THE STRATEGIC USE OF INTEGRATED MANUFACTURING: AN EMPIRICAL EXAMINATION

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The increasing importance of advanced manufacturing technology, total quality management, and just-in-time to manufacturing firms raises some basic questions as to the strategic use of these techniques in manufacturing. Does strategic use of these techniques influence performance? How is the impact of these techniques influenced by the competitive environment? Are the techniques actually being used strategically? A study in a large sample of manufacturing organizations confirms that the use of integrated manufacturing techniques—particularly total quality—influences performance, and that these effects are magnified or diminished by both the competitive environment and manufacturing strategy. It also shows that, in some cases, firms are missing opportunities to combine integrated manufacturing and strategy in ways that would substantially impact their performance.

Over the past few decades we have witnessed an enormous change in the way U.S. manufacturing firms organize to compete (Hayes and Wheelwright, 1984; Skinner, 1985). For 30 years following World War II, the manufacturing function was virtually ignored by top management, and consigned to the backwaters of day-to-day operations (Buffa, 1984). As a result of performance declines during the 1970s and 1980s, however, it became clear that manufacturing must play a significant role in shaping the competitive posture of organizations (Skinner, 1985; Fine and Hax, 1985; Garvin, 1993). In fact, evidence now exists that manufacturing parallels other functions in contributing to overall firm performance (Leong, Snyder, and Ward, 1990; Marucheck, Pannesi, and Anderson, 1990).

Researchers have noted that a paradigm shift that may be termed *integrated manufacturing* is occurring within organizations (Mortimer, 1985; Ciampa, 1987; Schonberger, 1987). Integrated manufacturing (IM) is driven by the widespread adoption of advanced manufacturing technology (AMT), total quality management (TQM), and just-in-time inventory control (JIT). AMT is the manufacturing subset of information technology, and comprises such specific technologies as flexible manufacturing systems (FMS), as well as the integration of aspects of manufacturing into computer-integrated manufacturing (CIM) systems (Majchrzak, 1988; Dean and Susman, 1989). JIT is a set of practices for reducing lead time and inventory, and is associated with reductions in number of parts and suppliers, and increased frequency of parts delivery (Schonberger, 1986; Gunn, 1987). Finally, TQM is a philosophy of management comprised of principles such as continuous improvement and teamwork with suppliers to improve quality (Dean and Bowen, 1994).

These three techniques—AMT, JIT, and TQM—combine to create 'a streamlined flow of automated, value-added activities, uninterrupted by moving, storage, or rework ... The elimination of barriers is the heart of IM' (Snell and Dean, 1992: 472). Together they have important

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strategic potential in that they blend the stages, functions, and goals of manufacturing. Rather than viewing performance as the result of trade-offs between, for example, cost and quality, the IM perspective posits that firms can pursue several outcomes simultaneously (cf. Ferdows and DeMeyer, 1990).

Given the emerging consensus on the strategic importance of manufacturing, and the development of powerful IM techniques, it seems likely that the utilization of these techniques will be related to performance differences in manufacturing firms. Exploring this relationship between IM and performance is the primary goal of our paper.

In order to understand this relationship, however, we must consider two important aspects of the context in which IM is implemented. First is the competitive context of the firms in question, including the growth or decline in their industries, as well as their industries' degree of concentration (e.g., Porter, 1980). Specifically, is the utilization of IM differentially related to performance as a function of the competitiveness of the industry? Or, alternatively, is its utilization equally valuable regardless of industry context? These issues will be explored in detail below.

Second, it seems likely that the performance implications of IM will also depend on firms' choice of manufacturing strategy. Hayes and Wheelwright (1984: 24) noted that 'manufacturing can be a formidable competitive weapon if managed properly, and the key to doing that is the development of a coherent manufacturing strategy.' This involves creating a distinctive competence in manufacturing that will produce a competitive advantage (Swamidass and Newell, 1987). Cost, quality, delivery performance, and flexibility are fundamental dimensions of manufacturing strategy that can help to achieve this task (Skinner, 1969; Wheelwright, 1981; Schroeder, Anderson and Cleveland, 1986; Leong *et al.*, 1990; Marucheck *et al.*, 1990; Garvin, 1993).

Despite several calls for research on the relationships between IM and manufacturing strategy (e.g, Meredith and Vineyard, 1993; Marucheck *et al.*, 1990), the assumptions and theories that underlie the two streams of research have not been well integrated, and few studies to date have examined how these two paths converge to influence performance. Some systematic research has emerged (e.g., Ward, Leong, and Boyer, 1994), but a great deal remains to be learned. Survey-based empirical work is especially needed (Leong *et al.*, 1990), as the field lacks an accumulation of reliable findings across a variety of firms (Swamidass and Newell, 1987). Finally, the actual strategic use of IM is worth examining. How do firms actually combine IM with manufacturing strategy? Is their approach consistent with the prescriptive literature? Are there opportunities for firms to better combine IM with strategy?

In summary, our study will consider four basic questions. First, is the utilization of IM related to performance in manufacturing firms? Second, is this relationship moderated by the competitiveness of the industry? Third, how is this relationship influenced by manufacturing strategy? Finally, how do firms combine IM and strategy? Each of these questions is discussed in detail in the following sections. Figure 1 shows a hypothetical model linking integrated manufacturing, competition, manufacturing strategy and performance, and illustrating the relationships among the research questions.

DEVELOPMENT OF A THEORETICAL FRAMEWORK

Integrated manufacturing and performance

Improving business performance is among the principal reasons firms implement IM. Managers expect that by utilizing AMT, TQM, and JIT, their performance on a variety of dimensions will improve—an expectation echoed by numerous scholars (e.g., Fine and Hax, 1985; Parthasarthy and Sethi, 1992). While the components of IM vary in their potential impact on different dimensions of performance, AMT, TQM, and JIT all

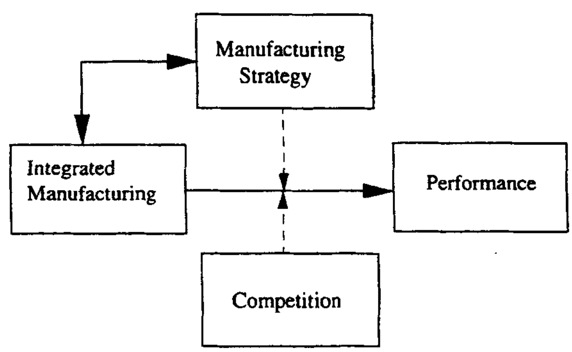

Figure 1. Model linking integrated manufacturing, strategy, competition, and performance

have the potential to increase the value provided to customers, by both reducing costs and providing better products to customers faster.

AMT reduces manufacturing costs by automating design, fabrication, assembly, and materials handling (Dean, Yoon, and Susman, 1992; Giffi, Roth, and Seal, 1990; Helfgott, 1988; Majchrzak, 1988). TQM advocates such as Crosby (1980) argue that pursuing total quality reduces the overall cost of quality, because the costs of ensuring good quality (e.g., through process improvement) are less than the penalty paid for poor quality (e.g., noncompliance and rework). Finally, Reid (1990) identified significant cost savings, particularly in terms of inventory, enjoyed by Harley-Davidson upon its implementation of JIT.

However, the potential performance impact of IM goes well beyond cost reduction. IM techniques have been found to improve performance in terms of what customers receive and when they receive it, i.e., quality (Meredith, 1988; Chen and Adam, 1991) and lead time (Meredith and Vineyard, 1993). In addition, many observers have commented on AMT's potential for flexibility, which can be used to create customized products (e.g., Lei and Goldhar, 1990).

Despite the presumed benefits of IM for manufacturing performance, most of the available evidence consists of case studies of single firms and single techniques or technologies. Many of these studies conclude that the use of a particular IM technique has in fact improved the performance of the firm in question (e.g., Mortimer, 1985; Schonberger, 1986). However, the available case literature does not portray companies' experiences with IM as an unalloyed success. While firms such as Allen-Bradley, Motorola and Harley-Davidson are well known for their successes with AMT, TQM and JIT, respectively, others such as General Motors have had great difficulty realizing performance improvements from AMT (Gerwin and Kolodny, 1992), and many firms attempting to practice JIT and TQM have been disappointed with their results (Zipkin, 1991; Fuchsberg, 1992).

Recent large-sample empirical studies have found mixed results on the question of the AMT–performance relationship (Swamidass and Kotha, 1994): AMT has indeed been linked to higher performance (Ward *et al.*, 1994); but also in certain situations to lower performance (Swamidass and Kotha, 1994). Such mixed results and experiences, which suggest that improved performance may not invariably flow from IM, lead to our first question:

Research question 1: Do firms that utilize elements of integrated manufacturing (AMT, TQM, JIT) perform better than those that do not?

The *timing* of any performance benefits stemming from IM is a complex issue that we can only begin to address in our study. It may be that performance begins to improve immediately after the implementation of IM, and continues to do so in a consistent manner for some time afterward. Alternatively, any performance improvements may be better represented by a step-function, in which a period of flat performance is followed by a substantial increase, followed by another performance plateau. Given the complexity of implementation associated with IM, however, performance may even temporarily *decline* after implementation, followed by a recovery that culminates in net increases in performance. Given current knowledge, one can only speculate about the amount of time that any of these trends would take (months? years?). As will become clear in our methods section, we will only be able to detect performance improvements over an 18-month period. Further complicating this issue is the fact that firms rarely implement all aspects of IM—or even any one of them—at once, thus the implementation itself may often be a protracted affair. Clearly this is an area in which further thought—and research—is required.

Integrated manufacturing, industry competitiveness, and performance

Looking more broadly at the relationship between IM and performance, it seems likely that this relationship is moderated by the level of competition in the industry in which a firm competes. By competition, we mean the 'intensity of rivalry among existing competitors' (Porter, 1980: 17), which influences the opportunity for firms to be profitable in an industry. Relating competition to our theoretical framework, the potential performance benefits of IM may be reduced in industries that are intensely competitive. There are several reasons why this may be the case.

First, it is likely that in highly competitive manufacturing industries a larger proportion of firms will be utilizing IM techniques. If IM is widespread in an industry, it will be harder to use it to develop a competitive advantage. As March and Sproull (1990: 157) put it, 'Under [some] circumstances, the gains from new technology are decreased by the fact that others are using it. Many kinds of production technology fall into such a category.' This implies that advantages over competitors may be short-lived for early adopters of IM in competitive industries, and nonexistent for later adopters. For example, in the automotive industry, JIT delivery has become the standard; suppliers that cannot operate in this manner are simply not viable (Corbett and Van Wassenhove, 1993).

Second, firms in competitive industries are likely to be undertaking other strategic initiatives that will parallel the impact of IM adoption. While AMT, JIT, and TQM may indeed be important for improving flexibility, quality, etc., they are certainly not the *only* way to do so (Garvin, 1993). For example, costs can be reduced to some degree simply by downsizing, or by moving production to lower-wage sites. While these may not be viable long-term solutions, they could offset in the short term the advantages of IM implementation by competitors.

Third, firms in highly competitive industries are likely to be operating with very few slack resources. Thus, even when they are able to devote resources to the implementation of IM, they will be less likely than firms in less competitive environments to invest additional time and money in activities such as training and organizational development, which may be necessary to implement IM successfully (e.g., Noori, 1990; Ward *et al.*, 1994). Markus and Robey (1988) have argued that the effects we often attribute to technology alone may actually be due to the interaction of technology and context, and most theorists now acknowledge that IM should not be implemented without explicit consideration of the organizational infrastructure (e.g., Zammuto and O'Connor, 1992; Ward *et al.*, 1994).

Snell and Dean (1992), for example, argued that changes in human resource management are necessary to capture the full benefits of IM, and in fact many successful IM practitioners have made such changes (e.g., Sheridan, 1994). Many firms apparently compromise the value of IM by not making corresponding changes in employee jobs (Jaikumar, 1986). If these observations are correct, simply implementing a new technology or quality program will not materially influence performance (Hayes, Wheelwright, and Clark, 1988). In fact, firms that neglect such organizational and infrastructural changes may actually see their performance decline (e.g., Boddy and Buchanan, 1986; Majchrzak, 1988).

For several reasons, therefore, it seems likely that industry competitiveness may diminish the advantages to be gained from the introduction of IM. This line of thinking is reflected in our second research question.

Research question 2: Does industry competitiveness moderate the relationship between integrated manufacturing and performance?

Integrated manufacturing, strategy, and performance

Theorists have long argued that strategy should drive the selection of technology (Skinner, 1969; Stobaugh and Telesio, 1983), and that technological capability should be the foundation for strategy (Hayes, 1985; Parthasarthy and Sethi, 1992). The premise of these complementary lines of thought is that neither manufacturing strategy nor technology (in this case, IM) will reach their potential except as components of an overall competitive platform.

One aspect of this argument is that a firm's major manufacturing decisions should be taken so as to advance its chosen basis of competitive advantage (Hayes *et al.*, 1988; Garvin, 1993). Decisions related to quality, production control and the use of manufacturing technology clearly figure among the major manufacturing decisions, as they make up a significant part of the manufacturing infrastructure (Leong *et al.*, 1990; Marucheck *et al.*, 1990). Thus AMT, TQM, and JIT implementation should be considered in light of a firm's strategy, if the strategy is to be effectively deployed.

The other side of this coin is that strategy formulation should be guided by a firm's existing technical capabilities (e.g., Hayes, 1985). According to this view, a firm's competence in manufacturing technology or quality processes is a 'springboard' for developing strategy (Parthasarthy and Sethi, 1992). Thus a firm's manufacturing strategy should reflect its manufacturing capabilities, including those provided by IM techniques. As Corbett and Van Wassenhove (1993: 110) have put it, 'core competences in manufacturing are of little value if they are not properly aligned with competitive positioning.' Based on these complementary arguments, firms trying to capture IM's performance benefits will have to implement it in conjunction with an appropriate manufacturing strategy (e.g., Parthasarthy and Sethi, 1992).

Beyond the general argument that strategy and technology should match, some scholars have proposed synergies between specific strategies and specific aspects of integrated manufacturing. Some examples follow.

AMT

Parthasarthy and Sethi (1992) argue that the capabilities of AMT are best suited to strategies that emphasize flexibility, and will not be used to its potential when implemented as part of a low-cost strategy, because its capability for flexible production will be underutilized if not ignored. Flexibility is also emphasized in the work of Blois (1985), Meredith (1988), and Lei and Goldhar (1990). Jaikumar (1986) discovered that AMT and flexible manufacturing systems were not being used to their potential because they were implemented in the context of strategies aimed at low costs, rather than increased flexibility.

Corbett and Van Wassenhove (1993), however, while also emphasizing the potential for flexibility represented by AMT, argue that in some cases it must be accompanied by attempts to reduce fixed manufacturing costs. Similarly, Haskins and Petit (1988) discuss the combined cost/flexibility advantage that can be gained by AMT. Indeed, it would be ironic if a low-cost strategy were inappropriate for AMT, because cost reduction is often the principal justification for its adoption (Dean, 1987). Finally, Parthasarthy and Sethi (1992) posit that the performance of firms using AMT will be increased by the implementation of a strategy involving quality leadership. Thus there is no clear consensus in the literature regarding the appropriate strategic context for AMT.

TQM

It appears that TQM will be most effective when accompanied by a manufacturing strategy that emphasizes quality. If strategic priorities are elsewhere, then a firm's TQM efforts may be undermined by policies and decisions that do not support quality. Even this seemingly obvious connection is not so simple, however, because it is possible to argue that TQM can simultaneously improve both cost and quality (Crosby, 1980; Belohlav, 1993), and TQM has also been linked to increasing flexibility of operations (e.g., Ciampa, 1991). These positions imply that multiple strategic thrusts may take advantage of, and thus be consistent with, the potential of TQM.

JIT

Less attention has been paid to the strategic context of JIT. Zipkin (1991) argues that strategies emphasizing cost and quality are well suited to JIT, while those emphasizing variety or availability are not. Swamidass and Newell (1987) and Zygmont (1989), however, argue that JIT can contribute to strategies emphasizing cost, quality, *and* flexibility. Thus there is only partial consensus on the strategies that complement JIT.

An alternative position is that IM techniques possess the potential to improve performance *regardless* of the type of manufacturing strategy pursued. Miller and Hayslip, for example, consider IM techniques to be ways to 'improve manufacturing's fundamental competitive capabilities' (1989: 23). These scholars see capability building and strategic planning as related but separate aspects of manufacturing strategy (cf. Corbett and Van Wassenhove, 1993). Regardless of the particular strategic goals it is called upon to achieve, a more capable manufacturing organization should, from this perspective, enjoy better performance. Given our discussion above, however, it seems unlikely that there are no relationships between manufacturing strategy and the performance benefits of IM. Thus we have framed our research question as follows:

Research question 3: How does manufacturing strategy moderate the relationship between IM and manufacturing performance?

Integrated manufacturing and strategy

While a prescriptive orientation guides our first three research questions, the final question addressed in this study was purely descriptive: Is there a relationship between firms' use of IM techniques and the manufacturing strategies they pursue? The argument that firms *should*, through careful planning processes, create linkages between their strategies and technologies was outlined above. If firms actually follow these recommendations, and plan technology with strategy in mind, and/or strategy with technology in mind, one would be able to observe relationships between integrated manufacturing and the pursuit of various manufacturing strategies. Marucheck *et al.* (1990) identified several firms where this was the case.

However, the extent to which firms in general coordinate their decisions about strategy and technology is an open question—indeed, we would need to observe cases where there were matches as well as mismatches between strategy and IM in order to detect statistically interactive effects of IM and strategy on performance (research question 3). There is some evidence that managers often do not think strategically when making technology adoption decisions (e.g., Giffi *et al.*, 1990), or are frustrated when they try to do so.

Meredith and Vineyard (1993) described the case of a business unit considering adoption of a flexible manufacturing system (FMS). Recognizing the strategic implications of the technology, the unit's managers requested a clarification of the company's strategic direction. When corporate managers could not or would not provide such clarification, the business unit purchased the FMS anyway, hoping that it would support whatever direction the company ended up pursuing.

While this example deals with AMT, one can easily see how the implementation of TQM or JIT could be unrelated to strategy. Both of these philosophies have become institutionalized in (at least North American and Western European) manufacturing culture. Managers feel considerable pressure to 'do something' about quality and JIT, whether this makes sense strategically or not. Intensifying such pressures is the tendency of some advocates of these techniques to recommend them under virtually any circumstances, with little regard for strategic or contextual factors (Anderson, 1991). These forces would weaken any relationships between IM techniques and manufacturing strategy.

Thus the arguments can be drawn either way. On the one hand, managers have been told for years to try to match their strategies and technologies effectively. On the other, there is evidence that they may not do so, particularly in the case of IM. Our study will provide data to address this question as well.

Research question 4: Is there a relationship between the use of integrated manufacturing techniques and manufacturing strategy?

METHODS

Data and procedures

A potential pool of 512 manufacturing firms was drawn from several segments of the metal-working industry: primary metals (Standard Industrial Classification (SIC) 33), fabricated metal products (SIC 34), industrial and metal-working machinery (SIC 35), transportation equipment (SIC 36) and precision instruments (SIC 37). We chose these industry segments for their acknowledged adoption of AMT (Majchrzak, 1986; Office of Technology Assessment, 1984), and identified firms in these industries using the *Harris Pennsylvania Industrial Directory*. Choosing a set of industries all related to metal-working also served to limit the variation in industry characteristics. For example, industries such as clothing or toys would exhibit quite different characteristics than those in our sample.

General managers

The initial contacts for the study were the general managers of the plants or business units at each site. We mailed a cover letter and questionnaire measuring AMT, TQM, JIT and performance to each general manager. After 3 weeks, we sent a prompting letter and a second copy of the questionnaire to all managers who had not yet responded. A final total of 160 general managers (31%) participated in the study. A comparison of the firms whose managers responded with a random sample of nonparticipating firms showed no significant differences for size or unionization.

Functional managers

Each general manager was also asked to provide the names of a manager in each of three functions: operations, quality, and production control. (An expert panel of 25 manufacturing managers had identified these three functions as the most likely to be knowledgeable about the use of IM in their firms.) Of the 160 participating general managers, 123 provided the names of functional managers. Functional managers were asked about the facet of IM most pertinent to their area of expertise: AMT for operations, TQM for quality, and JIT for production control. We used this information to corroborate the information provided by general managers. All functional managers were also asked about performance. After 3 weeks, we mailed a second letter and questionnaire to nonresponding managers. In total, 102 operations managers (82%), 109 quality managers (89%), and 97 production control managers (79%) participated.

Approximately $1\frac{1}{2}$ years later, a second wave of questionnaires was mailed to all the managers who responded to the first wave. The questionnaires in this wave measured manufacturing strategy and performance, and were identical for all managers. Based on the response to this wave of questionnaires, we were able to retain 92 firms for the analysis reported in this paper.

Measures

The measures used in this study and the respondents to whom they were administered are briefly described below. We used at least two informants per site for each variable, and mean values across respondents were used in all cases for subsequent analysis. Specific items used to assess the extent of utilization of IM, as well as various manufacturing strategies, are included in Appendices 1 and 2, respectively.

Integrated manufacturing

We pilot-tested the IM measures on a group of manufacturing managers to ensure construct validity, and used multiple items and multiple respondents to ensure both internal consistency and interrater reliability. The three components of IM were measured in the first wave as follows. *Advanced manufacturing technology* was an 18-item scale measuring the extent to which a firm has implemented and integrated computer technologies for manufacturing. Respondents were general managers and operations managers. *Total quality* was a 10-item scale measuring the extent to which a firm uses techniques to promote continuous improvement and devotion to fulfilling customer needs. Respondents were general managers and quality managers. *Just-in-time* was a 5-item scale measuring the extent to which a firm attempts to cut costs through reduced inventories and lead times and by controlling such features as the number of suppliers and size of deliveries. Respondents were general managers and production control managers. In each case the variables were coded by averaging across items, and then across respondents to produce a single score for each site on each variable. The unidimensionality of the scales used to measure AMT, JIT, and TQM has been established in previous research (Snell and Dean, 1992).

Competition

Competition is a complex and multifaceted construct, which can be conceptualized in a number of different ways. Our conception of competition is based on Porter, and focuses on the 'intensity of rivalry among existing competitors' (1980: 17). This approach to competition was chosen to be consistent with the role of this construct in our model, i.e., as capturing differences among industries that make it easier or harder to gain competitive advantage through implementation of IM. We utilized two variables to operationalize competition, each of which is rooted in both the literatures in strategic management (e.g., Porter, 1980) and organization theory (e.g., Dess and Beard, 1984).

The first is *munificence*, which measures the growth or decline in sales over time in an industry (Dess and Beard, 1984). As Porter (1980: 18) indicated, 'Slow industry growth turns industry competition into a market share game [in which] competition is a great deal more volatile than is the situation in which rapid industry growth insures that firms can improve results just by keeping up with the industry.' Data for munificence (as well as complexity, see paragraph below) were derived from the Commerce Department's Census of Manufactures and Moody's *Industrials*, at the 4-digit SIC code level.

Munificence is operationalized by using regression analysis to calculate the slope of the trend line for industry sales for the period 1982–86 (the 5 years just prior to the beginning of our first wave of data collection). More specifically, following Keats and Hitt (1988), we regressed the natural logarithm of sales against time (e.g., 1982, 1983, etc.). The antilogarithm of the regression slope was used as the index of munificence. Higher scores for munificence indicate industry growth, whereas lower numbers signal stagnation or even decline (Dess and Beard, 1984).

The second competition variable is complexity, which is a measure of industry concentration (Dess and Beard, 1984). Quoting from Porter (1980: 18) again, 'When the industry is highly concentrated ... there is little mistaking relative strength, and the leader[s] can impose discipline as well as play a coordinative role in the industry.' In other words, industries marked by high concentration are less competitive than those that are not. Complexity was assessed by using the MINL formula (Schmalensee, 1977) for sales concentration (cf. Boyd, 1990; Snell, 1992).[1]

Manufacturing strategy

Manufacturing strategy was measured in the second wave by 31 items that operationalized potential competitive priorities in manufacturing, including cost, quality, delivery, and flexibility. Respondents were general managers and functional managers. As there are minor differences in the sets of manufacturing strategy dimensions used by various authors, we used factor analysis (principal components with varimax rotation) to ensure the construct validity of our scales.

A two-stage rule was used to assign items to factors (cf. Nunnally, 1978). First, to make certain that a given item represented the construct underlying each factor, we used a loading of 0.50 as the minimum cutoff. Second, to avoid problems with cross-loadings, we required each item to clearly define only one factor. Operationally, if the difference between weights for any given item was less than 0.10 across factors, we deleted it from the final scale. This analysis produced four stable factors representing quality, delivery flexibility, scope flexibility, and cost, each of which had an eigenvalue above 1.0. This categorization of manufacturing strategies is quite consistent with existing literature (e.g., Skinner, 1969; Wheelwright, 1981; Schroeder *et al.*, 1986; Leong *et al.*, 1990; Marucheck *et al.*, 1990; Garvin, 1993). Appendix 2 shows the factor structure and loadings we obtained. Items that failed to meet either of the loading criteria are listed at the bottom of the table.

The first factor, *quality*, was comprised of virtually every quality-related item on our list (e.g., dependability, product performance). Two additional quality-related items, solving customer problems immediately and meeting customer expectations, loaded both on quality and the second factor, and thus were not included in this scale. The second strategy dimension, *delivery flexibility*, involved releasing new products and making deliveries on time, scaling production up or down and making deliveries quickly, and generally being flexible. Interestingly, the high productivity item also loaded on this factor, perhaps indicating the cost advantages of doing things quickly (cf. Stalk and Hout, 1990). The third dimension, *scope flexibility* (Parthasarthy and Sethi, 1992) contained items related to adjusting product mix, handling nonstandard orders, and making products to order and in small lots. The final dimension, *cost*, was made up of items dealing with low labor, material, and unit costs. The score for each case for each variable was calculated by averaging across items and then across respondents.

Performance

Performance was measured in the same manner in both waves of data collection. Performance

[1] The MINL formula for industry concentration is:

$$\text{MINL} = \text{MIN} + (\alpha_c - \alpha_2)^2\ [(N_i)^2 - 1]/(3N_i)]$$

where MIN is the minimum possible value of H (see below) under the assumption that all firms in the group have the same market share; α_i is the average market share of the largest four firms, and α_2 is the average market share of the next four firms. There are many formulae for measuring concentration, none of which are ideal for all purposes (Schmalensee, 1977). In an attempt to identify the best indicator, Schmalensee assessed the performance of 12 different surrogates for the H (Herfindhal) index, which is quite desirable but requires data at a level of detail that is very difficult to obtain. This analysis indicated that MINL and another indicator are the most accurate measures of concentration, and that, due to its simpler computation, MINL 'is probably the more attractive for most applications' (p. 192). In particular, it is worth noting that MINL was found to be far superior to both the four-firm and the eight-firm concentration ratio.

was an 8-item scale assessing the firm's current performance *relative to its industry* in terms of productivity, lead time, product quality, etc. Factor analysis (Dean and Snell, 1991), and Chronbach's alpha (0.75) indicate that these eight items compose a single unidimensional scale. To eliminate any effects for initial differences in performance across firms unrelated to our research questions, past performance (first wave) was entered into our regression equations first, in order to statistically control for it prior to examining the impact of IM, competition, and strategy on current performance (second wave).

This means that what we are actually testing is the ability of IM—as moderated by competition and strategy—to influence performance over an 18-month period. The inclusion of prior performance in our analysis essentially puts all of the organizations on equal footing regarding performance at the start of the study. Were we to omit this variable, we would have no way of knowing whether IM really had any influence on performance, or whether the differences in performance observed at the end of the study were simply a continuation of previous-existing differences in performance.

Such differences could be correlated with IM for any number of reasons, thus providing misleading evidence of the performance effects of IM. For example, better-performing firms may be more likely to implement IM, due to their possession of sufficient resources to do so. Alternatively, some third factor may create such a relationship, e.g., size: large companies may be both more successful and more likely to utilize IM.

The strength of our design, with the incorporation of the prior performance variable, is that it rules out *all* such rival hypotheses. Its limitation, as noted above, is that it only allows us to detect performance improvements attributable to IM over a 1.5-year period. As discussed in the theory section, we do not have a very precise idea of the time frame in which such improvements take place, thus it is possible that our design will not completely capture the performance benefits of IM.

RESULTS

Table 1 shows the means, standard deviations, coefficient alphas, interrater reliabilities (James, Demaree, and Wolf, 1984), and correlations. All coefficient alphas exceed 0.70, and all interrater reliabilities exceed 0.80; thus the scales demonstrate both strong internal consistency and strong interrater reliability.

Questions 1 and 2: Integrated manufacturing, competition, and performance

Table 2 presents the results relevant to research questions 1 and 2, that is, the direct effects of IM on performance, and the moderating effects of competition on these relationships. These questions were addressed using hierarchical multiple regression analysis. The prior performance of each organization was controlled for by entering it into the equation in step 1. Not surprisingly, prior performance was significantly related to current performance ($F = 18.6$; $p < 0.01$), and accounted for 17% of the variance.[2] In step 2, the two variables representing competition were entered. This step was also significant ($F = 1.90$; $p < 0.05$), and accounted for an additional 5.3% of the variance. Of the two variables, only munificence was positively and significantly related to performance ($t = 2.32$; $p < 0.05$).

In step 3, the IM variables—AMT, TQM, and JIT—were entered simultaneously. While the overall set of three variables was not significant, it accounted for an additional 4.8% of the variance in performance, and TQM was significantly and positively related ($t = 2.29$; $p < 0.05$) to performance. Finally, in step 4 the interactions between the IM variables and the measures of competition were entered, to test the moderating effect of competition on the IM–performance relationship. This step as a whole, which included six relationships, and accounted for an additional 7.1% of the variance, was not significant. However, the AMT/complexity interaction was significant ($t = -1.99$; $p < 0.05$), and the JIT/munificence interaction was approaching significance ($t = -1.664$; $p < 0.10$). The final regression equation was significant ($F = 3.48$; $p < 0.01$), and accounted for 34.2% of the variance in performance.

[2] The correlation between the prior performance variable and the error term of the regression is 0.00, thus alleviating any concern over correlated error variance.

Table 1. Descriptive statistics[a]

Variable	Mean	S.D.	Coeff. alpha	IRR	Correlations 1	2	3	4	5	6	7	8	9	10
1. Advanced Mfg. Tech.	2.17	0.56	0.86	0.96										
2. Total Quality Mgmt.	3.99	0.94	0.76	0.83	0.44**									
3. Just-in-Time	4.43	0.78	0.76	0.93	0.01	0.12								
4. Quality	5.62	0.71	0.85	0.94	−0.03	0.28**	0.12							
5. Delivery Flexibility	5.01	0.69	0.83	0.94	0.04	0.40**	0.04	0.43**						
6. Scope Flexibility	4.80	0.91	0.71	0.88	0.18	0.26*	0.00	0.34**	0.42**					
7. Cost	4.81	0.89	0.74	0.81	−0.09	0.02	−0.10	−0.08	0.32**	0.02				
8. Performance 1	3.52	0.49	0.76	0.98	0.38**	0.47**	0.06	0.00	0.19	0.08	−0.08			
9. Performance 2	3.35	0.41	0.75	0.96	0.08	0.35**	0.06	0.31**	0.48**	0.11	0.03	0.41**		
10. Munificence	1.08	0.06	NA	NA	−0.21*	−0.17	−0.04	0.07	0.04	−0.06	0.03	−0.02	0.19	
11. Complexity	8.16	11.54	NA	NA	0.06	0.23*	−0.03	0.00	0.03	−0.09	0.01	0.03	0.09	−0.24*

[a]$N = 92$; $*p < 0.05$ $**p < 0.01$

Table 2. Multiple regression analysis: The effect of integrated manufacturing variables and competition on performance[a]

Variable	Beta	T	Sig.	R^2	ΔR^2	F	Sig. F
Step 1							
Prior Performance	0.412	4.315	0.000	0.170		18.62	0.000
Step 2							
Prior Performance	0.409						
Munificence	0.224	2.328	0.022				
Complexity	0.132	1.365	0.176	0.223	0.053	3.04	0.053
Step 3							
Prior Performance	0.327						
Munificence	0.236						
Complexity	0.082						
Advanced Mfg. Tech.	−0.080	−1.043	0.300				
Total Quality Mgmt.	0.113	2.290	0.024				
Just-in-Time	0.014	0.292	0.771	0.271	0.048	1.90	0.135
Step 4							
Prior Performance	0.247						
Munificence	1.023						
Complexity	1.312						
Advanced Mfg. Tech.	−1.488						
Total Quality Mgmt.	−0.364						
Just-in-Time	3.631						
AMT × Munificence	1.540	0.698	0.488				
AMT × Complexity	−0.957	−1.994	0.050				
TQM × Munificence	0.674	0.256	0.798				
TQM × Complexity	−0.500	−0.866	0.389				
JIT × Munificence	−3.741	−1.664	0.100				
JIT × Complexity	0.175	0.244	0.806	0.343	0.071	1.45	0.206
Overall						3.48	0.000

[a]$N = 92$. All F statistics reported, except the overall F, are for the step, and not the equation as a whole.

Question 3: Integrated manufacturing, strategy, and performance

Tables 3–5 present the results of the analyses relevant to research question 3, the moderating effects of manufacturing strategy on the IM–performance relationship. Hierarchical multiple regression analysis was again used to analyze the data. The structures of the analyses were similar. In the first step, prior performance, munificence, and TQM were entered as control variables: these variables were all found to be significantly related to performance in the prior analysis.[3] The IM variable whose interactions were to be examined was also entered in step 1. In step 2, the manufacturing strategy variables (quality, delivery flexibility, scope flexibility, and cost) were entered. This step was necessary to control for the direct effects of these variables, before testing for their interactive effects. Finally, in step 3 the cross-products of the IM variables and the strategies were entered. Significant regression coefficients for these interaction terms constitute evidence for strategy's moderating effect on the IM–performance relationship.

[3] Complexity was not used as a control variable because it was found to have no direct impact on performance in our prior analysis. AMT and JIT were not used as control variables for the same reason.

Advanced manufacturing technology

Table 3 presents the results for AMT. The control variables in step 1 accounted for 26.6% of the variance in current performance ($F = 7.87$;

Table 3. Multiple regression analysis: The interactive effects of AMT and manufacturing strategy on performance[a]

Variable	Beta	T	Sig. T	R^2	ΔR^2	F	Sig. F
Step 1							
Prior Performance	0.327	3.055	0.003				
Munificence	0.218	2.307	0.023				
TQM	0.286	2.585	0.011				
AMT	−0.123	−1.162	0.248				
				0.266	7.87	0.000	
Step 2							
Prior Performance	0.316						
Munificence	0.173						
TQM	0.080						
AMT	−0.033						
Quality	0.134	1.312	0.193				
Delivery Flexibility	0.402	3.464	0.000				
Scope Flexibility	−0.134	−1.370	0.174				
Cost	−0.075	−0.786	0.434				
				0.404	0.138	4.81	0.001
Step 3							
Prior Performance	0.242						
Munificence	0.184						
TQM	0.165						
AMT	−1.217						
Quality	−0.786						
Delivery Flexibility	0.030						
Scope Flexibility	−0.281						
Cost	0.907						
AMT × Quality	1.884	2.402	0.019				
AMT × Delivery Flex.	0.784	0.812	0.419				
AMT × Scope Flex.	0.227	0.324	0.747				
AMT × Cost	−1.603	−2.759	0.007				
				0.512	0.108	4.38	0.003
Overall						6.91	0.000

[a]$N = 92$. F statistics are for each block; overall F for equation is at bottom.

$p < 0.01$). In step 2, the direct effects of the manufacturing strategies accounted for an additional 13.8% of the variance ($F = 4.81$; $p < 0.01$). Finally, the interactions between AMT and the strategies (step 3) accounted for an additional 10.8% of the variance ($F = 4.38$; $p < 0.01$). Two of the interaction coefficients were significant: the interaction of AMT with a quality strategy ($t = 2.40$; $p < 0.05$), and with a cost strategy ($t = -1.60$; $p < 0.01$). The directions of these interactions indicate that the AMT–performance relationship tends to be stronger in the context of a quality-oriented manufacturing strategy, and weaker—perhaps even negative—in the context of a cost-oriented strategy. The overall equation was significant ($F = 6.91$; $p < 0.01$), and accounted for 51.2% of the variance in performance.

In order to further explore the moderating effect of strategy on the AMT–performance relationship, we calculated the effect of AMT on performance for two different subsets of our sample. The first group (21 organizations) had high scores on quality strategy and low scores on cost strategy (relative to the median of the distributions). The second group (25 organizations) had low scores on the quality strategy and high scores for a strategic focus on cost. The same set of controls (munificence, prior performance, TQ) were included in the regression equations. For the first group, the beta coefficient for the relationship between AMT and perform-

Table 4. Multiple regression analysis: The interactive effects of TQM and manufacturing strategy on performance[a]

Variable	Beta	T	Sig. T	R^2	ΔR^2	F	Sig. F
Step 1							
Prior Performance	0.298	2.860	0.005				
Munificence	0.238	2.540	0.013				
TQM	0.248	2.342	0.021				
				0.254		10.00	0.000
Step 2							
Prior Performance	0.309						
Munificence	0.176						
TQM	0.068						
Quality	0.138	1.373	0.173				
Delivery Flexibility	0.406	3.552	0.001				
Scope Flexibility	−0.140	−1.458	0.149				
Cost	−0.073	−0.774	0.441				
				0.403	0.149	5.24	0.001
Step 3							
Prior Performance	0.223						
Munificence	0.180						
TQM	−0.403						
Quality	−0.361						
Delivery Flexibility	0.331						
Scope Flexibility	−0.477						
Cost	0.663						
TQM × Quality	1.144	1.011	0.315				
TQM × Delivery Flex.	0.116	0.099	0.921				
TQM × Scope Flex.	0.615	0.812	0.419				
TQM × Cost	−1.172	−1.647	0.103				
				0.456	0.053	1.95	0.111
Overall						6.10	0.000

[a]$N = 92$. F statistics are for each block; overall F for equation is at bottom.

ance was 0.40 ($t = 2.86$; $p < 0.01$), indicating a *positive* relationship between the utilization of AMT and performance. For the second group, the coefficient was −0.45 ($t = -1.69$; $p < 0.10$), indicating a somewhat *negative* relationship between the utilization of AMT and performance. Thus the strategic priorities of the firm can actually mean the difference between a positive and negative relationship between AMT implementation and performance. This is a striking finding, and may help to explain why the performance impact of AMT has differed so widely across firms.

Total quality management

Table 4 presents the results of the interaction analysis for TQM. The control variables accounted for 23.1% of the variance ($F = 10.00$; $p < 0.01$). The direct effects of the strategies accounted for an additional 14.9% of the variance ($F = 5.24$; $p < 0.01$). Finally, while the total set of interactions was not significant, an additional 5.3% of the variance was accounted for, and the interaction of TQM and cost was approaching significance ($t = -1.647$; $p < 0.10$). The sign of the beta indicates that the performance impact of TQM is somewhat weakened when it is implemented within the context of a manufacturing strategy emphasizing cost. The overall equation was significant ($F = 6.10$; $p < 0.01$).

Just-in-time inventory control

Table 5 presents the interaction analysis for JIT. The control variables accounted for 25.5% of the

Table 5. Multiple regression analysis: The interactive effects of JIT and manufacturing strategy on performance[a]

Variable	Beta	T	Sig. T	R^2	ΔR^2	F	Sig. F
Step 1							
Prior Performance	0.299	2.843	0.006				
Munificence	0.238	2.531	0.013				
TQM	0.245	2.291	0.024				
JIT	0.024	0.257	0.798				
				0.255		7.44	0.000
Step 2							
Prior Performance	0.309						
Munificence	0.177						
TQM	0.067						
JIT	0.004						
Quality	0.138	1.354	0.179				
Delivery Flexibility	0.406	3.531	0.001				
Scope Flexibility	−0.139	−1.443	0.153				
Cost	−0.073	−0.764	0.447				
				0.403	0.148	5.16	0.001
Step 3							
Prior Performance	0.309						
Munificence	0.189						
TQM	0.058						
JIT	0.064						
Quality	1.236						
Delivery Flexibility	−0.092						
Scope Flexibility	−1.036						
Cost	0.059						
JIT × Quality	−1.969	−1.556	0.124				
JIT × Delivery Flex.	0.773	0.546	0.586				
JIT × Scope Flex.	0.249	1.463	0.147				
JIT × Cost	0.007	0.010	0.992				
				0.439	0.036	1.25	0.296
Overall						5.15	0.000

[a]$N = 92$. F statistics are for each block; overall F for equation is at bottom.

variance ($F = 7.44$; $p < 0.01$). The direct effects of the strategies, entered in step 2, accounted for an additional 14.8% percent of the variance in performance ($F = 5.16$; $p < 0.01$). Finally, the set of JIT–strategy interactions was not significant ($F = 1.25$), and even though the final overall equation was significant ($F = 5.15$; $p < 0.01$) none of the individual interactions were significant.

Question 4: Integrated manufacturing and manufacturing strategy

Research question 4 was addressed by the multiple regression analyses presented in Table 6. The question here was whether there were any direct relationships between the use of IM and the choice of manufacturing strategies. As was discussed above, it is conceivable that IM influences the choice of strategies, strategy influences the implementation of IM, or both. Thus, our utilization of the manufacturing strategies as dependent variables was somewhat arbitrary.

Quality strategy

When quality strategy was used as the dependent variable, the group of IM variables was significant ($F = 3.79$; $p < 0.05$) and accounted for 11.4% of

Table 6. Multiple regression analysis: The relationship between integrated manufacturing and manufacturing strategy

Variable	Beta	T	Sig. T	R^2	F	Sig. F
Quality						
Advanced Mfg. Tech.	−0.241	−1.69	0.094			
Total Quality	0.268	3.12	0.002			
Just-in-Time	0.076	0.81	0.420			
				0.114	3.79	0.013
Delivery flexibility						
Advanced Mfg. Tech.	−0.208	−1.58	0.117			
Total Quality	0.353	4.45	0.000			
Just-in-Time	−0.019	−0.21	0.830			
				0.186	6.71	0.000
Scope flexibility						
Advanced Mfg. Tech.	0.139	0.76	0.452			
Total Quality	0.215	1.93	0.057			
Just-in-Time	−0.038	−0.32	0.753			
				0.073	2.31	0.082
Cost						
Advanced Mfg. Tech.	−0.211	−1.13	0.260			
Total Quality	0.091	0.82	0.417			
Just-in-Time	−0.120	−0.99	0.326			
				0.025	0.74	0.529

the variance. In terms of the individual coefficients, both AMT ($t=-1.69$; $p<0.10$) and TQM ($t=3.12$; $p<0.01$) were significantly related to the quality strategy. These results indicate that firms using AMT are marginally less likely to utilize a quality strategy, which is disconcerting given the findings (see Table 3) suggesting that the AMT–performance relationship is stronger in the context of a quality strategy. The results also indicate that firms practicing TQM are more likely to pursue a quality strategy.

Delivery flexibility strategy

When delivery flexibility was used as the dependent variable, the IM variables were also significant ($F=6.71$; $p<0.01$), and accounted for 18.6% of the variance. In terms of individual coefficients, TQM was significantly related ($t=4.45$; $p<0.01$) to the use of this strategy, indicating that firms using TQM are more likely to be utilizing a delivery flexibility strategy. This makes sense, because meeting delivery dates is an important aspect of quality. Our earlier analysis (Table 4), however, did not detect any interactive effect of TQM and the delivery flexibility strategy on performance.

Scope flexibility strategy

When scope flexibility strategy was used as the dependent variable, the equation as a whole was marginally significant ($F=2.31$; $p<0.10$), and accounted for 7.3% of the variance, with TQM being the only predictor ($t=1.93$; $p<0.06$). This finding suggests that firms are more likely to pursue a scope flexibility strategy when they practice total quality management. These findings are similar in implication to those of delivery flexibility above: adapting to changes desired by customers is consistent with TQM, but no interactive effect of TQM and delivery flexibility strategy was detected (see Table 4).

Low-cost strategy

When a low-cost strategy was used as the dependent variable, the equation as a whole is not significant ($F=0.74$), and none of the IM variables were significantly related to this strategy.

This finding is somewhat perplexing given the fact that one of the more obvious justifications for implementing IM is that AMT, TQM, and JIT can be used to decrease material and labor costs (Crosby, 1980; Dean *et al.*, 1992; Giffi *et al.*, 1990; Helfgott, 1988; Jaikumar, 1986; Majchrzak, 1988; Parthasarthy and Sethi, 1992; Reid, 1990; Zipkin, 1991). Our findings, however, suggest that the firms in our sample were not using IM techniques in conjunction with a strategy focused on cost.

DISCUSSION

Integrated manufacturing and performance

Overview of findings

Our first research question was whether the use of IM techniques influences organizational performance. Of the three IM techniques, only TQM was directly related to performance. The credibility of this finding is strengthened by the 1½-year time lag between the measurement of TQM and the measurement of performance, the high degree of internal consistency and interrater agreement for both constructs, and the fact that prior performance was controlled for in the equation. This finding is particularly interesting in light of the recent wave of skepticism concerning the efficacy of TQM (e.g., Fuchsberg, 1992), and certainly lends credence to those advocating TQM as a means for performance improvement (e.g., Schonberger, 1992). Given these results, TQM should continue to be taken very seriously as a tool for improving manufacturing performance.

Implications of findings

It is puzzling that neither AMT nor JIT was found to relate to performance, given the popularity of both practices, and the resources that have been devoted to implementing them. One possible explanation is that our controlling for past performance worked against these variables. To the extent that the effects of IM were reflected in the prior performance measure, it would be much more difficult to detect residual variance accounted for in the second performance measure. This possibility appears very likely to be the case for AMT, which was strongly correlated ($r = 0.38$; $p < 0.01$) with prior performance. Perhaps the performance-enhancing effects of AMT are concentrated in the period of time just after the equipment is up and running effectively. If the firms in the sample had implemented most of their AMT a number of months or years before the first performance measure was taken, it is quite likely that the performance improvements had already been realized. Extended time series analysis would be one way to empirically assess this possibility.

Alternatively, however, the differing strategic postures of firms implementing AMT may have resulted in a mixture of positive and negative relationships between AMT and performance that simply canceled each other out in the sample as a whole. The differing relationships between AMT and performance as a function of manufacturing strategy will be discussed in more detail below.

Unlike AMT, TQM is explicitly oriented toward continuous improvement. A firm that reported high levels of TQM during the first wave of measurement was saying that it was committed to pursuing a process likely to lead to further performance enhancements in the months and years ahead (Dean and Bowen, 1994). This may explain why TQM was related to current performance even after controlling for past performance. It does not, however, explain the lack of results for JIT, which was related to neither prior nor current performance, but shares to some extent the continuous improvement goal of TQM.

Integrated manufacturing, competition, and performance

The primary evidence for the moderating effect of competition was provided by the significant interaction between AMT and complexity. According to our findings, the AMT–performance relationship is likely to be stronger in the case of limited competition (i.e., high industry concentration). Where competition is high, the AMT–performance relationship is likely to be weaker. This finding is interpretable within the explanatory framework presented earlier in the paper. For example, in competitive environments, competitors in an industry are more likely to have implemented AMT or comparable strategic initiatives, thus limiting the performance impact of AMT for any firm.

The interaction between JIT and munificence, however, must be interpreted differently. In this case, the JIT–performance relationship was found to be marginally stronger under conditions of low munificence (i.e., low growth or decline in the overall market). It may be that growing markets are more forgiving of the inefficiencies that JIT tries to address, whereas stagnant or declining markets demand more of the disciplines concerning inventory, etc. that JIT offers. These interpretations must be offered with caution, however, due to the only marginally significant moderating effect of munificence on this relationship.

Integrated manufacturing, strategy, and performance

Overview of findings

Our third research question addressed the potential moderating effect of manufacturing strategy on the relationship between IM and performance. Our findings indicate that the deployment of a quality strategy strengthens the AMT–performance relationship, whereas a cost-oriented strategy weakens this relationship. Furthermore, the cost strategy also weakens to some extent the relationship between TQM and performance. Thus there is support for the moderating role of strategy, particularly the cost strategy. There was no indication of a moderating role for the flexibility strategies.

Implications of the findings

The firms in our sample using AMT enjoyed the greatest benefits in the context of a quality strategy, and firms using AMT and TQM benefited the least using a low-cost strategy. This last item is ironic insofar as cost reduction is probably the most prevalent justification for using AMT (e.g., Dean, 1987). Thus our findings generally do not fit the pattern of capability-building (Miller and Hayslip, 1989) or strategic transcendence (Schonberger, 1992), in the sense of IM exhibiting positive relationships with performance that were unaffected by strategy.

What could be responsible for the interactive effects we found? It seems likely that the key to the significance of strategy for successful use of IM is strategy's influence on organizational infrastructure—planning and control systems, product development policies, human resource management practices, and so on (e.g., Leong *et al.*, 1990). Experts on AMT and TQM have strenuously argued that these techniques cannot simply be dropped into any organization and be expected to work (e.g., Boddy and Buchanan, 1986; Deming, 1982). The organizational infrastructure must be prepared and maintained so as to provide fertile ground for these techniques.

Strategy, as the overarching competitive logic at work in the organization, will go a long way toward shaping this infrastructure, and thus will play a major role in determining whether the seeds of IM will fall on rocky or fertile soil. IM will only be beneficial for a firm if its strategy provides a way for IM's benefits to be reflected in competitive advantage. What is startling is the fact that a firm's strategic orientations can actually spell the difference between a positive and negative relationship between AMT and performance. This implies that, unless firms are willing to do the work involved in joint technology/strategy planning, they are literally better off not even attempting to implement AMT.

Integrated manufacturing and strategy

Overview of findings

Our last research question dealt with the actual links between the use of IM and manufacturing strategy. Our analysis has revealed combinations of IM and strategy that could either help or hurt performance. To what extent does the actual behavior of firms reflect these findings?

Firms using AMT were somewhat less likely to utilize a quality strategy, despite the fact that AMT's link to performance was significantly stronger when a quality strategy was used. Firms using AMT and TQM were no more or less likely to utilize a low-cost strategy, despite the fact that our analysis seems to indicate that low-cost strategies undermine the effectiveness of these aspects of IM. Total quality was positively related to delivery and scope flexibility, as well as to a quality strategy. None of the IM techniques was related to the use of a low-cost manufacturing strategy.

Implications of the findings

The most striking aspect of these findings is that the firms in our sample are systematically missing out on what appears from our data to be an opportunity to improve performance by combining AMT with a strategy emphasizing quality. While we found that the AMT–quality combination has a positive relationship with performance, the firms in our sample avoided using AMT in conjunction with this strategy. This may help explain our finding (research question 1) that AMT was in general not linked to high performance.

This lends support to those observers claiming that AMT's capacities are inappropriately utilized in many firms, because AMT is seen as merely an extension of labor-saving mass production techniques (e.g., Jaikumar, 1986; Zuboff, 1988). While several authors have argued that AMT should be used in conjunction with revenue-producing, rather than cost-cutting strategies (e.g., Susman and Dean, 1989; Lei and Goldhar, 1990), this apparently does not characterize the current strategic posture of most of the firms in our sample. This perspective is reinforced by the lack of relationship in our findings between the use of AMT and the use of either of the flexibility strategies. Overall, the strategic use of AMT by firms in our sample appears to be rather limited, as firms apparently are not taking advantage of the flexibility that the technology offers.

The link between TQM and the flexibility strategies is neutral in terms of our moderated regression findings, as these strategies neither positively nor negatively moderated the TQM–performance relationship. Perhaps some firms are using TQM to develop a competitive advantage based on flexibility, and the results of these efforts are not yet reflected in their performance.

The consistent failure of JIT to be associated with performance or any of the strategies raises several measurement issues. While the measure of JIT demonstrated good internal consistency and interrater reliability, we can still redirect our efforts at examining the content domain of the scales. While the measure certainly taps aspects of JIT that are most prevalent in the literature, perhaps it does not go far enough in capturing other aspects of the content domain (e.g., what firms actually do in implementing JIT). It is always difficult to sort out whether a set of non-findings is accurate or a function of research methods, but in this case it is hard to believe that JIT would not be related to any other construct in the study. Therefore future research should be directed at improving and refining measures of JIT.

CONCLUSION

There is enough evidence now to suggest that IM and manufacturing strategy are potentially synergistic—and clearly some of the firms we studied are using them synergistically. While our results suggest some independent performance benefit of using TQM, clearly the fullest impact comes from judiciously matching IM techniques with particular manufacturing strategies (Meredith and Vineyard, 1993; Marucheck *et al.*, 1990). In general, the effects of IM tend to be augmented when used in conjunction with a quality strategy, but diminished when used as part of a cost strategy.

Unfortunately, it appepars that many firms are not making the most of their investments in IM. Firms are in some cases pursuing IM–strategy combinations that will improve their performance, and in some cases doing just the opposite. AMT, in particular, appears to be often implemented in a way that does not take advantage of its potential to improve quality. Furthermore, our study revealed some important moderating effects of industry competitiveness on the IM–performance relationships, which firms should take into consideration in their manufacturing strategic planning processes. Specifically, firms in highly competitive environments should not expect to develop a competitive advantage through the use of AMT alone. This does not imply that they can forgo AMT, merely that it may be more of a competitive necessity than a competitive advantage.

Our goal in this study was to explore some initial questions about the relationships among integrated manufacturing, competition, strategy, and performance. We have discovered a number of relationships that can be replicated, extended, or challenged by additional research. In the final analysis, IM techniques are merely tools, albeit expensive and sophisticated tools, with which to compete (Hayes *et al.*, 1988). Organizations that become so enamored of particular tools that they lose sight of their overall strategic missions—or that use a tool in the context of a strategy to which it is ill suited—are unlikely to reap the competitive rewards the tool offers.

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REFERENCES

Anderson, P. (1991). 'Review of *Building a Chain of Customers: Linking Business Functions to Create the World Class Company*, by R. J. Schonberger', *Journal of Engineering and Technology Management*, **8**(1), pp. 88–89.

Belohlav, J. A. (1993). 'Quality, strategy, and competitiveness', *California Management Review*, Spring, pp. 55–67.

Blois, K. J. (1985). 'Matching new manufacturing technologies to industrial markets and strategies', *Industrial Marketing Management*, **14**, pp. 43–47.

Boddy, D. and D. A. Buchanan (1986). *Managing New Technology*. Basil Blackwell, Oxford, UK.

Boyd, B. (1990). 'Corporate linkages and organizational environment: A test of the resource dependence model', *Strategic Management Journal*, **11**(6), pp. 419–430.

Buffa, E. S. (1984). *Meeting the Competitive Challenge: Manufacturing Strategy for U.S. Companies*. Irwin, Homewood, IL.

Chen, F. F. and E. E. Adam, Jr. (1991). 'The impact of flexible manufacturing systems on productivity and quality', *IEEE Transactions on Engineering Management*, **38**, pp. 33–45.

Ciampa, D. (January, 1987). 'Integrated manufacturing: The only answer for U.S. companies', *Manufacturing Automation*, pp. 15–16.

Ciampa, D. (1991). *Total Quality: A User's Guide to Implementation*. Addison-Wesley, Reading, MA.

Corbett, C. and L. Van Wassenhove (1993). 'Tradeoffs? What tradeoffs? Competence and competitiveness in manufacturing strategy', *California Management Review*, **35**(4), pp. 107–120.

Crosby, P. B. (1980). *Quality is Free: The Art of Making Quality Certain*. McGraw-Hill, New York.

Dean, J. W., Jr. (1987). *Deciding to Innovate: How Firms Justify Advanced Technology*. Ballinger, Cambridge, MA.

Dean, J. W., Jr. and D. E. Bowen (1994). 'Total quality and management theory: Improving research and practice through theory development', *Academy of Management Review*, **19**(3), pp. 392–418.

Dean, J. W., Jr. and S. A. Snell (1991). 'Integrated manufacturing and job design: Moderating effects of organizational inertia', *Academy of Management Journal*, **34**(4), pp. 776–804.

Dean, J. W., Jr. and G. I. Susman (1989). 'Strategic responses to global competition: Advanced technology, organization design, and human resource practices'. In C. C. Snow (ed.) *Strategy, Organization Design, and Human Resource Management*. JAI Press, Greenwich, CT. pp. 297–332.

Dean, J. W., Jr., S. J. Yoon and G. I. Susman (1992). 'Advanced manufacturing technology and organization structure: Empowerment or subordination?', *Organization Science*, **3**(2), pp. 203–229.

Deming, W. E. (1982). *Out of the Crisis*. Center for Advanced Engineering Study, MIT, Cambridge, MA.

Dess, G. G. and D. W. Beard (1984). 'Dimensions of organizational task environments', *Administrative Science Quarterly*, **29**, pp. 52–73.

Ferdows, K. and A. DeMeyer (1990). 'Lasting improvements in manufacturing performance: In search of a new theory', *Journal of Operations Management*, **9**(2), pp. 168–183.

Fine, C. H. and A. C. Hax (1985). 'Manufacturing strategy: A methodology and an illustration', *Interfaces*, **15**, pp. 28–46.

Fuchsberg, G. (14 May 1992). 'Quality programs showing shoddy results,' *Wall Street Journal*, p. B1.

Garvin, D. A. (1993). 'Manufacturing strategic planning', *California Management Review*, **35**(4), pp. 85–106.

Gerwin, D. and H. Kolodny (1992). *Management of Advanced Manufacturing Technology: Strategy, Organization and Innovation*. Wiley, New York.

Giffi, C., A. V. Roth, and G. M. Seal (1990). *Competing in World-Class Manufacturing: America's 21st Century Challenge*. Business One Irwin, Homewood, IL.

Gunn, T. G. (1987). *Manufacturing for Competitive Advantage: Becoming a World-Class Manufacturer*. Ballinger, Cambridge, MA.

Haskins, R. and T. Petit (November–December 1988). 'Strategies for entrepreneurial manufacturing', *Journal of Business Strategy*, pp. 24–28.

Hayes, R. H. (1985). 'Strategic planning: Forward in reverse', *Harvard Business Review*, **63**(6), pp. 111–119.

Hayes, R. H. and S. C. Wheelwright (1984). *Restoring Our Competitive Edge: Competing through Manufacturing*. Wiley, New York.

Hayes, R. H., S. C. Wheelwright and K. B. Clark (1988). *Dynamic Manufacturing: Creating the Learning Organization*. Free Press, New York.

Helfgott, R. B. (1988). *Computerized Manufacturing and Human Resources*. Lexington Books, Lexington, MA.

Jaikumar, R. (1986). 'Postindustrial manufacturing', *Harvard Business Review*, **64**(6), pp. 69–76.

James, L. R., R. G. Demaree, and G. Wolf (1984). 'Estimating within group interrater reliability with and without response bias', *Journal of Applied Psychology*, **69**, pp. 85–98.

Keats, B. W. and M. A. Hitt (1988). 'A causal model of linkages among environmental dimensions, macro

organizational characteristics, and performance', *Academy of Management Journal*, **31**, pp. 570–598.
Lei, D. and J. D. Goldhar (1990). 'Multiple niche competition: The strategic use of CIM technology', *Manufacturing Review*, **3**, pp. 195–206.
Leong, G. K., D. Snyder, and P. Ward (1990). 'Research in the process and content of manufacturing strategy', *OMEGA*, **18**(2), pp. 109–122.
Majchrzak, A. (1986). 'A national probability survey on education and training for CAD/CAM', *IEEE Transactions on Engineering Management* **33**, pp. 197–206.
Majchrzak, A. (1988). *The Human Side of Factory Automation*. Jossey-Bass, San Francisco, CA.
Markus, M. L. and D. Robey (1988). 'Information technology and organizational change: Causal structure in theory and research', *Management Science*, **34**, pp. 583–598.
Marucheck, A., R. Pannesi and C. Anderson (1990). 'An exploratory study of the manufacturing strategy process in practice', *Journal of Operations Management*, **9**(1), pp. 101–123.
March, J. G. and L. S. Sproull (1990). 'Technology, management, and competitive advantage'. In P. S. Goodman and L. S. Sproull (eds.), *Technology and Organizations*. Jossey-Bass, San Francisco, CA, pp. 144–173.
Meredith, J. (1988). 'The role of manufacturing technology in competitiveness: Peerless Laser Processors', *IEEE Transactions on Engineering Management*, **35**, pp. 3–10.
Meredith, J. and M. Vineyard (1993). 'A longitudinal study of process technology strategy: Three empirical cases in flexible manufacturing systems', *International Journal of Operations and Production Management*, **13**(2), pp. 4–24.
Miller, J. G. and W. Hayslip (July/August 1989). Implementing manufacturing strategic planning', *Planning Review*, pp. 22–27, 48.
Mortimer, J. (1985). *Integrated Manufacture*. IFS (Publications) Ltd., Springer-Verlag, Berlin.
Noori, H. (1990). *Managing the Dynamics of New Technology: Issues in Manufacturing Management*. Prentice-Hall, Englewood Cliffs, NJ.
Nunnally, J. C. (1978). *Psychometric Theory*. McGraw-Hill, New York.
Office of Technology Assessment (1984). *Computerized Manufacturing Automation: Employment, Education and Workplace*. U.S. Congress, Office of Technology Assessment, Washington, DC.
Parthasarthy, R. and S. P. Sethi (1992). 'The impact of flexible automation on business strategy and organizational structure', *Academy of Management Review*, **17**(1), pp. 86–111.
Porter, M. E. (1980). *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. Free Press, New York.
Reid, P. C. (1990). *Well Made in America: Lessons from Harley-Davidson on Being the Best*. McGraw-Hill, New York.
Schmalensee, R. (1977). 'Using the H-index of concentration with published data', *Review of Economics and Statistics*, **59**, pp. 186–213.
Schonberger, R. J. (1986). *World Class Manufacturing: The Lessons of Simplicity Applied*. Free Press, New York.
Schonberger, R. J. (May 1987). 'Integrated manufacturing: Nothing succeeds like successful implementation', *Production Engineering*, pp. 4–32.
Schonberger, R. J. (1992). 'Is strategy strategic? The impact of total quality management on strategy', *Academy of Management Executive*, **6**(3), pp. 80–87.
Schroeder, R. G., J. C. Anderson, and G. Cleveland (1986). 'The content of manufacturing strategy: An empirical study', *Journal of Manufacturing*, **6**, pp. 405–415.
Sheridan, J. H. (1994). 'How do you stack up?', *Industry Week*, **23**(4), pp. 53–56.
Skinner, W. (1969). 'Manufacturing: Missing link in corporate strategy', *Harvard Business Review*, **47**(3), pp. 136–145.
Skinner, W. (1985). *Manufacturing: The Formidable Competitive Weapon*. Wiley, New York.
Snell, S. A. (1992). 'Control theory in strategic human resource management: The mediating effect of administrative information', *Academy of Management Journal*, **35**, pp. 292–327.
Snell, S. A. and J. W. Dean, Jr. (1992). 'Integrated manufacturing and human resource management: A human capital perspective', *Academy of Management Journal*, **35**(3), pp. 467–504.
Stalk, G., Jr. and T. M. Hout (1990). *Competing Against Time: How Time-Based Competition is Reshaping Global Markets*. Free Press, New York.
Stobaugh, R. and P. Telesio (1983). 'Match manufacturing policies and product strategy', *Harvard Business Review*, **61**(2), pp. 113–120.
Susman, G. I. and J. W. Dean, Jr. (1989). 'Strategic use of computer integrated manufacturing in the emerging competitive environment', *Computer Integrated Manufacturing Systems*, **2**(3), pp. 133–138.
Swamidass, P. M. and W. T. Newell (1987). 'Manufacturing strategy, environmental uncertainty and performance: A path analytic model', *Management Science*, **33**, pp. 509–524.
Swamidass, P. M. and S. Kotha (1994). 'Technology use, size, and performance in U.S. manufacturing firms', working paper, Thomas Walter Center for Technology Management, Auburn University.
Ward, P. T., G. K. Leong and K. K. Boyer (1994). 'Manufacturing proactiveness and performance, *Decision Sciences*, **25**(3), pp. 337–358.
Wheelwright, S. C. (1981). 'Japan, where operations really are strategic', *Harvard Business Review*, **59**(4), pp. 67–74.
Zammuto, R. F. and E. J. O'Connor (1992). 'Gaining advanced manufacturing technologies' benefits: The roles of organizational design and culture', *Academy of Management Review*, **17**(4), pp. 701–728.
Zipkin, P. H. (1991). 'Does manufacturing need a JIT revolution?' *Harvard Business Review*, **69**(1), pp. 40–50.
Zuboff, S. (1988). *In the Age of the Smart Machine: The Future of Work and Power*. Basic Books, New York.
Zygmont, J. (October 1989). 'Just-in-time controls more than inventory', *Automation*, pp. 30–32.

APPENDIX 1: MEASURES OF INTEGRATED MANUFACTURING VARIABLES

Advanced manufacturing technology

To what extent are each of the following technologies used in your plant? (1 = not at all; 3 = moderately; 5 = extensively)

(1) Manufacturing resource planning (MRP II)
(2) Computer-aided design (CAD)
(3) Numerical control (NC)
(4) Computer numerical control (CNC)
(5) Direct numerical control (DNC)
(6) Flexible manufacturing systems (FMS)
(7) Robotics
(8) Automated materials handling
(9) Computer-aided test/inspection
(10) Computer-aided process planning

To what extent are transactions between the following production processes integrated using computers?
(1 = not computer integrated at all; 3 = moderately computer integrated; 5 = completely computer-integrated)

(11) Product design/development and production planning
(12) Production planning and component manufacturing
(13) Component manufacturing and assembly
(14) Assembly and production scheduling
(15) Production scheduling and maintenance
(16) Maintenance and materials handling
(17) Materials handling and quality control
(18) Quality control and materials management

Total quality management

1. How much time does the plant management staff devote to quality improvement? (1 = very little; 4 = moderate amount; 7 = great deal)
2. How much time is spent working with suppliers to improve their quality? (1 = very little; 4 = moderate amount; 7 = great deal)
3. How well are you able to measure the cost of quality in your plant? (1 = not at all; 4 = to some extent; 7 = precisely)
4. How would you describe your current approach to providing quality products? (1 = inspecting it in; 4 = some of each; 7 = building it in)
5. What percentage of the plant's manufacturing processes are under statistical control?
6. What percentage of the plant's employees have quality as a major responsibility?
7. What percentage of the plant's employees are routinely given feedback about quality?

How would you describe the level of use within your plant of the following quality improvement methodologies? (1 = little or none; 4 = moderate use; 7 = consistent use)

8. Quality function deployment (QFD)
9. Taguchi methods
10. Continuous process improvements

Just-in-time

How much has each of the following changed in the past 5 years? (1 = huge decrease; 4 = same; 7 = huge increase—*reverse scored*)

1. The number of your suppliers
2. The size of their deliveries
3. The length of product runs
4. The number of total parts
5. The amount of buffer stock

APPENDIX 2: FACTOR ANALYSIS OF MANUFACTURING STRATEGY MEASURES

Questionnaire items	1	2	3	4
Product quality	**0.78**	0.12	–0.12	–0.03
High product reliability	**0.81**	0.02	0.09	–0.13
Exceptional product performance	**0.63**	0.15	0.24	–0.22
Conformance to specifications	**0.63**	0.19	0.12	0.02
Dependability	**0.76**	0.20	0.17	0.02
Zero defects	**0.60**	0.48	0.04	–0.03
Product serviceability	**0.50**	0.04	0.40	0.07
Durability	**0.67**	–0.16	0.43	0.08
On-time delivery	0.30	**0.69**	–0.18	0.05
Meeting release dates for new products	0.33	**0.50**	0.37	0.11
Flexibility	0.08	**0.69**	0.32	–0.07
Scale up/down production quickly	–0.10	**0.62**	0.50	0.04
Short lead time from order to delivery	0.14	**0.71**	0.13	0.03
High efficiency/productivity	0.27	**0.58**	0.06	0.28
Economies of scale	–0.05	**0.55**	0.09	0.26
Adapting to changes in product mix	0.04	0.40	**0.64**	–0.04
Handling difficult/nonstandard orders	0.10	0.07	**0.69**	–0.25
Products made to order	0.05	0.00	**0.61**	–0.11
Small lots	0.06	0.13	**0.65**	0.11
Low unit costs	0.08	0.23	–0.16	**0.73**
Low labor costs	–0.06	0.08	0.30	**0.74**
Low material costs	–0.01	0.12	0.03	**0.77**
Solving customer problems immediately	0.52	0.54	0.10	–0.01
Meeting customer expectations	0.50	0.50	–0.08	0.13
Providing customers 'peace of mind'	0.47	0.49	0.04	0.10
Taking lead in new product introduction	0.31	0.39	0.38	–0.14
Low life cycle costs	0.34	0.05	0.47	0.16
Economies of scope	0.15	0.44	0.47	0.09
Juggling orders to ensure rapid delivery	–0.12	0.52	0.52	0.10
Unique features	0.27	0.09	0.37	–0.46
High operating margins	0.18	0.04	0.35	0.10
Eigenvalue	8.55	3.16	2.76	1.72
Percentage of variance explained	27.6	10.2	8.9	0.56