaged. With the organic traits shown on the right extreme, high scores would indicate an organic structure and low scores would indicate a mechanistic structure.

Please indicate the characteristics of your business unit's overall organizational structure by circling one number for each of the following categories:

<u>Structure</u>								
<u>Characteristics</u>								
Departmentalization	Formal	1	2	3	4	5	Informal	
Coordination	Work Standards	1	2	3	4	5	Mutual Adjustment	
Decision-making	Central.	1	2	3	4	5	Decentral.	
Control Systems	Rules	1	2	3	4	5	Norms	
Task Forces	Rarely Used	1	2	3	4	5	Often Used	
Interdepartmental committees for new product decisions	Rarely Used	1	2	3	4	5	Often Used	
Line-Staff Responsibilities	Distinct	1	2	3	4	5	Blurred	
Hierarchy	Many Levels	1	2	3	4	5	Minimal Levels	
Interdepartmental Communication	Formal	1	2	3	4	5	Informal	
Reward Criteria	Seniority	1	2	3	4	5	Expertise	
Management Control & Info. Systems	Often Used	1	2	3	4	5	Rarely Used	

### III MEASURING MANUFACTURING STRUCTURE

Manufacturing structure was measured using a semantic differential scale. Six traits were used to measure three elements: shopfloor personnel skills, design-manufacturing integration, and use of project teams.

Please indicate the characteristics of your business unit's manufacturing structure by circling one number for each of the following characteristics.

#### Structure Characteristics

Job Design	Narrow	1	2	3	4	5	Multiple
	Job Scope						Roles
Operator Job	Formal	1	2	3	4	5	Informal
Description							
Operator Skills	Specialized	1	2	3	4	5	Diversified
Design-Mfg.	Preplanned						On-line &
Integration	& sequential	1	2	3	4	5	Parallel
Project Teams	Rarely Used	1	2	3	4	5	Often Used
Worker Autonomy	Low	1	2	3	4	5	High

### IV MEASURING PERFORMANCE

	<u>1987</u>	<u>1988</u>	<u>1989</u>
1. Sales revenue for your business unit (Approximate - \$ millions)	_____	_____	_____

Using the following classifications, please answer questions 2,3, & 4 below:

- |                    |                   |
|--------------------|-------------------|
| 1 = between 0-5%   | 2 = between 6-10% |
| 3 = between 11-15% | 4 = Over 15%      |

	<u>1987</u>	<u>1988</u>	<u>1989</u>		
2. Return on Investment	_____	_____	_____		
3. Return on Sales	_____	_____	_____		
4. Average sales growth during the last 3 years (%)	_____				
5. How would you rate your business unit relative to your competition on the following (Approximates are fine).					
	<u>Worse</u>	<u>Similar</u>	<u>Superior</u>		
Sales Growth	1	2	3	4	5
Profitability	1	2	3	4	5
Customer Satisfaction	1	2	3	4	5
Industry Perception for Product Quality	1	2	3	4	5
Industry Perception for Product Innovation	1	2	3	4	5

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