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

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**This article presents a framework for explaining the technology-strategy-structure relationship in the context of the current trends toward flexible automation. By linking technology choices directly to a firm's external environment and by invoking the concept of "fit," the framework places technology and strategy in a reciprocal relationship. The framework is used as a basis for examining the specific linkages arising from flexible automation and the posited relationship of this automation with strategy and structure. A set of research propositions is offered suggesting that superior performance can result when strategy and structure are congruent with the competencies and constraints of the firm's technological choice.**

For nearly two decades, manufacturing literature has underscored the need to focus a firm's manufacturing mission in the direction of its business strategy (Hayes & Schmenner, 1978; Hayes & Wheelwright, 1984; Skinner, 1974, 1985). A prolonged deterioration in U.S. manufacturing competitiveness (Hayes & Abernathy, 1980) could have engendered a sustained call for linking technology with business strategy. However, recent changes of a technical nature that are occurring in manufacturing automation (Groover, 1987) demand a step further in this line of thinking, that is, the integration of technology as a variable in the strategy formulation and implementation framework. Because different automation types possess different processing capabilities, they would indicate the need for a correspondence between the strengths of the chosen automation on the one hand and business strat-

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egy and organizational choices on the other. Notwithstanding the prima facie logic underlying this argument, little conceptual work has been presented in this area to guide theory development and systematic empirical testing of hypotheses.

Historically, 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. Its role in product decisions such as improving quality (defined here in terms of features; see Hayes & Wheelwright, 1979a, 1979b) or innovation was considered nonexistent.

Introduction of computers in the automation process has radically altered this static and passive view of technology by endowing it with new competencies in designing and processing products. By minimizing the changeover time from design to production, 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 variety production possible at costs that were previously realizable only through long production runs of standardized products. An implication of these developments for automation's mission is the larger degree of freedom that automation now enjoys in product design and production, namely: (a) executing planned operations according to predetermined criteria (objective driven) or (b) executing nonplanned operations in emergent ways (opportunity driven). Automated technology can thus be a formative as well as an implemental tool.

Studies pursuant to these developments in automation (Adler, 1988; Dean & Susman, 1989; Goldhar & Jelinek, 1983, 1985; Jelinek & Goldhar, 1984; Meredith, 1987) suggest various changes to be made in business strategy and organizational structure for successfully implementing alternative types of automation. The technology discussed in these studies is popularly known as flexible automation (FA) or advanced manufacturing technology. It typically involves (a) a computer-aided design system (CAD) that develops designs, displays them, and stores them for future reference; (b) a computer-aided manufacturing system (CAM) that translates CAD information for production and further controls machine tools, material flow, and testing (CAM facilitates scope production whereas CAD-CAM integration minimizes design time and enhances product producibility); (c) an automatic storage and retrieval system (AS/RS) for delivery or pick up of parts between machines and storage; and (d) a supervisory computer that integrates all of the above (see Groover, 1987).

In general, a technology-based approach, as opposed to the current marketing- and finance-based approach, is recommended for an FA user 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, 1987), or by comparing the new technology to the old technology on processing competencies (Nemetz & Fry, 1988). A considerable body of literature has since developed under the rubric of manufacturing strategy. The high frequency of 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 the implications they have for a firm's relative competitiveness.

In general, these studies have meaningfully created an awareness regarding the strategic implications of FA. Unfortunately, however, empirical research that would validate the speculations that these studies make on the strategy-technology linkage has not been forthcoming. What seems to be missing is a unifying theme within which the various claims of interrelationships among the concerned variables could be analyzed and empirically tested. The first step in this direction is an analytic framework that would synthesize existing ideas into a cohesive set of testable propositions and thereby complement and extend current knowledge. This paper is a step in that direction.

We start with a brief review of the current literature on business strategy formulation and implementation and the place that manufacturing technology presently occupies in this literature. We then propose a framework that incorporates the influential as well as the implemental role of technology in the strategic management process. The framework describes a firm's technology as evolutionary and explains its influence over strategy and structure based upon its changing competencies. Concepts of technological evolution as a dominant industry variable (Rosenberg, 1982; Sahal, 1981) and that of "fit" (Miles & Snow, 1984) provide the necessary theoretical underpinnings to link a firm's technology directly to its external environment in an expanded mode of strategy and structure choices. Ideally, the framework calls for a change in the existing strategic management paradigm with regard to the selection and implementation of strategic choices: from an environment-based approach only to a technology-based competency approach as well; from an opportunity-seeking approach only to an opportunity-driven approach as well. The expanded framework serves as a basis for examining the specific linkages among FA technology, business strategy, and organizational structure.

We contend that superior performance will result when business strategy (both content and process) and organizational structure choices are congruent with the competencies and constraints of the firm's technological choice. We offer propositions—emanating from the relationships posited in the framework—that provide the bases for future research and theory development. In conclusion, we note the implications of the proposed framework for strategic management theory and practice.

## STATE OF THE CURRENT LITERATURE

### Strategy Formulation: Deliberate and Dynamic Approaches

The concept of change and consequent need for congruence among 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 has an impact on an organization in either one of two ways: (a) by providing it with new growth opportunities or (b) by bringing in threats to the organization's existing business. Exploring the sources of change and experimenting for internal competencies 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.

Two different perspectives of how strategy is formulated and fitted with other choices are described in the literature. A synoptic perspective (see, e.g., 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 socioeconomic environment to identify opportunities and threats and arrive at broad strategy choices. This is followed by the selection or modification of choices at the operational and administrative levels that lend support to the chosen strategy by serving as effective implementation mechanisms. The sequence in this case can be characterized briefly as an "outside-in and top-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 toward a lower level component along the logical sequence than toward 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), by modifying the implementation mechanisms to suit the needs of strategy, or by creating a new configuration through sequential adjustments, 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 formulation or for regaining fit conditions. This approach can briefly be characterized as a "bottom-up and inside-out" process. Strategy formulation in this approach occurs in an evolutionary manner based on 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 strategy choices. However, research that would test this implication thus far has been sparse and studies have dealt only 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 (e.g., Hrebiniak & Joyce, 1984: 90; Szilagyi & Wallace, 1983: 495).

In summary, the "outside-in and top-down" approach appears to be the predominant view to explain strategy formulation. Current views largely hold the socioeconomic environment as the referent in strategy making because 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 could also be evolutionary and, consequently, serve as a springboard for strategy creation remains in a nascent state in strategic management research and writings.

**Strategy Formulation and Technology**

Manufacturing technology has not been an issue of concern in conceptualizations relating to the strategy formulation process or strategy content. Though 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 mutely implements the various business strategies formulated by top management from time to time. As a result, product, market, and strategic choices are often made without concern for manufacturing capabilities, creating in the process a mismatch between strategy and technology.

Among others, an important reason for disregarding technology in strategy formulation pertains to the manner in which the manufacturing function has been perceived and treated in strategic management (Hayes, Wheelwright, & Clark, 1988; Wheelwright & Hayes, 1985). Traditionally, manufacturing has been the repertoire of the mechanical 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 subtasks and integrating them sequentially, mechanical engineering has introduced standardization in manufacturing in order to ensure predictability. On the one hand, 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 regarding product, market, and business strategy choices. Its responsibility is not to get involved in strategy formulation but only to execute the chosen strategy in an efficient manner.

Philosophical discussions for linking the choices of manufacturing technology with business strategy choices were first initiated in the production/operations management literature (Skinner, 1969, 1974). Subsequent studies (Hayes & Schmenner, 1978; Porter, 1988; Stobaugh & Telesio, 1983) attempted in varying ways to conceptually integrate manufacturing with the overall strategic posture of the firm. However, a problem with these studies is the assumption that they (though implicitly) make: namely, that the technological choice of a firm is a natural corollary to its strategic choice. Consequently, the objective of the chosen technology is to dedicate itself to the firm's planned strategic choices. An implication of this assumption is that a match between strategy and technology can be achieved only if a sequential adjustment is made in the manufacturing objective, starting from strategy. In other words, a firm's technology cannot induce the creation of new strategy in order to achieve the required parity between the two.

Linear assumptions in strategy-technology relationship such as these are obviously inconsistent with the dynamic views of technology currently being argued by other scholars (Hayes, Wheelwright, & Clark, 1988; Wheelwright, 1985). Process technology is now being considered more than the use of mere tools and equipment; it also comprises systems, people, and stored knowledge, which are the "exclusives" that a firm may possess to create a competitive difference in the industry by way of new products or processes (Parthasarthy, 1990). Besides, the evolutionary trends currently observed in the area of technology (due to computerized automation) demand that researchers change their perceptions about automated technology. Clearly, there is a need for new conceptualizations that relate manufacturing technology and business strategy in interactive terms.

**Strategy Implementation and Technology**

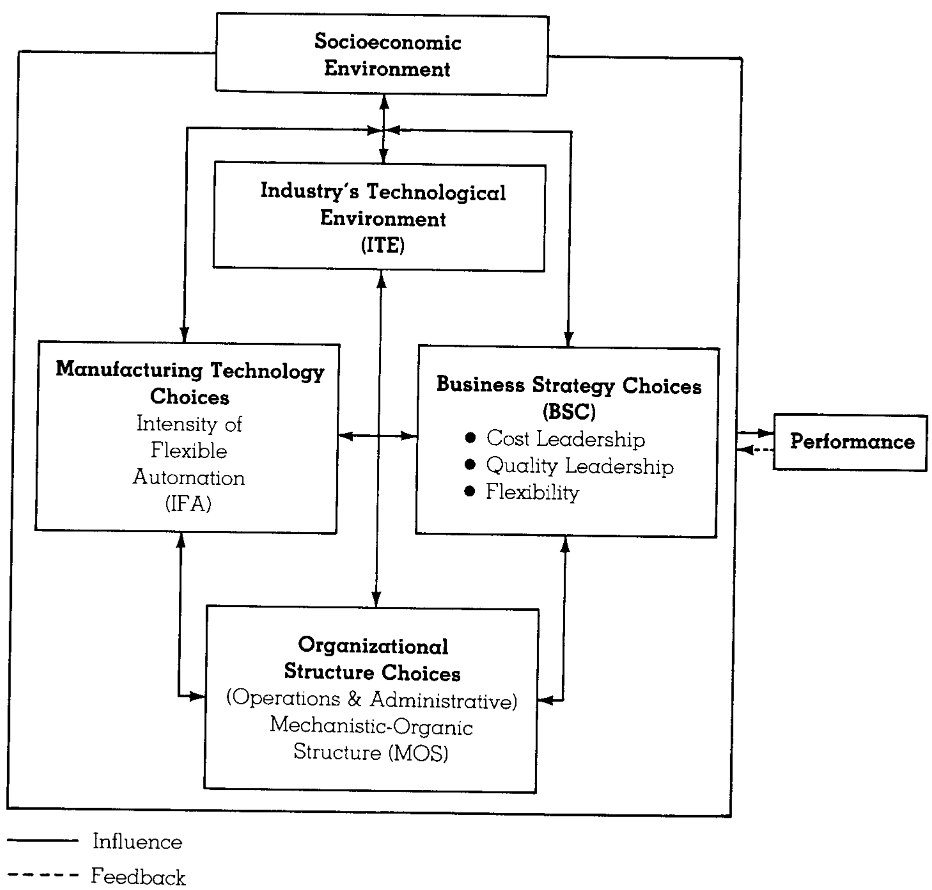
Management literature describes strategy implementation as occurring through structural mechanisms that are designed pursuant to strategy formulation. Strategy is thus a precursor to organizational structure. Structural mechanisms, nevertheless, must be congruent with the demands of strategy to ensure effective implementation of the latter (Chandler, 1962). These demands pertain to the division of task, allocation of resources, and their subsequent integration in order to maximize performance on the firm's competitive choice. Strategy is thus a determinant of structure as well. Strategic management literature does not consider any other variable save strategy while discussing the determinants of structure. In contrast, a large number of studies in the organization theory literature assert that technology has an influence over organizational structure (Harvey, 1968; Lawrence & Lorsch, 1969; Woodward, 1965). These influences have been described in terms of the integration needed among product design, production, and marketing functions based upon the processing competencies of technology. Writings on FA (Boddy & Buchanan, 1986; Dean & Susman, 1989; Helfgott, 1988; Majchrzak, 1988) have added significant weight to these assertions, thereby indicating the need to examine the role of technology in strategy implementation.

## THE PROPOSED FRAMEWORK

The framework proposed here is shown in Figure 1.

Following the evolutionary models of technological change (Rosenberg, 1982; Sahal, 1981), the proposed framework describes a firm's technology as an endogenous variable that undergoes frequent adaptive change to remain technically competitive within the industry's technological environment (ITE) (for some examples here, see Schroeder, 1990; Schroeder, Congden, & Gopinath, 1988). A firm's technology is thus directly affected by the dynamics of ITE. The business strategy choices (BSC) of a firm are affected by the changes occurring in the firm's socioeconomic environment. The framework links a firm's technology, business strategy, and structure and their influence on performance within the constraints posed by the industry's technological environment (ITE) and the general socioeconomic environment. The dynamics of the relationship between the two prin-

**FIGURE 1**
**Elements of the Proposed Framework and Posited Relationships**



cipal constructs, namely, intensity of flexible automation (IFA) and business strategy choices (BSC), are found within the firm's internal environment where they jointly influence both the mechanistic and organic structure of the organization (MOS). The degree of fit among these three constructs (i.e., IFA, BSC, and MOS) affects a firm's performance on various dimensions.

The framework posits, inter alia, that

1. An adaptive view of technology as described above would suggest that a firm's technology is evolutionary.
2. An evolutionary view of technology would suggest an interactive relationship and influence between strategy and technology. Such an approach would embrace both the "outside-in/inside-out and top-down/bottom-up" approaches of strategy formulation.
3. A firm's technology would influence both its operational and administrative structures.
4. To realize superior performance, a firm must achieve a maximum fit among environment, technology, strategy, and structure.
5. The framework recognizes the thinking that structure constrains both strategy and technology choices (Jelinek & Burstein, 1982). However, it has been excluded from analytical discussions here since it falls outside the scope of this article.
6. The technological state of an industry can be described in terms of the technical know-how of the industry leader. Thus, a firm's technology will affect the ITE. This aspect too has been excluded from analysis here for the same reason mentioned in 5 above.

## Elements of the Proposed Framework

**Socioeconomic environment.** This environment, external to the organization, consists of macro-level conditions: social, cultural, political (including regulatory), and economic forces that both define and constrain a firm's potential product and market opportunities.

**Industry's technological environment (ITE).** The evolutionary nature of technological choices posited in this article 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 environment, external to the organization, refers to the industry trends in new technology development and adoption by firms to achieve competitive capabilities in the areas of product design, manufacturing, testing, storage, retrieval of inventory, and so forth.

**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 in order 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, thus the name *fixed automation*. In contrast, 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 among machines must 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 descriptions compare the basic distinctions between fixed and flexible automation in machining operations. However, firms have been known to automate by using computers to link only some or several manufacturing activities (e.g., machining with design, or testing, or both). Manufacturing competencies would depend upon such linkages. Further, automation invariably occurs both in stages and in a piecemeal fashion. It is therefore more appropriate to describe a firm's technology as falling within a flexibility continuum that is 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:

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

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

The above description is a composite measure of flexibility. However, measures that would capture a firm's flexibility strengths in design and processing separately would be necessary for performing intricate data analyses. The following makes that distinction:

$$\text{IFA (Design)} = \frac{\text{Capital Outlay in CAD (Replacement Value)}}{\text{Total Outlay in Design Operations (Replacement Value)}}$$
(Includes both mechanical and electronic design tools)

$$\text{IFA (Processing)} = \frac{\text{Capital Outlay in CAM (Replacement Value)}}{\text{Total Outlay in Machine Tools (Replacement Value)}}$$
(Includes both programmable and nonprogrammable tools)

Of the measures just described, the latter indicates the scope flexibility strengths of technology; both measures taken together, assuming that design and processing have been integrated, would indicate speed flexibility strengths.

An alternative measure for IFA is by surveying the *extent of computerization* that has occurred in successive activities of the manufacturing process. Four distinct activities can be identified in this process: (a) designing the product, (b) feeding the machines, (c) making the product, and (d) moving the product between machines. Using a semantic differential scale, flexibility can be assessed by asking respondents to provide information on these activities as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Product Design** | Manual/Mechanical | 1 | 2 | 3 | 4 | 5 | Computer-Aided |
| **Processing** | | | | | | | |
| Machine Feeding | Manual | 1 | 2 | 3 | 4 | 5 | Robotic |
| Making Products | Machine Tools (Nonprogrammed) | 1 | 2 | 3 | 4 | 5 | DNC Machines (Central Computer Control) |
| Machine Transfer | Dedicated Transfer Line | 1 | 2 | 3 | 4 | 5 | Programmed Transfer Line |
| **Design-Processing Integration** | Manual & Disjointed | 1 | 2 | 3 | 4 | 5 | Computer Integrated (CAD/CAM) |

In the above measure, "processing" scores indicate scope flexibility, whereas "design-processing integration" scores indicate speed flexibility. Both of these measures are indeed rough measures of IFA and are candidates for significant refinement.

The rationale for using IFA as a proxy for technology choices can be best understood in terms of (a) the range of choices available to a firm between fixed and flexible automation and (b) the evolving reciprocal relationship among technology, strategy, and structure that is posited in this article.

The degree of FA for a firm and the choice of a particular mode of automation would depend, among other things, on industry imperatives. It is therefore important to note that in this scheme of things, a firm's technical competencies do not lie in any absolute level of FA but in its relative level compared with the overall industry trends. Thus, for making interindustry comparisons, it would be necessary to standardize data using some benchmark (e.g., mean level of FA in different industries).

Other factors in determining the desirable level of FA for a firm would be that firm's competitive position vis-à-vis its competitors', in terms of manufacturing costs and market positioning, technical competence, capital and human resources availability, and preferred strategic choices.

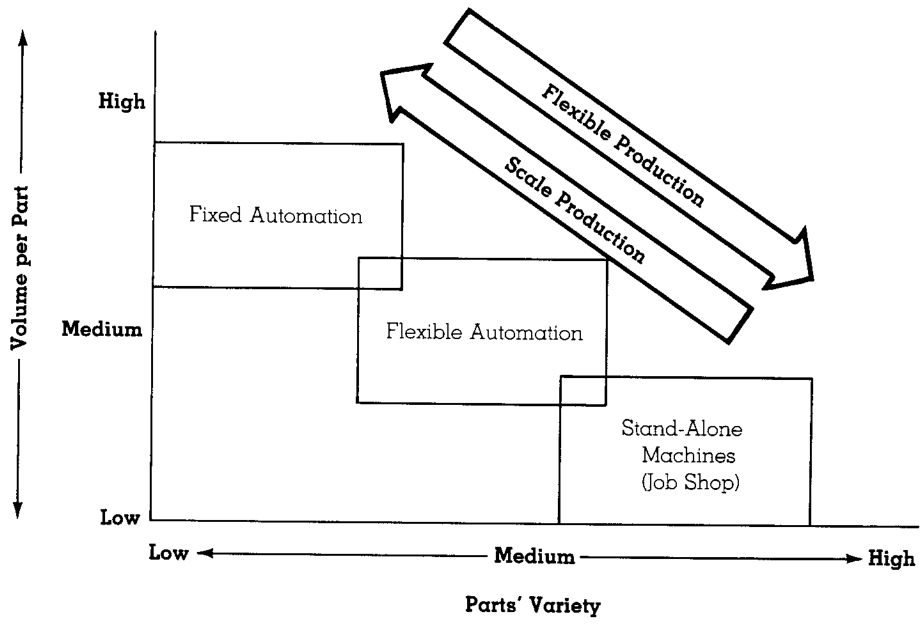
**FA competencies.** Although precision in manufacturing and conformity to standards are the hallmarks of automation of any type, differences in machine control and integration techniques used by fixed and flexible automations indicate that they will have opposing competencies in processing volume and variety. At the extremes, fixed automation can maximize volume and cost efficiencies in a single operation (scale production competency), whereas FA is strong in product or volume change, processing speed, and machine utilization (i.e., flexible operation competency). Figure 2 explains these differences diagrammatically.

Evidently, FA is not conducive to maximizing volume on a single product, just as fixed automation is not, in regard to variety. However, because the technology of a firm is described to be on a flexibility continuum, the issue of what is FA's processing competency would depend on the nature and degree of the firm's IFA in individual FA technologies.

**Business strategy choices (BSC).** Business strategy answers the following question: How will a firm compete in one business or in a particular product or market segment? Three strategic choices that are directly related to manufacturing competencies are considered here: cost leadership, quality leadership, and flexibility (Dean & Susman, 1989; Wheelwright, 1978).

1. *Cost leadership* refers to the firm's intentions to strive for the lowest cost or most efficient producer status in the industry. The manufacturing approach associated with this strategy is that of fixed automation: efficient machinery, long production runs, limited product mix, and reasonable quality standards. Although product quality cannot be totally ignored here (i.e., basic product performance is still required), cost minimization is the

**FIGURE 2**
**Types of Manufacturing Systems and Competencies**[a]




[a] From "Flexible Manufacturing: Your Balance Between Productivity and Adaptability" by D. E. Hegland, 1981, *Production Engineering*, 28(5). Reprinted with permission of *Automation* magazine.

single competitive criterion and an overriding priority. The firm competes at the lower end of the market where the product differential is minimal and the consumer is highly price sensitive. Hyundai exemplifies this strategy in automobiles. Asking strategic business unit (SBU) general managers to indicate for their business unit, relative to their direct competition, the importance of product selling price, volume sales, operating efficiency, process R&D, and refining of existing products would measure this strategy (Dess & Davis, 1984; Govindarajan, 1988). A high value on these items would mean that the firm's competitive priority is low cost. Low values would mean that this strategy is relatively unimportant. Additionally, respondents may be asked to place in rank order the importance of cost, quality, and flexibility (after defining these measures and providing examples) for the firm so their relative importance can be understood.

2. *Quality leadership* refers to the firm's intentions to strive for leadership position in the industry based on product quality and is measured in terms of product performance, reliability, and features. (See Hayes & Wheelwright, 1979a, 1979b for a definition of quality in terms of product features as opposed to replicability.) Unlike the cost leadership strategy that emphasizes low cost per unit, quality strategy emphasizes high quality per unit and small production runs. Thus, if a cost–quality continuum can be assumed, cost leadership would represent one end of that continuum and quality leadership would represent the other end. Although cost minimization is important in this case, maintaining and improving quality through multiple and unique product attributes is the overriding priority. The Mercedes Benz exemplifies this strategy in automobiles. Asking SBU general managers to indicate for their business unit (relative to their direct competition) the importance of unique or advanced product design, product features, brand identification, product quality (adding high value), and product R&D would measure this strategy. A high value on these items would mean that the firm's competitive priority is high quality leadership. Low values would suggest that this strategy is relatively unimportant.

3. *Flexibility* refers to the firm's intentions to compete in several segmented 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 in this article: *scope flexibility* (competing in a single market or diverse markets based on product mix, volume or size mix, custom production, etc.) and *speed or changeover flexibility* (competing in a single market or diverse markets based on innovation frequency, faster delivery on custom orders, etc.). (For examples, see Gerwin, 1989; Meredith, 1987; also, compare Susman & Dean, 1989.) Currently, some of the automobile, aerospace, and consumer electronics companies are reported to be pursuing this strategy. Scope flexibility can be measured by asking respondents to indicate the importance that their business units attach to product variety, volume flexibility, and custom production. Similarly, speed flexibility can be measured using such items as frequent new

product introductions, speed in innovation (i.e., minimizing the R&D-manufacturing-marketing time lag), fast delivery, product R&D, on-line supplier and customer interface, etc.).

A firm's choice of business strategy will depend upon its manufacturing competencies, the constraints posed by the firm's internal mechanisms (i.e., its technology and structure), and the demands of the external environment.

**Organizational structure choices.** Organizational structures have been classified based upon the division of task (horizontal differentiation), the distribution of decision-making authority (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 and that has become popular is the bipolar continuum, mechanistic-organic structure (MOS) (Burns & Stalker, 1961), also referred to as bureaucratic-adhocratic (Mintzberg, 1979). A structure is considered mechanistic (or bureaucratic) to the extent that its behavior is standardized, but it is considered organic (or adhocratic) when standardization is absent (Mintzberg, 1979: 86–87).

Organizational structures are considered a function of the firm's environment (Lawrence & Lorsch, 1969), strategy (Chandler, 1962), and technology (Woodward, 1965). Consistent empirical support exists for strategy as a determinant of the firm's structure (Rumelt, 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 structure. The framework proposed in this article therefore includes technology in explanations relating to the causes of structure. Regarding the environment, although its impact on structure is recognized, no attempt has been made to include it in theoretical discussions.

In the proposed framework, a firm's position on the mechanistic-organic continuum can be identified based on the extent of task and authority differentiation in the firm's structure, the type of integrative mechanisms used, and the reward criteria used. Specifically, "mechanicness" or "organicness" of a structure can be measured by using a semantic differential scale comprising the bipolar dimensions on task grouping, decision making, coordination, control systems, hierarchy, reward criteria, and so forth. The respective dimensions here are formal-informal grouping, centralized-decentralized, work standardization-mutual adjustment, formal rules-informal norms, many levels-minimal levels, and seniority-expertise (cf. Miller & Droge, 1986).

At the operational level, manufacturing structure can similarly be measured using dimensions of job design, operator job description, operator skills, design-manufacturing integration, and so on. The respective dimensions are narrow job scope–multiple roles, formal/planned–informal/flexible, specialized–diversified, and preplanned/sequential–on-line/parallel.

**Performance.** For the purpose of this article, measures of performance should accomplish two goals:

1. They should demonstrate the efficacy of the combined effect of all the input variables and their interactive influence in maximally achieving the firm's long-term financial and competitive goals. These measures may be termed *output efficiency–based performance measures* (OEBP). They include the conventional measures of a firm's performance (e.g., return on sales, return on assets). However, they also may include measures that have a more direct relationship to FA-related input. These are different measures of customer satisfaction such as product quality, warranty claims, useful life, etc.

2. They should also demonstrate the efficient usage of a specific input element that the firm considers as 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 for success. These measures may be termed *input efficiency–based performance measures* (IEBP), and they include variables such as product manufacturing cost, defect-free production rate, worker productivity, machine utilization, and so on.

The proposed framework seeks to measure the impact of FA using both of these approaches (cf. Meredith's, 1987, internal and external measures). The objective of OEBP measures is to provide an understanding of the performance effects of FA in association with strategy and structure. IEBP measures try to assess the independent and immediate effects of FA on performance.

These are, indeed, only approximate measures, and they may suffer from the contaminating effects of various internal and external factors. Under ideal conditions, the researcher would like to isolate such contaminants so that he or she could measure the true impact that FA has on performance. However, such ideal conditions are well nigh impossible. In the measurement scheme presented here, a firm may have a high IFA and a sound internal fit and yet it may 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 general economic conditions, government fiscal and taxation policies, industry structure and competitive environment, or national and international political changes, to name a few such variables. Similarly, customer satisfaction may be affected by relative changes in performance by a firm's competitors, general attitudes toward certain products, or distribution channels.

Measures of IEBP pose similar problems. Because of the relatively nascent nature of FA technology, firms have not yet developed cost accounting schemes that would relate FA inputs to process-based or *in-pipeline* outputs (cf. Kaplan, 1986). Also, firms do not compile cost data that would reveal the independent effects that technology has on the firm's financial or market performance.

A carefully structured research design may, however, significantly reduce the problems in this area. For example, in the case of OEBP measures, the researcher may minimize the effects of exogenous variables by controlled sample design or by using measures of relative changes. As for internal measures of efficiency and in-process output, data may be derived through careful questionnaire design and data-collection techniques (e.g., structured interviews or selective sampling). In any event, until more robust measures are proposed in this area, the suggested measures should be used with caution, and the results may need to be interpreted accordingly.

**Linking the Elements**

The framework proposed here invokes the concept of fit for hypothesizing about the relationships among the pertinent variables. The concept of fit (as such) is not new to the organization theory or policy literature. In the business policy field, it has become a dominant paradigm for explaining the strategic management model and for investigating diverse streams of thinking. Notwithstanding, research in strategy formulation and implementation has focused on using this concept primarily for studying specific linkages (e.g., strategy and structure or technology and structure) although global frameworks for examining strategic management relationships have been called for (Jemison, 1981; Waterman, Peters, & Phillips, 1980). Consequently, most previous research works (for examples, see Drazin & Van de Ven, 1985) using this concept have excluded performance as a variable in their models, possibly due to an implicit assumption that performance is inherent under "fit" conditions. As Fry and Smith (1987) noted, 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. The framework proposed here uses the fit paradigm by paying attention to these issues.

In formal terms, the framework suggests that superior performance results when there is a fit among the firm's environment, strategy, technology, and structure. But changes in the socioeconomic environment or the industry's technological environment necessitate either a change in the firm's strategy or an addition/alteration to its technology, thus disrupting the firm's internal fit. In the context of strategy, fit is regained by adjusting technology and structure to suit the task demands of strategy (top-down approach). In the context of technology, fit is regained by adjusting strategy and structure to suit the competencies and constraints of the new technology (bottom-up approach). The strategy-environment fit in the latter-mentioned context is achieved proactively, by altering the rules of competition in the industry. This argument is consistent with Porter's (1988) reasoning and the dematurity logic proposed by Abernathy, Clark, and Kantrow (1983). The changing nature of competition in the automobile industry due to changes in technology is a good empirical example in this area. (For other examples, see Meredith, 1987.)

Fit among technology, strategy, and structure is conceptualized in this article using the *matching* and *moderating* perspectives discussed in the contingency theory literature (Schoonhoven, 1981; Venkatraman, 1989). Given that different perspectives of fit have implied biases (Drazin & Van de Ven, 1985; Tosi & Slocum, 1984), it is desirable that authors use more than one perspective. The matching perspective implies that for different technology values (measured by using IFA), there is a unique value for a specific strategy type and a unique value for a specific structure type in terms of high performance. The moderating perspective, a multiplicative model, implies that technology's impact on performance varies across different values of specific strategy types (or structure types). Measuring various strategy types using a multi-item interval scale of competitive priorities (e.g., using such items as frequent innovation, fast delivery, and speed in innovation, to measure speed flexibility) should enable researchers to capture the dimensions of specific strategy types and to relate them to technology in order to understand performance implications. Similarly, structure can be measured using an interval scale on the mechanistic-organic dimension and related to IFA.

## STRATEGIC AND ORGANIZATIONAL IMPLICATIONS OF FA

The framework proposed here can be used to analyze the strategic and organizational implications of FA and to suggest propositions for an FA user. The unit of analysis is a company (or SBU) that uses FA as defined and described previously in this article. Specifically, the firm's technology should have a CAD-CAM integration.

### Implications for 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 suggests that under evolving technological conditions, strategy formulation should be based on the competencies and constraints of the firm's technological choice. The competencies of FA involve both scope and speed flexibility. Its strengths are in the economical production of variety, frequent design changeovers, and rapid processing of design and market information. Its constraints are its unsuitability for efficiently producing in large volume a standardized product. Translated in terms of tasks and objectives, the mission of an FA user should specify a broad scope for its products or markets and include product and process innovation as a critical theme for the business. Long-term objectives should emphasize growth or profitability through diversity and change rather than through market share in a single product or 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 strategic choices. Inferentially, at higher levels of IFA, the importance that a firm would attach to such objectives should also be higher.

> *Proposition 1: Performance of an FA firm will be higher when its business objectives are derived from FA strengths of scope (i.e., product or market diversity) and change (i.e., innovation). Other things remaining equal, the higher the IFA, the higher will be performance when such business objective conditions are emphasized.*

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 suggests the creation of a product-market strategy portfolio for the firm, consisting, for example, of such choices as product mix, volume/size mix, market diversity, and custom production. That is, the business strategy choices of an FA firm should be such that they fully complement its core competency strengths by directing their attention toward diversified products and markets (cf. Dean & Susman, 1989; Susman & Dean, 1989). This complementarity should be higher at higher levels of IFA.

> *Proposition 2: Performance of an FA firm will be higher when its business strategy reflects scope flexibility choices (e.g., product mix, volume/size mix). Other things remaining equal, the higher the IFA, the higher will be performance when such business strategy choices are given higher importance.*

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 frequently and quickly manufacturing small to medium lot sizes of a product mix for diversified markets. They can rapidly and efficiently substitute new products for those that are currently being manufactured and distributed. Because the markets in which an FA firm can survive are fragmented and short-lived, frequent changes in product features or new product introductions are crucial to the firm's success. Competitive choices that do not emphasize change but mainly concentrate on defending an existing market through pricing would be inconsistent with this technology (cf. Richardson, Taylor, & Gordon, 1985; Tombak, 1986).

> *Proposition 3a: Performance of an FA firm will be higher when its business strategy involves speed flexibility and/or quality leadership choices. Other things remaining equal, the higher the IFA, the higher will be performance when such business strategy choices are given higher importance.*

> *Proposition 3b: Performance of an FA firm will be lower when its business strategy involves cost leadership. Other things remaining equal, the higher the IFA, the*

*lower will be performance when cost leadership strategy is given higher importance.*

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 and business elements (engineering, manufacturing, marketing) and external constituencies relevant to product and process development (suppliers, distributors, equipment vendors, scientific 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 (Ettlie, 1983; Hayes, Wheelwright, & Clark, 1988: 191–202). Similar on-line links with customers are reported to be in use at some FA organizations to enable the customers to make any last-minute design modifications on their products (Meredith, 1987; Zygmont, 1987). When the IFA level in the firm's technology is higher, the importance attached to these links should also be higher.

*Proposition 4: For FA firms, direct automated links between their technical core and environmental constituencies relevant to operations such as suppliers, distributors, equipment vendors, customers, and industry experts enhance their flexibility, and consequently, their performance. Other things remaining equal, the higher the IFA, the higher will be performance when the importance attached to such linkages is higher.*

### Implications for Strategy Implementation

Strategy implementation occurs through organizational 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. Whereas strategy mainly specifies the task, and technology its coordination, both strategy and technology determine how the task and authority will be divided.

In general, 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 (Dean & Susman, 1989). A flexible technology calls for an integration of product planning and execution that 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 those in charge of each differentiated part can think and act in a holistic manner. Clearly, the common theme to these three contingencies is *integration*. Evidently, traditional structures that emphasize a high level of differentiation in task and authority would be inappropriate for these conditions. Instead, an integrative structure that incorporates diverse disciplines under one banner by using task forces and committees and that makes product, market, and technology decisions based on expert knowledge rather than the traditional managerial authority will be needed. The resulting arrangement is an organic or a team structure, also described as a competitive adhocracy (Mintzberg, 1979: 455) or a dynamic network (Miles, 1989).

Theoretical arguments (Mintzberg, 1979: 434–435) and empirical findings (Finein, 1988; Johne & Snelson, 1988; Meredith, 1987; Veraldi, 1988) support the team structure contention for an FA firm. (For some case study examples, see Boddy & Buchanan, 1986; Hayes & Jaikumar, 1988; and Walton, 1989.) When the IFA level in the firm's technology is higher, the importance attached to team characteristics in its organizational structure should also be higher.

> *Proposition 5: Performance of an FA firm will be higher when its organizational structure is of a team type. Other things remaining equal, the higher the IFA, the higher will be performance when the organizational structure reflects a high importance for team characteristics.*

At the operational level, the correspondence between technology and structure is relatively more pronounced (Child, 1972; Child & Mansfield, 1972; Hickson, Pugh, & Pheysey, 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. Fixed automation focuses on controlling the transformation of tangible inputs into outputs. Depending on the level of automation used (i.e., small or large batch), employee skills in this arrangement range from direct product and process knowledge to monitoring the machines engaged in production. FA, in contrast, 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 selection, processing, and transmission of information, in addition to those necessary for the physical transformation of products (Adler, 1988; Majchrzak, 1988: 132–135). Further, because the complexity of the information and the speed at which it must be handled are both high for FA, there is a need at the shop floor level for workers to possess diversified skills and to act swiftly by exercising judgment. When the IFA level is higher, the degree of diversified skills needed should also be higher.

> *Proposition 6: Performance of an FA firm will be higher when its shop floor personnel possess diversified skills. Other things remaining equal, the higher the IFA, the higher will be performance when the degree of such diversified skills is also higher.*

Integration of various activities at the operational level requires a basis on which the flow of work among product design, production, and marketing can be organized. Fixed automation technologies, built on rational principles, rely upon the logical sequence of the work flow 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 coordination among operational activities include rules and procedures, hierarchical referrals, or emphasis of the goal itself (Galbraith, 1974).

Flexible automation is based on discrete processing concepts. The hallmark of FA is its ability to facilitate planning and execution of products in real time. Almost instantaneously, product design and manufacturing cycle can be set in motion to meet changing market needs. Because these activities are undertaken on-line, a preplanned work flow 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, namely, from planning to executing, is inappropriate here. Instead, it calls for a parallel approach where both the design and manufacturing needs (e.g., tooling) are undertaken side by side. At higher levels of IFA, the need for a parallel integration will be equally higher.

> *Proposition 7: Performance of an FA firm will be higher when its design and manufacturing activities are undertaken in parallel. Other things remaining equal, the higher the IFA, the higher will be performance when a parallel integration is given high importance.*

Besides planning for the sequencing of activities, specific methods must be designed to achieve coordination among diverse functions at the operational level. Fixed automation technologies rely on prespecified rules because of their rational logic and sequential flow of activities. For FA, because 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 Ettlie & Reifeis, 1987, for data on the popularity of the team techniques among FA firms at their operational level.) When the IFA level is higher, the need for a frequent use of such teams will also be higher.

> *Proposition 8: Performance of an FA firm will be higher when it uses project teams for achieving functional coordination at the operational level. Other things remaining equal, the higher the IFA, the higher will be performance when such teams are used more frequently.*

## CONCLUSION

Various claims, mostly prescriptive, have been made in the manufacturing literature regarding the impact that FA technologies have on business strategy and organizational structure. The strategic management literature, however, lacks a body of scientifically designed studies that would validate these claims. This article presents a framework within which substantive claims of interrelationships among the concerned variables could be analyzed and empirically investigated.

Existing models of strategy formulation mainly follow an outside-in and top-down approach, that is, industry analysis and strategic choice followed by choices of technology and structure. Though interactive models have been proposed and popularized via what is known as "strengths, weaknesses, opportunities, and threats" (SWOT) paradigm, the socioeconomic environment is still considered as the reservoir and starting point for strategy making; the internal elements are, for the most part, viewed more as static constraints than as resource bases in strategy formulation. Following the evolutionary model of technology currently argued in the manufacturing literature and using the fit paradigm, this article presents a dynamic framework that suggests that the changing technological competencies of a firm could equally be a driving force in strategy formulation.

The framework suggests that the adoption of a new technology will not ipso facto guarantee performance but will further require appropriate changes in the firm's strategy content, process, and implementation in order to be effective. Apparently, successful FA users can be distinguished from the unsuccessful ones by comparing their strategic and organizational choices.

The framework should serve as a benchmark for describing the role of alternative manufacturing technologies in strategy formulation and implementation. When operationalized, the research findings should provide a basis for the creation of concepts that will explain competition based upon FA competencies in manufacturing. In general, research based on this framework should provide the groundwork for developing a formal theory of manufacturing technology-based competition.

For a practitioner, the framework emphasizes the importance of relating manufacturing technology with the overall strategic posture of the firm. Strategic management frameworks, mainly drawn from a marketing and finance base (Jemison, 1981), have long described the role of a top manager as one of surveying markets and allocating funds based upon survey results. Operational decisions involving product design, production, and choice of manufacturing process have been considered as only tangential (or even inconsequential) to the role of strategy making. This lopsided treatment of manufacturing technology has presumably come about due to long-prevailing myths in theory and practice, namely, technology is a perfunctory, problem-solving tool that is better left to the care of engineers. Change, the basis of strategic management, in contrast, is considered due to macro economic and social imperatives and, hence, the emphasis given to finance and marketing by the strategic manager. Recent environmental developments have, however, proved technology (both product and process) to be evolutionary, capable of creating new products and businesses or liquidating existing ones. Because the competitive fate of many businesses is now linked to technology, the responsibilities of top management should obviously include the making of informed business strategy choices based on technological strengths. By including manufacturing technology in the strategic management model, the present framework emphasizes the need for a technology-based business strategy. The importance of such a strategy for U.S. manufacturing firms can be understood within the context of their presently dwindling competitive strengths in world markets.

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