

# Strategy, advanced manufacturing technology and performance: empirical evidence from U.S. manufacturing firms

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## Abstract

This study investigates the complex relationships among strategy, advanced manufacturing technology (AMT) and performance using survey responses from 160 U.S. manufacturing firms. In contrast to previous studies that emphasize only the flexibility dimension of AMT, this study adopts a multidimensional view of AMT by stressing the information processing capability inherent in AMTs. The study found support for four dimensions of AMT: information exchange and planning technology (IEPT), product design technology (PDT), low-volume flexible automation technology (LVFAT), and high-volume automation technology (HVAT). The results found also indicate empirical support for the study's major premise that a fit between certain strategy–AMT dimensions will be associated with superior performance. Using the findings, the study discusses the implications of the findings and suggests several avenues for future research. © 2000 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

The study of advanced manufacturing technologies (AMTs) and its relationship with business strategy is currently receiving much scholarly attention. It is widely recognized that AMTs, especially those that support the technical transformation process in organizations, are a major determinant of strategy and vice versa. An increasing number of researchers frequently posit that maximum benefit will accrue if there is a *fit* between AMTs employed by the firm

and the firm's strategies (cf. Skinner, 1984; Voss, 1986; Meredith, 1987; Boyer et al., 1996; Dean and Snell, 1996). This notion of strategy–AMT *fit* is identical to the contingency theory arguments linking strategy and other organizational variables. However, this hypothesis has escaped rigorous empirical validation. The objective of this exploratory study is to examine whether strategy–AMT fit is indeed associated with superior performance using survey data from 160 U.S. manufacturing firms.

The notion of fit between strategy and certain variables is built on the “internal consistency” argument which asserts that a functionally motivated step that seems to have merit when viewed alone may lead to poor results because of its mismatch with the

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firm's strategy orientation (Andrews, 1971). In extending this argument, it is only logical that a number of scholars assert that strategy and AMT should *fit* each other for the firm to perform well (e.g., Blois, 1985; Lei and Goldhar, 1990; Williams and Novak, 1990; Grant et al., 1991; Parthasarthy and Sethi, 1992, 1993; Boyer et al., 1996; Dean and Snell, 1996). On face value, this argument has intrinsic appeal but the evidence directly supporting it is sparse (Boyer, 1997).

The strategically important interdependence between AMTs and marketing is well-recognized in the literature. Improved fit between manufacturing capabilities and marketing is now possible with the advent of new AMTs (Blois, 1985; Lei and Goldhar, 1990). For example, Blois (1985) argues that improved effectiveness results when manufacturing capabilities are matched with appropriate changes in the marketing function; a poor match (i.e., lack of fit) will exacerbate the natural differences between the two functions. Many observers (Swamidass, 1988; Williams and Novak, 1990) echo Blois's observations that AMTs can complement marketing strategies thereby enhancing competitive advantage in the following situations where: the product variety demanded by the customers is high, and the markets that the firm competes in are volatile and unpredictable (Pine, 1993).

Other manifestations of the strategic AMT–market relationships can be found in firms competing on time-to-market and product variety. For example, Lei and Goldhar (1990) explain why firms that compete on the basis of time-to-market and product variety adopt AMTs that emphasize flexibility (see also Pine, 1993). Another view of strategy–AMT fit can be traced to the notion of “optimal” use of manufacturing technology. According to Grant et al. (1991), “optimal” technology for a business is contingent upon the firm's strategic goals, its available resources, and the nature of its product–market environment. Additionally, Parthasarthy and Sethi (1992) discuss the importance of the reciprocal relationships between technology and strategy.

A review of this literature suggests the following conclusion. First, while some arguments for strategy–AMT fit have been put forth, the underlying theoretical rationale for such a match is not fully developed. Perhaps, the notion of strategy–AMT fit

is so appealing at face value that a strong theoretical rationale to explain this idea has been slow in coming in the literature. Consequently, the existing AMT classifications need to be reassessed so that strategy orientations and AMT choice at the business unit level can be directly investigated. Second, in recent years, there has been an emphasis on the “flexible” nature of AMT. It is common to classify AMT as either fixed or flexible while other attributes of AMT such as its information processing capabilities are not sufficiently emphasized (cf. Meredith, 1987; Parthasarthy and Sethi, 1993). Is this conceptualization of AMT reasonably complete? Could it be expanded to incorporate or consider the inherent information processing capabilities of AMT that go beyond “flexibility” per se? These issues are addressed as part of this paper. This exploratory study employs a broader conceptualization of AMT in examining whether the *strategy–AMT fit leads to superior firm performance*.

This paper is organized as follows. First, the paper proposes a classification of AMT that captures its multifaceted nature and emphasizes the information processing capability of AMTs. Second, it discusses the theoretical rationale for linking strategy and AMT, and proposes a set of hypotheses highlighting the nature of the linkages. Third, it describes the methods and analysis undertaken to test these hypotheses. Finally, the study's results and avenues for future research on the topic are discussed.

## 2. Theoretical rationale

This study is based on the thesis that strategy–AMT fit leads to superior performance. The “information processing perspective” of organizations (Galbraith, 1973; Egelhoff, 1982; Keller, 1994) provides this study's theoretical rationale for the investigation of strategy–AMT fit. The logic underlying this perspective is as follows: organizations are open social systems that must cope with environmental and organizational uncertainty. To be effective, they must develop information processing mechanisms capable of dealing with uncertainty, where uncertainty is defined as the difference between the amount of information required to perform a task and the amount of information already possessed by the or-

ganization (Galbraith, 1973). According to Egelhoff (1988) (p. 18):

A key assumption underlying this information-processing model is that organizations will attempt to close the information gap (uncertainty) by processing information... This activity is likely to involve the gathering of additional data, transforming the data, and storing or communicating the resultant information. Thus there is a relationship between the amount of uncertainty faced by an organization and the amount of information processing that must go on in organizations. Effective organizations are those that fit their information-processing capacities (for gathering, transforming, storing and communicating information) to the amount of uncertainty they face.

In this context, AMTs are viewed as tools that enable firms to increase their information processing capability. Based on this logic, AMT choice can be determined by the information processing requirements resulting from the pursuit of a selected strategy (e.g., differentiation, cost leadership, etc.). Given the above logic, the information processing capabilities of AMTs deserve emphasis, along with flexibility, because it is this inherent capability that makes them effective strategic “tools” for dealing with uncertainty associated with different strategies.<sup>2</sup>

On a more practical level, the potential to improve business performance is among the principal reasons why firms employ AMTs (Boyer et al., 1996; Dean and Snell, 1996). Numerous scholars have argued that AMT reduces manufacturing costs by automating design, fabrication, assembly, and material handling, among other things (Majchrzak, 1988; Swamidass, 1988; Giffi et al., 1990).

<sup>2</sup> In order to deal with uncertainty, Galbraith (1973) has proposed a range of mechanisms such as rules and programs, planings, employing formal information systems, and creating lateral relationships among the departments. Tushman and Nadler (1978) have argued that formal information systems are most amenable to deal with uncertainty when information is quantifiable or formal in nature, while lateral relationships are most appropriate when information is less quantifiable. CAD and other product related computer systems are therefore most useful when information is quantifiable or formal in nature.

## 2.1. Conventional manufacturing technologies

The conventional view of manufacturing, before the advent of AMTs, stressed its mass-production capability and its inflexible nature. For example, scaling procedures used in the measurement of process technology stressed “the degree to which automated, continuous, fixed-sequenced activities are present” in a production process (Yasai-Ardekani, 1989, p. 136). This view of technology, called “explicitness of technology” (Gerwin, 1981), has been widely researched under different labels such as “technological complexity” (Woodward, 1965), “mechanization” (Blau et al., 1976), “production continuity” (Child and Mansfield, 1972) and “automicity” (Inkson et al., 1970).

## 2.2. Advanced manufacturing technologies

Over time, with the advent of computers and microprocessors, inflexibility in process technology gave way to flexibility. Over the last decade, flexibility became the mark of new technologies called AMT. Several conceptual schemes have been offered to grapple with the flexible nature of AMT (e.g., Goldhar and Jelinek, 1985; Adler, 1988; Swamidass, 1988; Dean and Snell, 1991, 1996; Dean et al., 1992; Gerwin, 1993; Gerwin and Kolodny, 1992; Parthasarthy and Sethi, 1993). These schemes make valuable contributions to understanding AMTs. A broader conceptualization of AMTs is offered as an alternative by some authors (cf. Kaplinsky, 1983; Kotha, 1991). We use the classification of AMTs of Kotha (1991) which groups the various manufacturing technologies into four groups on the basis of the imbedded information processing capabilities (see Appendix A for complete list of AMTs and their descriptions).

(1) *Product design technologies* (PDT). This group includes technologies such as computer-aided design (CAD), computer-aided engineering (CAE), and automated drafting technologies that focus primarily on product definition, and design-related information processing functions.

(2) *Process technologies* (PT). This group includes technologies such as flexible manufacturing

systems (FMS), numerically controlled (NC) machines, and programmable controllers that focus on the process aspects of manufacturing. In other words, these technologies control manufacturing processes and generate process related information on the factory floor.

(3) *Logistics / planning technologies (LPT)*. This group of technologies focus on controlling and monitoring the material flow from the acquisition of raw materials to the delivery of finished products, and related counterflows of logistical information. It includes production scheduling systems, shop floor control systems and materials requirements planning (MRP) systems.

(4) *Information exchange technologies (IET)*. This group helps facilitate the storage and exchange of information among process, product, and logistics technologies identified above. Technologies such as common databases, system translators, data transfer protocols, and intra- and inter-factory networks belong to this group.

This broader view of AMTs facilitates the study of AMT–strategy connection because it permits the many dimensions of AMTs to be matched against several possible business-level strategies while studying the notion of fit and its implications for firm performance. Therefore, this conceptual classification of AMT forms the basis for the operationalization of AMT in this study.

Section 3 discusses the implications of the multidimensionality of AMTs for strategy and performance. To guide the empirical analyses, three hypotheses are proposed. The first two hypotheses deal with strategy–AMT fit, and the third deals with strategy–AMT–performance fit relationships.

### 3. Hypotheses

#### 3.1. Strategy dimensions

A low-cost strategy represents attempts by firms to generate a competitive advantage by becoming the lowest cost producer in an industry (Porter, 1980). In pursuing such a strategy, the emphasis is on efficiency and on the rigorous pursuit of cost reduction from all possible sources. On the other hand, firms can pursue a product differentiation strategy that

emphasizes a chosen form of uniqueness that stems either from the product, process or service. Even though many types of differentiation strategies have been recognized in the literature (cf. Miller, 1988; Mintzberg, 1988), our focus here is on product differentiation.<sup>3</sup> These two (i.e., low-cost and differentiation) are commonly accepted “generic” dimensions of strategy that have successfully withstood many empirical tests in the strategy literature (e.g., Dess and Davis, 1984; Robinson and Pearce, 1988; Nayyar, 1993). Given the robustness of these strategy dimensions, we use them to study the complementarities between generic strategies and the AMT dimensions proposed earlier.

#### 3.2. Cost leadership and AMT

Firms pursuing a low-cost strategy seek stable and predictable markets to minimize product adaptation costs and to achieve economies in manufacturing (Miller, 1988). Internally, the emphasis is on cost reduction because this strategy is dependent on a firm’s ability to design, produce and market a comparable product more efficiently than its competitors. From a manufacturing perspective, the logic of maximizing throughput efficiency dictates that firms place a greater reliance on standardization and simplification through low product variety and high-volume production (Porter, 1985). This emphasis — low product variety and high volume — has the potential to minimize inventory carrying costs, and enables the full exploitation of mass production techniques (Hayes and Wheelwright, 1979; Hambrick, 1983). Along with the standardization of both products and

<sup>3</sup> Miller (1988) argues that there are at least two types of differentiation strategies: product differentiation and marketing differentiation. Unlike a product differentiation strategy, a marketing differentiation strategy is based on creating customer loyalty by uniquely meeting a particular psychological need. Since advertising, market segmentation and prestige pricing are used to create a favorable image, this strategy involves incremental tactics such as launching a new advertising campaign, establishing more convenient distribution channels, and altering packaging. Most activities are confined to the marketing department; production and R&D people are less likely to be dramatically influenced by changes in marketing practices or by relatively minor changes carried out on the product. Hence, we limit our discussion here to product differentiation.

processes, mass production technologies require tightly sequenced integrated operations. This, in turn, can result in process structures with fewer discontinuities, machine pacing of material flow and fewer work-in-process inventories, all of which are requisites for low-cost production (Kotha and Orne, 1989).

Additionally, in the monolithic and ritualized orientation that prevails in this environment, relatively less complex and more routine inter-departmental interaction and information processing is needed (Miller, 1988). Thus, relative to a product differentiation strategy (which is discussed later), the overall need for information processing requirements are likely to be less complex, but more routine.

The implication of the foregoing discussion is that pursuing a low-cost strategy requires the process side of manufacturing to be tightly integrated for effective cost minimization. From an information processing perspective, such integration requires more information processing on the manufacturing process side, and relatively less on the product side. Hence, the need to store and rapidly manipulate manufacturing process oriented data is very high. In other words, firms pursuing a low-cost strategy must rely on technologies that assist in storage, retrieval and manipulation of large quantities of process-related information usually on a real-time basis (i.e., data is captured and processed as it is generated in the field). Consequently, in this manufacturing environment, technologies such as CAM, NC machines and programmable controllers, which focus on manufacturing processes are emphasized. Hence,

**Hypothesis 1.** *A cost-leadership strategy will be positively associated with the use of PT.*

### 3.3. Differentiation and AMT

A firm seeking to be unique in its industry along dimensions valued by buyers tends to pursue a differentiation strategy. Such a firm selects one or more attributes that consumers perceive as important and positions itself uniquely to meet those needs, and seeks reward for its uniqueness by charging a premium price (Porter, 1985, p. 14). Manufacturing implications of this strategy are as follows. First, product innovation is likely to be more critical for

firms pursuing differentiation strategy. Hence, differentiators are likely to exhibit greater product innovation and greater dynamism in product mix than cost leaders (Porter, 1980). Firms pursuing this strategy tend to produce a wide range of products in order to respond to a variety of market needs (Hambrick, 1983). Second, differentiation strategy often results in a low market share and thrives on a perception of exclusivity (Porter, 1980). This exclusivity, and the resulting low volume of production, in turn, may require unique product design and distinctive styling. However, a lower volume of production, combined with an emphasis on flexibility and adaptiveness toward the marketplace, results in a mode of production that stresses multipurpose equipment and requires skilled labor capable of performing a variety of tasks with great craftsmanship and adaptiveness. Hence, frequent new product development and high product variety are the foundations of a product differentiation strategy.

Manufacturing units serving a differentiation strategy will tend to have more complex product lines and several discontinuities in the process side to facilitate greater product variety (Kotha and Orne, 1989). The implications of the foregoing discussion is that the information needs of a differentiation strategy are varied and diverse.

As product diversity or variety increases, there will be an increase in both market diversity (i.e., environmental complexity) and manufacturing and technological complexity (Egelhoff, 1982). In turn, as environmental and technological complexities increase, requirements for information exchange and processing between interdependent subunits also increase (Galbraith, 1977). Thus, the need for information exchange and processing technologies increases for firms pursuing a differentiation strategy. Additionally, along with the increased need for information exchange, there is also an increased need for tactical and strategic information processing related to product matters (Egelhoff, 1982). Hence, the technologies essential for a differentiation strategy are those that assist in the storage, retrieval and manipulation of product-related information, so that these firms can manage the associated uncertainty and complexity; that is, firms pursuing product differentiation strategy need to emphasize several dimensions of AMT. Hence, the following hypothesis,

**Hypothesis 2.** *Given the diverse information processing needs of a differentiation strategy, it will be positively associated with the usage of several dimensions of AMT.*

### 3.4. Combination strategies and AMT

Many authors have argued that under certain industry conditions it is possible for firms to simultaneously pursue both cost-leadership and differentiation strategies orientations (e.g., Hill, 1988; Jones and Butler, 1988; Kotha and Orne, 1989; Pine, 1993). Kotha and Orne (1989), for instance, argue that: “[R]ecent advances in computers and communication technology are making this combined strategy orientation an attractive profit leadership position, especially for firms in industries with consolidated oligopoly structures” (p. 226).

This notion that firms can pursue a cost-leadership *and* differentiation strategy simultaneously has been a source of continuing debate in the business strategy literature. For example, some researchers have questioned Porter’s assertions that generic strategies are mutually exclusive by arguing that generic strategies are the underlying dimensions of firms’ competitive strategies (Karnani, 1984; Wright, 1987; Hill, 1988; Mintzberg, 1988). Some have found empirical evidence that firms that emphasize both a cost-leadership *and* differentiation orientation outperform others that focus on a single strategy (cf. Hambrick, 1983; Wright, 1987). On the other hand, a more recent investigation of Porter’s generic strategies by Nayyar (1993) found no evidence of combined cost-leadership and differentiation strategies in a study of a large U.S. multiproduct firm at the product-level. Nayyar concluded that although a firm may employ combinations of strategies across diverse product lines, individual products appear to use only one generic strategy.

Not surprisingly, this debate has spilled over into the manufacturing strategy area (cf. Ferdows and DeMeyer, 1990; Clark, 1995; Corbett and Wassenhove, 1995). Corbett and Wassenhove (1995), on the one side of the debate, argue that the changing nature and the increasing complexity of trade-offs (e.g., efficiency vs. flexibility) in manufacturing strategy decisions make traditional “either–or” arguments

incomplete in accessing the appropriateness of a firm’s manufacturing strategy. Arguments such as those presented above suggest that pursuing multiple competitive priorities (e.g., cost, flexibility, quality and dependability) in manufacturing is now a viable option. This is because a plethora of advanced manufacturing techniques (e.g., TQM, JIT and DFM) and computer-based information technologies (e.g., CAD/CAM and numerical control tools) make the “traditional” notion of trade-offs less important.<sup>4</sup>

On the other side of the debate, Clark (1995) notes that the notion of trade-offs is still at the heart of manufacturing strategy, while acknowledging that the emergence of the new advanced manufacturing techniques and technologies have reduced the need for a trade-off between cost and variety. For example, these new techniques and technologies shift and/or flatten the trade-off curve representing cost and variety. Accordingly, he argues that despite the availability of advanced manufacturing tools and techniques firms still confront the issue of trade-offs (see also Porter, 1996 for similar arguments). In the context of this debate, our position is that a dual strategy, as opposed to a trade-off, is more convincing. For a dual strategy to be effective, it will use technologies needed to support cost leadership as well as differentiation strategies. Hence, we propose the following hypothesis:

**Hypothesis 3.** *A dual strategy will be positively related to the usage all dimensions of AMT.*

Given the growing consensus on strategic importance of manufacturing, and the increasing availability of various AMTs, it is reasonable to expect that the utilization of AMTs in manufacturing firms will be related to performance (Parthasarthy and Sethi,

<sup>4</sup> It should be noted that AMTs are not necessarily at the center of such assertions. For instance, Ferdows and DeMeyer (1990) argue that sustainable manufacturing performance improvements can be achieved without trading-off different manufacturing capabilities such as quality and cost. They present a model where sequential managerial attention focuses on different capabilities such as quality, dependability, flexibility, and cost efficiency. By focusing on manufacturing quality before cost efficiency, they argue that this order of attention allows for the accumulation of capabilities instead of trade-offs between them.

1992; Dean and Snell, 1996). Yet, evidence directly supporting AMT–strategy–performance relationships is relatively rare (Boyer, 1997).<sup>5</sup> Therefore, we take this opportunity to test the contingency theory inspired question using the following hypothesis:

**Hypothesis 4.** *The relationships predicted in Hypotheses 1, 2 and 3 will be stronger in superior performing firms than in poorly performing firms.*

## 4. Methods

### 4.1. Sample

The data for the study were collected through a mail survey of manufacturing firms listed in the 1990 Compact Disclosure Database which contains financial and management information on over 12 000 companies. The manufacturing firms selected for this study belonged to Standard Industrial Classification (SIC) codes 34–39. These categories include firms involved in making fabricated metal products, industrial non-electrical machinery, electronic and other electric equipment, transportation equipment, instrumentation and related products, and miscellaneous manufacturing (see Table 1). If the SIC classification for a firm could not be determined from the response, because some respondents failed to identify themselves or their firms, the firm was classified as “other”.

The selected firms are from these industries because they involve the manufacture of discrete products based primarily on metal and non-metal fabrication, and exclude all process (i.e., continuous production) industries. Given the need for a large sample size, and the need to keep the industries relatively homogeneous (from a manufacturing/production perspective), this group of six industries is a reasonable compromise that accomplishes both goals. More importantly, the study focuses on these seg-

ments because of their acknowledged adoption of AMTs (Majchrzak, 1986; U.S. Department of Commerce, 1988; Dean and Snell, 1991; Ward et al., 1994).

The first set of survey questionnaires, along with a letter indicating the purpose of the survey, was mailed out during the first week of October 1990. This was followed by a second mailing 6 weeks later. Out of the 1652 firms listed under the SIC codes 34–39, questionnaires were sent to 851 firms with complete information in the database; 31 of these firms declined to participate citing company policy, and 22 questionnaires were undeliverable. This left questionnaires in the hands of 798 potential firms. Approximately 10% of the 851 firms, randomly selected, were sent two questionnaires, each to be filled out by a different senior manager in the firm. Out of these 86 firms, only 17 firms returned both questionnaires. These 17 responses were used for inter-rater agreement analysis described later.

In all, 177 completed responses were received yielding a response rate of 20% that is comparable to mail surveys with similar objectives (Hitt et al., 1982; Robinson and Pearce, 1988; Dean and Snell, 1991). Of these, 17 represented two responses from the same firm. In case of multiple responses from the same firm, only the response from the more senior officer was included in the analysis, and the second response was used for inter-rater agreement. Overall, 160 responses were used in subsequent analyses, 18% of the original sample.

### 4.2. Respondents

A letter accompanying the questionnaire asked that the survey be completed by a top level official in-charge of manufacturing and/or technology in the firm, or the business unit in the case of businesses with multiple units. Forty percent of the respondent were CEOs or presidents, and approximately 70% of the respondents held titles such as vice-presidents or higher (see Table 2).

#### 4.2.1. Response bias

A comparison of the composition of the 160 responding firms with the composition of the 851 target firms, found no prime facie reason to expect bias towards any particular industry. Further, a Chi-

<sup>5</sup> Recently, a few studies have examined the AMT performance linkage (e.g., Boyer et al., 1996; Dean and Snell, 1996) and found no link direct link between AMT and performance.

Table 1  
Industries represented in the sample

SIC code	Industry description	No. of responses	% of responses	Questionnaires mailed to	% of total mailed
34	Fabricated metal products	11	7.4	63	7.4
35	Industrial machinery and equipment	36	28.3	259	30.4
36	Electronic and other electric equipment	33	25.9	239	28.1
37	Transportation equipment	9	7.0	57	6.7
38	Instruments and related products	32	25.2	188	22.1
39	Miscellaneous manufacturing industries	6	4.7	45	5.3
Other <sup>a</sup>		33	–	–	–
Total		160	100% <sup>b</sup>	851	100%

<sup>a</sup> Respondents who failed to disclose the identity of their firms.

<sup>b</sup> Excluding ‘‘other’’.

squared test confirmed that there are no statistically significant differences between the two sets of percentages in Table 1.

Table 3 gives the results of tests for non-response bias. These tests did not reveal any statistically significant differences between respondents and non-respondents in terms of employment, 5-year growth in sales, and 5-year growth in income.

#### 4.3. Instrument

The questionnaire was developed and refined as follows: (1) nearly all items in the strategy and AMT sections of the questionnaire were adapted from previous published work (e.g., Dess and Davis, 1984; Robinson and Pearce, 1988; U.S. Department of Commerce, 1988); (2) preliminary drafts of the questionnaire were discussed with academic scholars to assess the content validity prior to pilot testing; and (3) a pilot test was conducted with a group of five firms, whose inputs were used to improve the clarity, comprehensiveness and relevance of the research instrument.

Table 2  
Type of respondents

Type of respondents	No. of responses	% of responses
Chairman/CEO/Chief Operating Officer	26	16.3
Presidents	36	22.5
Senior VP/Executive VP/VPs	49	30.6
Directors/General Managers	16	10.0
Others	33	20.6
Total	160	100%

#### 4.3.1. Strategy

Cost-leadership strategy was operationalized using a five-point Likert-type scales (1 = not very important to 5 = very important). Respondents were asked to indicate the degree of emphasis their firm attached to the following three items over the past 3 years: operating efficiency of the business unit, continuing concern for cost reduction in terms of product, and continuing concern for cost reduction in terms of process. Product differentiation strategy was also operationalized using a five-point Likert-type scales. The respondents were asked to indicate the emphasis their firm attached to the following five items over the past 3 years: new product development, enforcement of strict product quality control procedures, quality of the product, extensive service capabilities, and specific efforts to insure a pool of highly trained experienced personnel. The items used here for cost leadership and differentiation have been used in previous empirical studies (Dess and Davis, 1984; Robinson and Pearce, 1988).

Table 3  
Results of tests of non-response bias

Characteristics	Respondents		Non-respondents		<i>t</i>
	Means	S.D.	Means	S.D.	
No. of employees	2808	17533	2008	7307	0.432
5-year growth in income	25%	59%	14%	43%	1.349
5-year growth in sales	36%	61%	33%	85%	0.427

Composite strategy measures were computed by averaging the items making up the measures. Cronbach's alpha values (i.e., reliability measures) for the low-cost strategy measure was 0.72, and 0.74 for the product differentiation strategy measure.

#### 4.3.2. AMT items

The section on technology included 19 items (see Appendix A). These items have been used extensively in previous studies (e.g., Meredith, 1987; U.S. Department of Commerce, 1988; Boyer et al., 1996; Dean and Snell, 1996). Respondents were asked to rate how frequently a particular technology was used in his or her firm on a five-point Likert-type scales, where 1 = not used and 5 = very extensively used. A factor analysis of the responses was then conducted to establish meaningful patterns in the data and for grouping the 19 items into factors (discussed in detail below).

#### 4.3.3. Performance

The questionnaire section on performance measurement contained six items which included the following: after-tax return on total assets, after-tax return on total sales, net profit position; market share gains relative to competition, sales growth position relative to competitors, and overall firm performance/success. A combination of these items has been used successfully by previous researchers (e.g., Swamidass and Newell, 1987; Robinson and Pearce, 1988; Venkatraman, 1989).

The respondents were asked to subjectively rate their business units on these six items using Likert-type scales where 1 = top 20% and 5 = lowest 20%. To check the reliability of the self-reported performance measures, we estimated the correlation between normalized self-reported performance data and normalized, objective performance data obtained from COMPUSTAT II database for a randomly selected 20% of the responding firms. The resultant correlations were 0.72 and 0.82 for ROA and ROS. These high correlations provide acceptable reliability measures for the self-reported measures of performance in the questionnaire.

#### 4.3.4. Control variables

The context in which AMTs is adopted can explain not only differences in implementation patterns

among firms, but also their performance differences (Jaikumar, 1986; Williams and Novak, 1990; Boyer et al., 1996). Two critical variables often used to control for contextual effects include: industry membership and size (cf. Dess et al., 1990). Here, industry membership based on SIC codes is used to control for volatility and unpredictability.

#### 4.4. Inter-rater agreement

An inter-rater agreement analysis using the percent agreement procedure was then conducted (cf. Jones et al., 1983). This analysis was conducted for both the 19 technology and six performance items using data from 17 firms, whose that provided two questionnaires each. The estimated median value of percent agreement were 0.75 and 0.73 for the technology and performance items, respectively.

#### 4.5. Analyses

##### 4.5.1. Empirical development of AMT dimensions

A principal factor analysis of the AMT items (see Appendix A) based on varimax rotation was carried out. From a scree test, four interpretable factors with eigenvalues greater than 1.0 emerged. Based on the items that exhibited loadings greater or equal to  $\pm 0.4$ , the four interpretable factors are represented in Table 4 (cf. Kim and Mueller, 1986). Six of the 19 technology items (T12, T19, T14, T17, T18 and T7) loaded on more than one factor, suggesting that the factors have overlaps. Together, the four interpretable factors accounted for 62% of the variance. The empirically derived factors parallel three of the four conceptual dimensions proposed earlier: IET, PDT and PT.

The seven AMT items that loaded on factor 1 include: local area network (LAN) for factory use, computers used for control on factory floor, LAN for technical data, computers for production scheduling, electronic data interchange, MRP I and MRP II systems, and inter-company networks. Since technologies in this list assist in information exchange (e.g., inter-company and intra-company networks) and production planning and control (e.g., MRP I and MRP II systems), we labeled this factor as *information exchange and planning technology* (IEPT). Upon comparison, one finds that IEPT di-

Table 4  
Results of factor analysis — advanced manufacturing technologies

Technology items		Mean	S.D.	IEPT	PDT	HVAT	LVFAT
				I	II	III	IV
T16	LAN for factory use	2.23	1.63	0.76	0.18	0.31	−0.08
T13	Computers used for control on factory floor	2.93	1.66	0.66	0.21	0.10	0.30
T15	LAN for technical data	2.55	1.66	0.63	0.37	0.23	−0.20
T12	Computers for production scheduling	3.87	1.44	0.59	0.43	−0.09	0.28
T19	Electronic data interchange	2.21	1.57	0.57	−0.03	0.31	0.40
T14	MRP I and MRP II systems	3.37	1.72	0.49	0.46	0.10	0.27
T17	Inter-company networks	1.95	1.51	0.47	0.04	0.42	0.34
T3	Automated drafting technologies	3.08	1.66	0.15	0.84	0.07	0.00
T1	CAD	3.60	1.65	0.26	0.81	0.04	0.22
T2	CAE	2.91	1.64	0.07	0.77	0.28	0.14
T11	Computer-aided quality control performed on final products	2.62	1.74	0.04	0.32	0.73	−0.04
T10	Computer-aided inspection performed on incoming or in process material	1.97	1.48	0.04	0.19	0.70	0.29
T6	Robots others than pick and place	1.24	1.13	0.36	−0.06	0.61	0.24
T5	Pick and place robots	1.64	1.46	0.21	0.02	0.57	0.16
T18	Manufacturing automation protocol	1.37	1.08	0.50	0.08	0.57	0.23
T8	NC/CNC	2.17	1.81	0.13	0.18	0.11	0.83
T9	Programmable controllers	2.42	1.70	0.02	0.05	0.23	0.67
T4	CAD/CAM	1.94	1.51	0.32	0.39	0.22	0.53
T7	FMC/FMS	1.93	1.59	0.44	0.11	0.34	0.44
	Eigenvalue			7.30	1.90	1.30	1.20
	Percentage of variance explained			38.60	10.20	7.10	6.30

mension isolated here empirically combines the LPT and IET proposed earlier in our conceptual model.

The three AMT items, CAD, CAE, and automated drafting technologies, that loaded on factor 2 correspond to product design dimension proposed in the literature, hence we label it as *product design technology* (PDT). This dimension is as proposed in our conceptual model.

In contrast to a single process dimension presented earlier, the analysis of the AMT items resulted in two separate factors with process technology items loading onto them (see Table 4). More specifically, there were five AMT items — computer-aided quality control performed on final products, computer-aided inspection performed on incoming or in-process materials, robots other than pick and place, pick and place robots, and manufacturing automation protocol — that loaded on factor 3, and there were four items — NC/CNC machines, programmable controllers, CAD/CAM, and FMC/FMS — that loaded on factor 4.

In examining the items that load on factor 3, it appears that these are the technologies that are extremely useful and necessary in high-volume manufacturing of discrete products. In contrast, the technology items that load on factor 4 are often associated with flexibility, and for their ability to assist in rapid changes in production volume and product introductions. The group that load on factor 4 is extremely useful for low-volume and high-variety manufacturing. Therefore, factor 3 is labeled as *high-volume automation technology* (HVAT), and factor 4 as *low-volume flexible automation technology* (LVFAT). These two process dimensions have split away from a single process technology dimension presented earlier.

Further, the empirically identified factors offer a refinement of the *process technology* dimension proposed in the literature (Kotha, 1991). In other words, the empirical analysis of the AMT items indicate that PT have two independent dimensions: high-volume process automation and LVFAT. This empirical find-

ing helps us to refine Hypothesis 1 because HVAT dimension is presented in the literature as being compatible with low-cost manufacturing.

Whereas the earlier hypothesis stated that a cost-leadership strategy will be positively associated with process technology use, it is now refined as:

**Revised Hypothesis 1:** *A cost-leadership strategy will be positively associated with HVAT.*

Factor scores for each respondent were computed using methods described in basic texts on factor analysis (Rummel, 1970). Factor scores were computed in accordance with the following formula:  $f_i = a_{1i}z_1 + a_{2i}z_2 + \dots + a_{ji}z_j$ , where:  $a_{ji}$  is the factor score coefficient for technology item  $j$  ( $j = 1, \dots, 19$ ) on the factor  $i$  ( $i = 1, 2, 3, 4$ ), and  $z_j$  is the respondent's standardized value on technology item  $j$ . These factor scores were then used in subsequent regression analyses. To check the reliability of the factor scores, the salient items under each factor were combined to form composite variables, and Cronbach's alpha measures estimated. The Cronbach's alpha measures varied from a low of 0.75 for factor 4 to a high value of 0.84 for factor 2 and were well within the accepted limits (Nunnally, 1978).

#### 4.5.2. Performance factor scores

To identify imbedded factors, the six performance related items were factor analyzed using a principal factor analysis with varimax rotation. Two factors resulted from this analysis, one stressing *profitability* and the other stressing *growth*. Together, these factors explained about 88% of the variance in the data (see Table 5). Subsequently, factor scores were estimated for these two factors and used them as two *independent* performance measures in all the regression models. To check the reliability of the factor scores, the salient items under each factor were combined to form composite variables, and Cronbach's alpha measures estimated. The Cronbach's alpha measures were 0.85 and 0.82. These values are well within the accepted limits for this kind of study (Nunnally, 1978).

#### 4.5.3. Operationalizing fit

In order to test the proposed hypotheses, this study used the notion of fit. The fit concept, rooted in the contingency tradition, has been central to both

Table 5  
Factor analysis — performance measures<sup>a</sup>

No.	Items and descriptions	Factor 1 profitability	Factor 2 growth
P2	After-tax returns on total sales	0.9488	
P1	After-tax returns on total costs	0.9398	
P3	Net profit positions relative to competition's	0.8804	
P6	Overall firm performance/success	0.7281	
P5	Sales growth positions relative to competition's		0.9282
P4	Market share gains relative to competition's		0.9127
Eigenvalue		4.06	1.22
Percent of variance explained (total = 88.1%)		67.8	20.3

<sup>a</sup>Note: Only factor loadings > 0.55 reported.

theoretical and empirical research in strategic management (Drazin and Van de Ven, 1985; Venkatraman, 1989). It suggests that an organization's ability to achieve its goals is a function of the congruence between selected organizational components and the environment. Since it is hypothesized that specific strategies require the use of certain AMTs for superior performance, the study operationalized strategy-AMT fit using *interaction* or *moderation* analysis advocated in the literature employing regression analyses (Drazin and Van de Ven, 1985; Venkatraman, 1989).

To estimate the necessary regression models, the appropriate *factor scores* were used for the technology factors (i.e., independent variables) as well as the strategy variables (i.e., dependent variables). To examine the relationship between a dual-strategy orientation and AMTs, the study used two approaches to operationalize the strategy construct. The first approach used a composite variable of dual strategy created by adding the cost-leadership and differentiation strategy variables. In the second approach, the composite variable, denoting a dual-strategy approach, was created by multiplying the cost-leadership and differentiation strategy variables.

#### 4.5.4. Analytical approach

Two approaches for examining fit were used in this study: the moderated regression analysis and

regression based on subgroup analysis. The moderated regression requires that one conceptualize fit as “the interactive effect of strategy and AMT factors” with implications for performance. Based on a series of moderated regression analysis using this conceptualization of fit, we found that none of the moderated regression models were significant. According to Venkatraman (1989), this is not unusual because a particular data set may support one form of fit and not the other. This lack of significance could also be due to non-linearity or discontinuity in the relationships in the dataset.

Therefore, in order to conduct an alternative test of the hypotheses concerning *strategy-AMT-performance* fit, the study adopted the “subgroup” approach (e.g., Lenz, 1980; Miller and Friesen, 1986; Miller, 1988). Consequently, the sample was subdivided into three parts by using the *two independent performance measures* (i.e., growth and profitability) developed earlier. Based on these performance measures, the upper third of the respondents were considered superior performers and the bottom third were considered poor performers in all the regression models presented in Table 8; the middle third of the sample was dropped from the analyses.

## 5. Results

The means, standard deviations, coefficient alphas, and zero order correlations (between the dependent and independent variables) are reported in

Table 6. Many of the independent variables (AMT factors) are correlated with the dependent variables (e.g., cost leadership and differentiation) as expected. Since factor scores based on orthogonal factors were employed for operationalizing the various AMT variables, little inter-item correlations were found among them.

As noted, size (logarithm of employment) and industry membership were the control variables. However, the regression models presented here do not include an industry control variable because a MANOVA analysis of the four technology factors and the six industries represented in this study was not significant ( $p < 0.16$  Hotellings test;  $p < 0.17$  Wilks test). This finding is also consistent with those found by others in the literature. Boyer et al. (1996), for instance, based on a study of AMT adoption in firms that belong to SIC codes 34–38 (a grouping similar to this study), conclude that technology adoption patterns were not significantly different across firms from these industries.

The results of the regression models are presented in Tables 7 and 8. The three models (i.e., Models 1, 2 and 3) presented in Table 7 are based on the *entire* sample. In Model 1, *differentiation* strategy is the dependent variable, and AMT factors along with size, the control variable, are the independent variables. In Model 2, *cost-leadership* strategy is the dependent variable and AMT factors along with size are the independent variables. In Model 3, a *dual-strategy* orientation is the dependent variable, and AMT factors and size are the independent variables.

Table 6  
Pearson's zero order correlation (Cronbach's alpha along the diagonal for the strategy constructs)  
NA = Not applicable.

	Mean	S.D.	1	2	3	4	5	6	7
1. IEPT	0.01	1.03	NA						
2. PDT	0.00	1.02	0.01	NA					
3. HVAT	-0.04	1.03	-0.01	0.02	NA				
4. LVFAT	-0.02	1.07	0.00	-0.02	-0.02	NA			
5. Cost leadership	4.05	0.66	-0.01	0.04	0.28*	0.14	0.72		
6. Differentiation	4.00	0.60	0.33***	0.33***	0.25*	-0.04	0.19	0.74	
7. Size (log of employment)	5.74	1.77	0.37***	0.05	0.19	0.46***	0.10	0.00	NA

\*  $p < 0.01$ .

\*\*  $p < 0.05$ .

\*\*\*  $p < 0.001$ .

Table 7  
Regression analysis for the overall sample: technology and strategy variables  
Standard errors in parentheses.

Model no.	Differentiation	Cost leadership	Dual strategy (cost leadership $\times$ differentiation)
	1	2	3
Size (log of employment)	-0.1261*** (0.0416)	-0.022 (0.0531)	-0.5145 (0.2896)
IEPT	0.3058*** (0.0592)	-0.010 (0.0747)	1.079** (0.4120)
PDT	0.2449*** (0.0585)	0.057 (0.074)	1.201*** (0.4072)
HVAT	0.2233*** (0.0674)	0.1985** (0.0861)	1.644*** (0.4694)
LVFAT	0.0965 (0.0604)	0.1346* (0.0771)	0.8326** (0.4204)
Adjusted $R^2$	0.345***	0.05*	0.25***
Sample size	83	83	83

\*  $p < 0.10$ .

\*\*  $p < 0.05$ .

\*\*\*  $p < 0.005$ .

In Table 7, both differentiation and dual strategies are explained by the use of AMT factors (adjusted  $R^2 = 0.34$  and  $0.25$ , respectively). However, the model for cost-leadership strategy is not conclusive because, although the model is significant, it has a low adjusted  $R^2$  value of  $0.05$ . In order to improve the explanatory power of the models, we developed additional models for superior performers and poor performers using profitability and growth variables as the dependent variables. The resulting 12 regression models are reported in Table 8.

In Table 8, Models 1 and 2 aid in the comparison of superior and poor performers when *differentiation* strategy is the dependent variable and *profitability* is used to subdivide the sample. Models 5 and 6 help us compare superior and poor performers when *differentiation* strategy is the dependent variable and *growth* is used to subdivide the sample. Models 3 and 4 highlight the relationships between *cost leadership* and AMT use when *profitability* is used to subdivide the sample, and Models 7 and 8 do the same when *growth* is used to subdivide the sample. Models 9 and 10 aid in the comparison of superior and poor performers when a *dual-strategy* orientation is the dependent variable and *profitability* is used to subdivide the sample. Finally, Models 11 and 12 do the same when *growth* is used to subdivide the sample.

Importantly in Table 8, seven out of the 12 regression models are statistically significant and the adjusted  $R^2$  values are significantly higher than the those presented in Table 7. Clearly, the subgroup

approach employed here improves our ability to isolate the effect of the fit between AMT use and strategy upon performance.

### 5.1. Cost-leadership strategy and AMT use

Revised Hypothesis 1 predicted a positive relationship between a cost-leadership strategy and the use of HVAT. Results of Model 2 in Table 7 indicate a significant and positive relationship between a cost-leadership strategy and HVAT ( $\beta = 0.198$ ,  $p < 0.005$ ). However, the overall adjusted  $R^2$  for this model is negligible at 5%, and the regression equation is barely approaching statistical significance at  $p < 0.1$ . Additionally, an examination of Models 3 and 7 in Table 8, indicate that HVAT is not associated with cost-leadership strategy. Consequently, Revised Hypothesis 1 is not supported.

### 5.2. Differentiation strategy and AMT use

Hypothesis 2 predicted a positive relationship between a differentiation strategy and the use of several AMT factors. In Model 1 (Table 7), differentiation strategy variable is positively associated with three of the four technology factors. It is interesting that LVFAT factor is not associated with a differentiation when the entire sample of firms is used, a result that is inconsistent with the “flexibility requirements” arguments found in the literature. However, when only superior performers (profitability) are considered (Model 1, Table 8), it is clear that

Table 8  
 Subgroup regression analysis: strategy, technology, and performance  
 Standard errors in parentheses. S = superior performers; P = poor performers.

Model no.	Samples based on financial performance				Samples based on growth performance				Samples based on financial performance		Samples based on growth performance	
	Differentiation		Cost leadership		Differentiation		Cost leadership		Dual strategy			
	S	P	S	P	S	P	S	P	S	P	S	P
	1	2	3	4	5	6	7	8	9	10	11	12
Size (employment)	-0.2170** (0.0776)	ns	0.2169* (0.1105)	ns	-0.1893** (0.0858)	-0.1566** (0.0701)	0.0239 (0.1233)	ns	0.0879 (0.6354)	ns	-0.5753 (0.6704)	ns
IEPT	0.3437*** (0.0753)	ns	-0.1736 (0.1073)	ns	0.3565*** (0.1007)	0.3416*** (0.0994)	0.0512 (0.1448)	ns	0.6925 (0.6167)	ns	1.442 (0.7872)	ns
PDT	0.2949*** (0.0875)	ns	0.1746 (0.1247)	ns	0.2438*** (0.0795)	0.3269*** (0.1058)	0.2789** (0.1143)	ns	1.816** (0.7164)	ns	2.027*** (0.6213)	ns
HVAT	0.0587 (0.1067)	ns	-0.0147 (0.1520)	ns	0.2601** (0.1144)	0.1967 (0.1257)	0.0615 (0.1644)	ns	0.2715 (0.8731)	ns	0.1390 (0.8936)	ns
LVFAT	0.2485** (0.0854)	ns	0.0484 (0.1216)	ns	0.2195** (0.0883)	0.0537 (0.1237)	0.2144* (0.1270)	ns	1.129 (0.6988)	ns	1.750** (0.6901)	ns
Adjusted $R^2$	0.660***	ns	0.204*	ns	0.379***	0.426***	0.173*	ns	0.28*** 0.003	ns	0.34**	ns
Sample size	26	26	27	27	29	29	25	25	26	26	29	29

\*  $p < 0.10$ .

\*\*  $p < 0.05$ .

\*\*\*  $p < 0.005$ .

LVFAT is in fact associated with this strategy as expected.

Model 5 in Table 8 shows that all four AMT use is associated with a differentiation strategy in firms showing superior growth. In contrast, in firms showing poor growth (Model 6), there is no correlation between differentiation strategy and the use of HVAT and LVFAT. This suggests that these technologies are critical to growth when pursuing a differentiation strategy. Taken together, these results support Hypothesis 2.

### 5.3. Dual strategy and AMT use

Hypothesis 3 predicted a positive relationship between a dual-strategy orientation and the use of all AMTs. Model 3 (Table 7) that represents this orientation is statistically significant and explains 25% of the variance. Results from this model indicate that AMT factors are positively related to a dual-strategy orientation (i.e., cost leadership  $\times$  differentiation) as predicted.<sup>6</sup>

Although Hypothesis 3 finds support in Model 3 in Table 7, it does not find support in Models 9 through 12 in Table 8. In Table 8, only selected technologies are used in firms pursuing a dual-strategy orientation. For instance, only PDT use is associated with a dual strategy in profitable firms. Only PDT and LVFAT factors are associated with a dual strategy in firms showing superior growth. Thus, the findings do not confirm Hypothesis 3 which states that the use of all technologies will be associated with a dual strategy.

### 5.4. Strategy, AMT use and performance

Hypothesis 4 states that the relationships predicted in Hypotheses 1, 2 and 3 will be stronger in

superior performing firms than in poorly performing firms. The results presented in Table 8 indicate that while all six models representing superior performers are statistically significant, none of the models (with the exception of Model 6) representing the poor performers are statistically significant. This finding answers the primary question of this study: Is the fit between strategy and AMT use associated with improved performance? Based on Table 8, the answer is a “yes”, because all six models for superior performers group are statistically significant, and the adjusted  $R^2$  values for the superior performers in Table 8 exceeds those found in Table 7. Thus, Hypothesis 4 is strongly supported.

An incidental finding is that, in profitable firms, size correlates with cost-leadership strategy (Model 3). But, size does not correlate with cost-leadership strategy in firms showing superior growth (Model 7). Also, in Models 1, 5 and 6 (Table 8), size correlated negatively with a differentiation strategy regardless of the measure of performance used to form the subgroups. Thus, an inspection of the 12 models in Table 8 reveals that size has a mixed effect on strategy; it is positively related in some cases, negatively related in others, and is not related to strategy in some other cases.

## 6. Discussion and implications

The purpose of this paper was to empirically examine the relationships between AMT use and strategy orientations in U.S. manufacturing firms. The hypothesized relationships were: (1) a cost-leadership strategy will be positively related to the use of high-volume process automation technologies; (2) a differentiation strategy will be positively related to the use of several forms of AMTs; (3) a dual-strategy orientation (i.e., a combined strategy of differentiation *and* cost leadership) will be positively related to use of all AMTs; and (4) strategy-AMT fit will be stronger in superior performers than in poor performers. A summary of the important findings from Tables 7 and 8 are provided in Table 9 to aid the discussion in this section.

<sup>6</sup> As noted in Section 4.5, two different approaches were used to construct the dual-strategy orientation variables. The results presented in Tables 7 and 8 indicate that the dual-strategy (a combination approach of differentiation and cost leadership) composite variable was formed by *multiplying* the cost-leadership and differentiation variables. The results pertaining to the second approach employed, where the dual-strategy orientation composite variable was formed by *adding* the cost-leadership and differentiation variables, were very similar and thus not presented here.

Table 9

Summary of findings for superior performers (for models identified below refer to Table 8)

Strategic orientation	Performance = profitability	Performance = growth
Cost leadership	Cell 1 Indifferent to technology use (Models 3 and 4)	Cell 2 PDT and LVFT associated with growth (Model 7)
Dual strategy	Cell 3 PDT associated with profitability (Model 9)	Cell 4 PDT and LVFT associated with growth (Model 11)
Differentiation	Cell 5 IEPT, PDT and LVFT associated with profitability (Model 1)	Cell 6 All four factors (PDT, IEPT, LVFT, HVFAT) associated with growth (Model 5) PDT and IEPT alone are inadequate for success (Model 6)

### 6.1. Profitability, strategy and AMT

This study found that none of the AMT factors is significantly related to a cost-leadership strategy in firms showing superior *profitability* (see Cell 1, Table 9). In other words, profitable firms emphasizing a cost-leadership approach are indifferent to AMT use. This result is consistent with the findings provided by Dean and Snell (1996) who found no relationship between a cost-leadership strategy and AMT. These authors lament that this result is ironic because many firms use cost reduction as their principal justification for adopting AMTs.<sup>7</sup> This finding is also consistent with the arguments of Parthasarthy and Sethi (1992) that AMT's flexibility capabilities are not likely to be used to its potential when it is utilized as part of a cost-leadership strategy. In this setting, *size* is the only variable that is correlated with cost-leadership strategy. Perhaps, the traditional arguments that a cost-leadership strategy emphasizes high-volume production and efficiency appear to be still valid (Clark, 1995). AMTs may indeed be important for gaining a competitive advantage but they are by no means the *only* approach to competing (Garvin, 1993).

In contrast to a cost-leadership approach, firms pursuing a differentiation strategy employ more AMTs (compare Cells 1 and 5 in Table 9). This validates earlier arguments that AMT use requirements are higher for firms pursuing a pure differentiation strategy than a cost-leadership approach.

<sup>7</sup> Although Dean and Snell (1996) used 18 different items for their AMT construct, they did not distinguish between different dimensions of AMTs as done in this study.

A comparison of Cells 1 and 3 suggests that a dual strategy is more AMT dependent than a cost-leadership approach. Also, with regards to its dependency on AMT, a dual strategy lies in-between a cost-leadership and differentiation extremes. This suggests a need for a progression in AMT induced flexibility and information processing capability (FIPC) from a cost-leadership strategy to a dual strategy to a differentiation strategy.

### 6.2. Growth, strategy and AMT use

From Table 9, it is clear that firms that show superior *growth* emphasize AMT use more than firms showing superior *profitability* (compare columns 2 and 3 in Table 9). In high-growth firms, two technologies, PDT and LVFT, are consistently utilized (column 3, Table 9). PDT provides a firm with an enhanced capability to design products more rapidly, while LVFT provides a firm with an enhanced capability to manufacture products in low volumes without incurring the significant additional costs associated with frequent volume changes. Results found here suggest that it is the *combined* use of these two technologies that enable firms to pursue a high-growth strategy.

Results also suggest that firms using differentiation strategies are more AMT dependent than other strategies regardless of the performance measure (see Cells 5 and 6). Further, high-growth firms pursuing a differentiation strategy are more AMT dependent when compared to other approaches (see Cell 6); in other words, a differentiation strategy in superior growth firms appears to be a "technology hog".

In the case of Model 6 (Table 8), the use of IEPT and PDT factors are associated with poor growth in

firms that use a pure differentiation strategy. But, the successful firms pursuing this strategy employ all four technology factors (Model 5, Table 8). This suggests that the use of a few AMTs is insufficient for success, but the use of the same technologies along with other technologies (e.g., LVFAT and HVAT) can be effective. The use of all AMT factors increases the potential for *integration*, which may be at the heart of AMT effectiveness as argued in the extant literature (cf. Meredith, 1987; Dean and Snell, 1996).

### 6.3. Implications

The implications of these findings for practitioners is rather straight forward. Results of this study validate the key premise that a fit between strategy and AMT use is associated with successful performance. In other words, it is the judicious matching of AMT and strategy that leads to superior performance. It appears that, although AMTs offer greater information processing capability and/or flexibility, these capabilities are not necessarily associated with superior profitability when cost leadership is the strategy. These findings strongly echo the observations that scale and cost competition may be inconsistent with AMT use (Jaikumar, 1986; Lei and

Goldhar, 1990; Parthasarthy and Sethi, 1992). This caveat should be considered seriously in evaluating suggestions that, in highly competitive environments, all firms will be forced to adopt AMT (cf. Pine, 1993).

Another striking finding is that firms that are superior growth performers emphasize AMT use regardless of their strategy orientation. This confirms what others have consistently argued, that AMTs should be utilized in conjunction with a revenue-producing (i.e., growth) rather than cost-cutting strategy (Lei and Goldhar, 1990).

Fig. 1 captures the evidence on the interactions between strategy types and AMT induced FIPCs in successful firms. The X-axis identifies the three strategy types discussed in the paper, the Y-axis represents FIPC. To make this figure possible, we are presuming that the use of any one dimension of AMT contributes to a quantum increase in FIPC represented by the Y-axis. The resulting figure brings greater clarity to the preceding discussions.

Cell 1 in Table 9 is represented at the far left end of the figure, which represents a cost-leadership orientation in profitable firms. Cell 1 in the figure becomes the lowest reference point for FIPC. Similarly, the point associated with Cell 6 in the figure represents maximum FIPC in manufacturing firms.

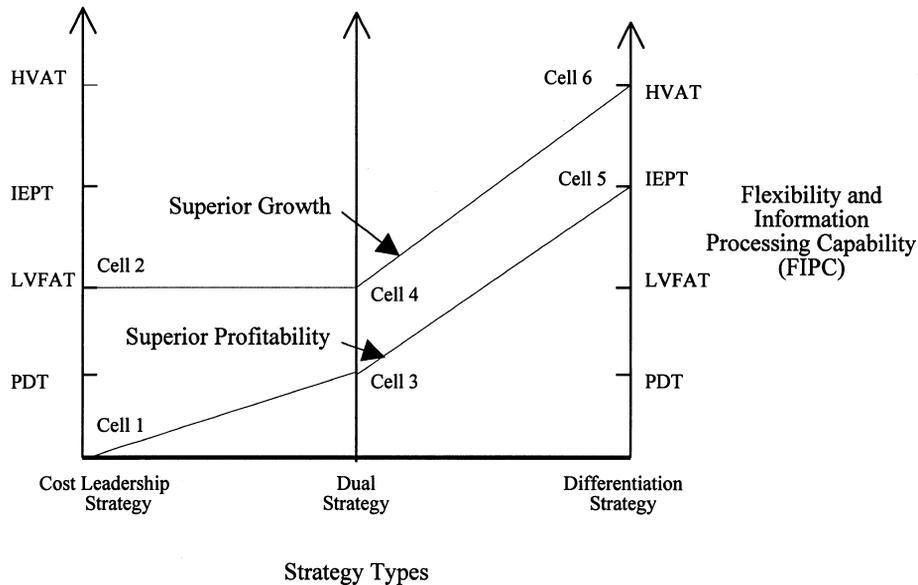


Fig. 1. Interaction between strategy types and AMT-induced flexibility and information processing capability.

Unexpectedly, dual strategy lies in between the two pure strategies at the extremes. This may be because a dual-strategy orientation can occur when firms using cost-leadership strategies begin widening their product strategies to include some form of differentiation. Therefore, the evidence from the use of AMTs suggests that a dual strategy is not a full blown combination of the two extreme strategies; it is more likely a user of cost leadership *creeping* towards some form of differentiation.

The results have few strong implications for researchers. In contrast to earlier studies that have employed AMT as a unidimensional construct (e.g., Dean and Snell, 1996), this study finds that AMT is a multidimensional construct. Using a multidimensional approach to conceptualizing and testing AMT–strategy–performance relationships has enabled this study to examine in greater detail the often subtle relationships among these constructs than was possible in previous studies (cf. Dean and Snell, 1993). The implications for future researchers examining the AMTs is that they need to consider it as a multidimensional construct.

The results offered here are early, but strong, empirical evidences to illustrate the relationships between strategy and AMT use. In contrast to previous studies (e.g., Boyer et al., 1996; Dean and Snell, 1996) that found no relationship between strategy–AMT–performance, this study found many significant relationships. However, given the fact that some researchers and practitioners prescribe AMTs indiscriminately as a panacea for *most* problems faced by U.S. manufacturers, this study stresses the need to be *discriminating* in the adoption of AMT; that is, carefully match strategy and AMT in seeking growth or profitability. General Motors' ineffective investment of nearly US\$80 billion in manufacturing technology during the eighties (Keller, 1989) is a good example of why it is important to be discriminating regarding such investments. The findings of this study offers guidance on how strategy and AMT investment can be selectively matched to attain either a profitability or a growth objective.

#### 6.4. Avenues for further research

As noted earlier, this study focused on discrete product manufacturing industries (SIC codes 34–39).

This is because these are the industries that have been acknowledged to employ AMTs extensively. Moreover, industries that belong broadly to this SIC code employ similar discrete manufacturing processes to manufacture products. Perhaps, this latter reason is the cause for several investigations of this industry specific grouping in the literature (cf. U.S. Department of Commerce, 1988; Swamidass, 1996). Hence, given this limited choice of industries, the findings are generalizable only to these SIC categories.

This study also relied on cross-sectional data to examine strategy–AMT fit. Although the cross-sectional nature of this study is not a serious limitation, it does not permit the study to highlight the causal directions between strategy–AMT relationship. Further, it does not permit the examination of performance impact of AMT adoption over time. Given that: (a) firms rarely adopt all AMTs simultaneous (Twigg et al., 1992), and (b) the performance impact of AMT adoption may vary significantly over time (Dean and Snell, 1996), an evolutionary perspective that examines how firms adopt and utilize AMTs over time is needed.

This study used two commonly articulated *generic* strategies — cost leadership and product differentiation. However, it is recognized that more studies examining strategy–AMT–performance relationships using an expanded notion of strategy (cf. Mintzberg, 1988) are needed. This is especially important because some researchers (e.g., Parthasarthy and Sethi, 1993) have argued that the performance of firms employing AMTs will be increased in the context of quality leadership strategy. Also, dimensions of strategy that help better capture operational issues such as speed to market, agility, product co-development with customers should be employed. Doing so could help researchers better highlight the causal linkages between AMTs and important operational strategy dimensions.

Past research indicates that generic strategies are appropriate in a wide variety of competitive environments, both in advanced and developing nations. Since a firm's strategy reflects the environment in which it operates, we expect our arguments to apply to environments where generic strategies are appropriate. However, it is recognized that future studies should explicitly consider organizational infrastruc-

ture measures, and the competitive context in which strategies are pursued.<sup>8</sup> Such explicit consideration is important because the effective utilization of AMTs can be seriously impacted by both organizational and the external contexts (Zammuto and O’Conner, 1992). Finally, researchers should seek to understand the intriguing findings concerning dual strategy, which, according to evidence, lies midway between the two pure generic strategies.

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## Appendix A

Here, we list the definitions provided by the U.S. Department of Commerce (1988) for a host of AMTs. For additional details, see also Meredith (1987).

- CAD and CAE. Use of computers for drawing and designing parts or products and for analysis and testing of designed parts or products.
- Automated drafting technologies. Use of computers for drafting engineering drawings.
- CAD output used to control manufacturing machines (CAD/CAM). Use of CAD output for controlling machines used in manufacture of the part or product.
- Pick and place robots. A simple robot, with 1, 2, or 3 degrees of freedom, which transfers items

from place to place by means of point-to-point moves. Little or no trajectory control is available.

- Robots other than pick and place. Use of sophisticated robots that can handle tasks such as welding or painting on an assembly line. Here trajectory control is available.
- Flexible manufacturing cells (FMC). Two or more machines with automated material handling capabilities controlled by computers or programmable controllers, capable of single path acceptance of raw materials and single path delivery of a finished product.
- FMS. Two or more machines with automated material handling capabilities controlled by computers or programmable controllers, capable of multiple path acceptance of raw materials and multiple path delivery of a finished product. A FMS may also be comprised of two or more FMC’s linked in series or parallel.
- NC/computer numerically controlled (CNC) machine(s). A single machine either NC or CNC with or without automated material handling capabilities. NC machines are controlled by numerical commands punched on paper or plastic mylar type, while CNC machines are controlled electronically through a computer residing in the machine.
- Programmable controllers A solid state industrial control device that has programmable memory for storage of instructions, which performs functions equivalent to a relay panel or wired solid state logic control system.
- Computer-aided inspection performed on incoming or in process materials. This denotes the use of computers for inspecting incoming materials.
- Computers used for control on the factory floor. These include computers that may be dedicated to control, but which are capable of being reprogrammed for other functions. It excludes computers imbedded within machines, or computers used solely for data acquisition or monitors.
- MRP I and MRP II systems. Use of computers and computer modules for controlling the entire manufacturing system from order entry through scheduling, inventory control, finance, accounting, accounts payable, and so on.
- LAN for technical data and LAN for factory use. Use of LAN technology is employed to exchange technical data within design and engineering

<sup>8</sup> It should be pointed out that in this study we did control for industry membership effects. Although industry membership could be considered as a surrogate measure of the external competitive environment, more explicit measures for the external environment should be used.

departments. LAN for factory use denotes the network employed to exchange information between different points on the factor floor.

- Inter-company computer networks linking plant to subcontractors, suppliers, and/or customers. This denotes the computerized networks used to exchange information with the firm's external constituents.

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