Advanced manufacturing technology adoption and performance: the role of management information systems departments

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Abstract
This study uses information obtained from the advanced manufacturing technology (AMT) literature to develop a conceptual framework that seeks to illustrate the impact of the management information systems (MIS) department on the different facets of AMT adoption. A detailed survey instrument was administered to a cross-section of manufacturing firms in the USA to collect the data required to test five hypotheses relating to the efficacy of this framework. The results of this study indicate that the proposed framework is particularly useful in explaining the role of MIS departments in firms that are attempting to integrate advanced process and information technologies. This finding and other results of this study and their implications are discussed.

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Background

Advanced manufacturing technology (AMT) represents a wide variety of modern computer-based systems devoted to the improvement of manufacturing operations and thereby enhancement of firm competitiveness. AMT, in its varying forms, has been credited with the potential to bestow, among other things, earlier entrance to market, faster responses to changing customer needs, increased productivity, and higher quality products with improved consistency and reliability. However, results of several empirical studies indicate that while most firms achieve some benefits, many of them are not fully exploiting their AMT's touted capabilities (Beatty, 1990; Beaumont and Schroder, 1997; Boer *et al.*, 1990; deRon, 1995; Gunasekaran *et al.*, 1994; Inman, 1991; Jaikumar, 1986). Since the technical capabilities of AMT are well proven, failure to achieve the potential benefits has often been attributed to infrastructural problems such as inadequate organizational planning and preparation for the adoption of the AMT or faulty execution of other aspects of the implementation process (Chen and Small, 1994; Chung, 1996; Frolich, 1998; Hayes and Jaikumar, 1991).

AMT implementation requires organizations to make adaptations in the following four areas: process technology, human resources, operational structures, and information systems (Chung, 1996; Frolich, 1998; Lei *et al.*, 1996; Sabbaghi, 1990; Siegel *et al.*, 1997). Specifically, it has been found that among these adaptations, information systems adaptation may be the most important variable in explaining operational performance (Frolich, 1998). It has also been indicated that as an organization moves along the technology scale from stand-alone AMT towards integrated systems such as computer-integrated manufacturing (CIM), the need for high quality and timely production-related information will also increase (Brandyberry *et al.*, 1999). Further, Upton and McAfee (2000), indicate that non-stop floor information technology is, in itself, an important category of AMT. These findings suggest that information is the key that is needed to unlock the improvements in competitiveness promised by AMT. If this is indeed the case, there should be a key role for the MIS department and MIS professionals in the implementation and eventual operation of such systems. However, while the literature related to the process technology, human resources and operational structure aspects of AMT is already voluminous and growing, very little attention has been paid to some of the information systems requirements. Indeed, our extensive search of the literature failed to reveal any empirical articles that dealt specifically with the seemingly important role and functions of the MIS department in the AMT implementation process. Clearly, there is a pressing need for research in this area.

Responding to this need, the authors examined the AMT literature to develop a conceptual framework that addresses the desirable roles, functions and activities of MIS personnel/departments in AMT implementation. We then undertook a relatively large cross-sectional survey of US manufacturing firms in order to gain insights into the roles that MIS departments are currently playing in actual AMT implementations; information on firm performance on several key operational and business measures was also collected. This study provides several meaningful theoretical and practical contributions to the

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AMT implementation literature. Foremost among these are:

- This study presents results about the involvement of MIS departments in the planning and implementation phases of a wide cross-section of technologies ranging from low complexity systems to high complexity systems which include advanced information and manufacturing technologies such as MRPII, and computer-integrated manufacturing (CIM).
- It also addresses the relationships between organizational performance on a composite of 12 business and technical performance measures and the involvement of the MIS department in planning, justifying and installing AMT.
- Managerial implications of the findings reported in this study are also presented.

The overall results of this study should be particularly useful to the management of firms that are contemplating the adoption of AMT or that are in the early stages of the implementation process. In addition, researchers can use the conceptual framework presented in this study as a base for further studies on MIS involvement in AMT adoption and implementation. The framework can also be extended to explain the roles of other functional departments.

Literature review

Planning, justification and installation of AMT

Voss (1988) defines a life-cycle implementation process which consists of the following three phases:

1 pre-installation (planning and justification);
2 installation and commissioning (acquisition, installation and start-up); and
3 post-commissioning (monitoring and evaluation).

Implementation is typically viewed as a combination of the actions in the installation and commissioning and post-commissioning phases. It is widely held that issues in both the pre-installation and installation phases of AMT implementations appear to have a direct impact on the performance of AMT projects (see, for example, Chen and Small, 1994; Small and Yasin, 1997). Therefore, management of firms that are contemplating the adoption of AMT need to recognize, understand and address these issues in order to overcome or circumvent the problems of previous installations.

The literature on planning, justification and installation of advanced manufacturing technology can be divided into eight distinct but interrelated phases or modules as detailed below:

1 The recognition of an increasingly complex and competitive global and national business environment. The first step in consideration of the adoption of advanced manufacturing technology typically occurs when a firm recognizes that its current manufacturing processes or procedures are inadequate to meet current or expected future strategic or competitive changes in their business environment (Amoako-Gyampah and Maffei, 1989; Dean and Snell, 1996; Green *et al.*, 1994; Sabbaghi, 1990).
2 The need for strategic responses (which include the adoption of advanced manufacturing technology and advanced information technology) to meet these competitive demands, along with careful planning for the adoption of these technologies. In firms where the adoption of AMT is a feasible option, researchers have indicated that implementation is more likely to be successful if the decision to acquire the technologies is based on strategic considerations (Cleland and Bursic, 1992; Meredith and Vineyard, 1993; Sabbaghi, 1990; Swamidass and Waller, 1991). It has also been noted that AMT creates a world of opportunities that will only be converted to advantages if the adopting firm adopts a systematic integrative planning approach (Chung, 1991). Such a planning approach, which takes a long-term, comprehensive view of business, marketing, technology and manufacturing issues, is considered to be a critical precursor to successful AMT adoption (Udoka and Nazemetz, 1990; Zahra and Covin, 1993). The core of the planning approach is considered to be an integrated systematic business plan that is based on corporate goals and objectives. This business plan provides the vision and sense of direction for each organizational unit to meet the company's business objectives (Hershfield, 1992). There also appears to be widespread support for separate functional plans especially in the areas of manufacturing, marketing, and technology including information technology. However, the need for integration of all functional departmental plans with the business plan has also been stressed (Blois, 1991; Doll and Vonderembse, 1987; Hill, 1985).
3 The need to establish organizational goals and performance measures during the

Michael H. Small and Mahmoud Yasin
Advanced manufacturing technology adoption and performance: the role of management information systems departments

Integrated Manufacturing Systems
14/5 [2003] 409-422

strategy formulation and planning phases. The performance of an AMT system should be judged, primarily, on its ability to meet the organizational goals for which it was acquired. Therefore, it has been suggested that firms should identify the desired strategic and competitive benefits during the strategy formulation process and convert these benefits to specific business, marketing and technical performance measures during the planning and justification phase (Beaumont and Schroder, 1997; Chen and Small, 1994; Falkner and Benhajla, 1990; Lefley, 1996; Primrose, 1991). The development of information systems that are capable of gathering, transforming, storing and communicating all pertinent information and information flows related to these measures is also critical.

4 The need for structural (process) changes to meet organizational goals. The manufacturing literature suggests that firms may need to make investments in new process technology to build the capabilities required to provide the business, marketing and technical performance outcomes that are desired to meet current and future strategic and competitive needs (Leong *et al.*, 1990; Ward *et al.*, 1994). It should be recognized that each technology offers a theoretical basket of benefits and that care should be taken to ensure that the system or portfolio of systems under investigation can indeed provide the benefits desired by the adopting firm.

5 The need for infrastructural adjustments to support the new technology structure. It is felt that structural investments such as AMT adoption are more likely to be successful if pursued in conjunction with supportive infrastructural adjustments (Frolich and Dixon, 1999; Noori, 1990). In unsupportive environments AMT can quickly lead to the unraveling of an organization. It is for this reason that manufacturers are wisely cautioned against making premature AMT adoption decisions. Beatty (1990) suggests that, given the costliness of these systems and the potential risks involved, other less costly infrastructural innovations and interventions should be investigated prior to, or in conjunction with, consideration of AMT. In this regard, applicable changes in management practices are also believed to be useful pre-conditions for the adoption of AMT (Dornan, 1987). The need for carefully planned and supportive information systems is also of great importance (Brandyberry *et al.*, 1999; Upton and McAfee, 2000).

6 Investment justification of advanced manufacturing technology. Investment justification should include consideration of the operational costs and strategic and operational benefits of these systems together with consideration of the costs and benefits of the infrastructural adjustments (e.g. information technology adjustments, employee training and development costs) that are required to successfully implement these systems (Lefley, 1996; Primrose, 1991; Swamidass and Waller, 1991). Therefore, investment justification should only be attempted after a firm has identified the benefits that they require, investigated alternative AMT that can bestow these benefits, and considered the organizational infrastructure changes that are required to successfully implement the varying types of AMT or AMT portfolios.

7 Technology choice. Choice of AMT should reflect both the benefits that the organization expects to achieve and the quality of organizational preparation and support for the adoption of the chosen system (Small and Yasin, 1997; Parthasarthy and Sethi, 1992; Udoka and Nazemetz, 1990).

8 AMT performance evaluation. It has been reported that many AMT firms are not adequately measuring the performance of their systems (Lefley, 1996). It has also been stated that while firms adopt these systems for strategic purposes they are often evaluated on technical performance alone (Primrose, 1991). Some have suggested that it is more difficult to develop strategic performance measures than technical measures. However, Primrose (1991) indicates that using appropriate proxies and utilizing sensitivity analysis can lead to useable measures of strategic objectives related to, for example, quality and flexibility. In addition, measurement of AMT performance must be focused on assessing progress towards the original strategic, business and organizational objectives for implementing the systems (Udo and Ehie, 1996).

AMT portfolios

Advanced manufacturing technologies have been classified as stand-alone systems, intermediate systems and integrated systems (Brandyberry *et al.*, 1999; Small and Yasin, 1997). Technologies such as computer-aided design (CAD) and computer numerical control machines (CNC) are typically categorized as stand-alone systems. Automated inspection and testing systems (AITS) and automated material handling systems (AMHS) are often classified as intermediate or functional systems. Integrated technologies can be categorized as either: integrated process technologies (e.g. computer-integrated manufacturing (CIM) and flexible manufacturing systems (FMS)) or integrated information/logistic technologies (e.g. just-in-time production (JIT), manufacturing resources planning (MRPII), and enterprise resources planning (ERP)).

The general trend in empirical research on AMT has been to examine implementation and performance of individual technologies (e.g. CAD, CNC or FMS) or of specific technology classifications (e.g. stand-alone systems or integrated systems). However, firms must often combine technologies from across various technology classifications to achieve a desirable set of strategic and technical capabilities. A firm's combination of technologies or its technology portfolio presents an intriguing unit of analysis that has not received significant coverage in the AMT literature.

Paul Swamidass (1996) in a report on a survey of advanced manufacturing technology usage in the USA indicated that 85 per cent of manufacturers were using CAD and 73 per cent were using CNC. Just-in-time systems were being used by 74 per cent of the respondents while computer-aided manufacturing (CAM) and manufacturing cells were being used by 64 per cent and 58 per cent of manufacturers respectively. A 1997 National Skills Standard Board Survey indicated that 90 per cent of US manufacturers were using CAD, while about two-thirds were using CNC, JIT, and CAM. With such widespread usage, CAD and CAD/CAM networks are clearly vital components of most AMT systems (Lei *et al.*, 1996). Indeed, for smaller manufacturing facilities CAD and CNC are major components and oftentimes the only components of their AMT portfolio (see, e.g. Richel and Burns, 1997). However, JIT and MRPII systems appear to be gaining increasing popularity among small-to-medium sized firms (Richel and Burns, 1997).

For larger manufacturing firms CAD/CAM systems and CNC appear to be basic technology requirements (Small and Yasin, 1997). In addition, when compared to their smaller counterparts, larger firms tend to have higher adoption rates for the more extensive integrated technologies of JIT, MRPII, CIM and FMC/FMS. However, it appears that the larger firms are more likely to adopt JIT and MRP II than the more expensive and less easily justifiable integrated process technologies of FMS and CIM. Some researchers have also suggested that the integrative effects of the information/logistic technologies of JIT and MRPII and their lower costs make them useful pre-cursors to the implementation of the integrated process technologies of FMS and CIM (Beatty, 1990; Dornan, 1987).

The literature presented above suggests that, among manufacturing firms, there will be at least three mutually exclusive groups of advanced manufacturing technology portfolios with varying levels of sophistication or complexity. The low complexity portfolio group would consist of firms that are using only stand-alone and intermediate technologies, primarily CAD and CNC. The moderate complexity portfolio group would consist of firms that are using CAD and CNC and at least one of the integrated information/logistic technologies of JIT and/or MRPII. Such firms will not be using the integrated process technologies of FMS and CIM. The high complexity portfolio group would consist of firms that have adopted at least one of the integrated process technologies (FMS or CIM), at least one of the integrated information logistic technologies (JIT or MRPII) and the stand-alone technologies of CAD and CNC.

Information systems

While there is an existing and growing literature on the relationships between advanced manufacturing technology adoption and information systems or information technology requirements, much of this literature addresses the strategic nature of this relationship (Das *et al.*, 1991). There is also a branch of research in this area that has generated significant findings on appropriate information systems design from software engineering and user acceptance perspectives (Ba *et al.*, 2001). While the existing literature has done much to illustrate the critical link between automation technology and information technology very little effort has been exerted on establishing how this link can be generated and maintained on the shop floor. In this regard, Goldhar and Lei (1995) suggest that such a link depends on the adopting firm's cultivation of organizational practices that encourage continuous organizational learning and knowledge-creation activities. Therefore, unveiling knowledge about the actual activities of MIS departments and personnel with respect to automation and advanced information projects will be crucial to unraveling the MIS piece of the AMT implementation puzzle.

Research framework and hypotheses

The research conducted in this study is guided by the need to analyze the interrelationships illustrated in the conceptual framework which is depicted in Figure 1. The framework establishes desirable linkages between MIS involvement in the AMT implementation process and key aspects of AMT adoption: first, the choice of technology or technology portfolios being used by firms; second, relationships with AMT hardware and software vendors; and third, the business and operational performance of the firm after AMT implementation. While the framework details the desirability of linking and coordinating the activities of the MIS department and other functional departments, the major emphasis of this research is to consider the role of the MIS department. Therefore, our hypotheses and findings will be restricted to an analysis of MIS department involvement in the AMT adoption process. Our five hypotheses are presented below:

Research hypotheses

H1. The higher the level of complexity of a firm's AMT portfolio the greater the likelihood that the firm would have a dedicated MIS department or MIS personnel.

H2. The higher the level of complexity of a firm's AMT portfolio the greater the likelihood that the MIS department will be involved in:
(a) planning for the AMT;
(b) AMT justification activities; and
(c) AMT installation activities.

H3. Firms that adopt the highly complex AMT portfolios will place higher emphasis on MIS involvement throughout the AMT implementation process than firms with AMT portfolios that are less complex.

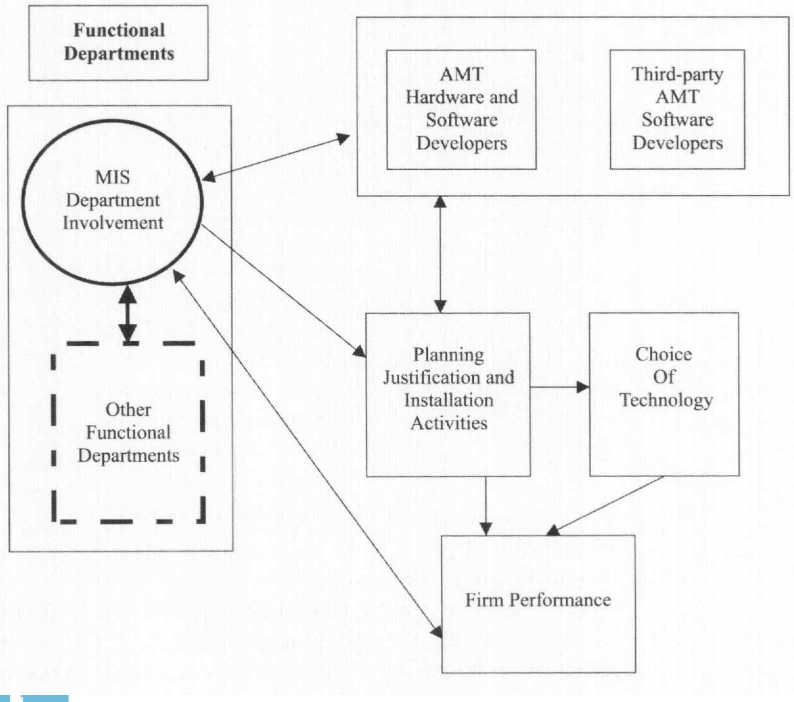
H4. Firms that involve the MIS department in their AMT implementation process will be more likely to seek and acquire AMT software solutions that are provided by third-party AMT software developers than other firms.

H5. Firms that involve the MIS department in the AMT implementation process will achieve higher levels of performance.

Rationale for the hypotheses

The fact that information plays such a vital role in the operation and evaluation of these systems suggests that firms need to utilize their MIS departments and/or personnel at all stages of the implementation to ensure that the chosen system will be capable of

Figure 1
A framework for MIS involvement in the AMT implementation process



providing the types of data required to assess whether the strategic, business and operational objectives of the implementation have been met. However, it is well known that many manufacturing concerns do not have dedicated MIS departments and that many of the MIS departments that do exist are understaffed. Nevertheless, it appears that firms that are desirous of implementing complex integrated technologies will be more likely to set up MIS departments or hire MIS personnel. Moreover, it has been suggested that as organizations move from low complexity technology portfolios towards more complex technology portfolios, the need for high quality and timely production-related information will also increase (Brandyberry *et al.*, 1999). Hence, firms that adopt the more complex portfolios will be expected to seek higher levels of involvement from their information systems personnel.

While firms with no internal information systems department may be forced to accept information technology solutions provided by their AMT hardware vendors, internal IS departments will, in most cases, be capable of assessing information technology solutions proffered by these vendors as well as from other independent external sources. Therefore, it is highly likely that firms that use their IS department in the various stages of the implementation process will acquire more of their AMT software requirements from third-party sources than firms that are not using MIS departments.

Finally, given the close and strategic link between automation and information systems requirements, it is highly plausible that firms that utilize their MIS departments in technology implementation will have a better perspective on the demands on and the capabilities of their information systems. They should also be able to coordinate the information systems requirements at both the business and operational levels with the objective of providing timely and accurate information to all functional areas and to customers and suppliers. Since timeliness and quality of information should result in better and faster responses to customer needs, which is a key requirement for achieving or maintaining competitiveness, these firms should be capable of achieving higher levels of business and operational performance.

Method

Procedure and sample

A cross-sectional survey methodology was employed for this study. The surveyed population consisted of firms whose major products were classified in several subgroups of standard industrial classification (SIC) major groups 35-37 (the discrete parts, durable goods manufacturing classifications). A survey of articles in the industrial engineering and manufacturing engineering practitioner journals and reports in the popular press indicate that firms in these SIC classifications continue to be major adopters of AMT. Questionnaires were mailed to a randomly selected sample of 584 manufacturing firms throughout the USA. The correspondence containing the questionnaire and a cover letter was addressed to top-level corporate managers with responsibility for technology, manufacturing or manufacturing engineering. A total of 125 responses were obtained from this survey. However, nine of these responses were unusable and 15 questionnaires were returned as undeliverable. Thus, a survey response rate of 22.0 per cent was achieved; the usable response rate was 20.4 per cent. Analyses of non-response, including analysis of variance and goodness-of-fit chi-square tests, revealed that there were no significant differences between respondents and non-respondents with respect to annual sales distributions or employee levels at the 0.05 level.

Measurement instrument

The questionnaire used in this study was reviewed by several academic experts, AMT consultants, managers at various firms that had installed AMT, and a few board members of the American Production and Inventory Control Society (APICS). The reviewers were asked to critique the content, structure and relevance of the survey instrument. The 15 reviewers also responded favorably to the questionnaire, indicating that there was a need for the type of data to be collected. The final survey instrument incorporated some minor changes such as revised definitions of the technologies that were suggested by the reviewers. The questionnaire solicited information on the involvement of the information systems department or IS personnel during each of the implementation stages: planning, justification and installation. Respondents were also asked to indicate whether their AMT software requirements were met by their AMT hardware vendors and/or third-party software dealers/developers. They were also asked to evaluate their systems with respect to several performance measures.

Type of technology

For this study, a firm's technology type is determined by the level of sophistication of

Integrated Manufacturing Systems
14/5 [2003] 409-422

the technologies contained in its portfolio of technologies. Three technology groups were defined as low complexity, moderate complexity and high complexity portfolio firms using the categorizations presented earlier. Each firm was classified into only one of the three technology portfolios. Typical technologies being used by each of the groups are detailed below:

1 *Low complexity portfolio*: computer-aided design (CAD); computer numerical control (CNC).
2 *Moderate complexity portfolio*: (all technologies in the low complexity group); just-in-time (JIT) and/or manufacturing resources planning (MRPII).
3 *High complexity portfolio*: (all technologies in the moderate complexity group); flexible manufacturing systems (FMS) and/or computer-integrated manufacturing (CIM).

MIS involvement

MIS usage was captured as a dichotomous variable. Firms were classified as either having or not having an MIS department or MIS personnel. For firms with MIS departments, information on the level of MIS involvement in AMT implementation process activities is captured as a dichotomous variable (1 – if MIS department or personnel were actively and substantively involved, 0 – if no involvement at all or if involvement was not significant). Respondents were asked to self-select their level of involvement in each of the three phases of their AMT adoption process (planning, justification, and installation). The following definition of active and substantial involvement was provided as a guideline for their assessment:

> involvement as a leader, coordinator or team-member in the committee, team or group that had responsibility for all or a substantial proportion of the activities in that phase of the implementation process. Such involvement would include active participation in the operational activities of that phase, regular deliberations on the work of the committee and any sub-committees, participation in group decision making and provision of recommendations to management oversight committees or AMT project oversight committees. Provision of *ad hoc* or one-time services of a consulting or advisory nature to such a committee, team or group would not be considered as active and substantial involvement.

Respondents with no MIS department or personnel were considered not to have any MIS involvement at any stage of the implementation.

AMT software acquisition

Respondents were asked to respond to two questions:

1 Did you acquire any of the software used to drive your AMT systems from your hardware vendor?
2 Did you acquire any of the software used to drive your AMT systems from third party software providers?

The possible responses to both questions were yes and no.

Overall project performance

A composite measure of performance for each firm that had completed installation of their AMT project was achieved using the 12 performance variables listed below:

1 ability to change production lot sizes;
2 variety of part-types or products manufactured;
3 the average number of tasks performed by an operator;
4 operator output rates;
5 plant revenues from manufacturing operations;
6 delivery lead times;
7 overhead costs;
8 product quality;
9 inventory turnover rates;
10 production changeover times;
11 time needed for a major change in an existing product; and
12 time-to-market for a new product.

These 12 variables were chosen to reflect the competitive priorities of cost, quality, flexibility and time-based competition. Another major consideration was that the chosen variables should reflect the capabilities of the technologies being surveyed.

The composite measure of performance for each firm that had completed installation of their AMT project was achieved using the measurement process described below. Each of the 108 respondents who had completed installation of their AMT projects were asked to rate the firm's level of performance on each of the 12 performance variables on a scale of −3 to +3. Where −3 represented a precipitous decline in performance and +3 represented a significant improvement in performance. The Cronbach's alpha value for the performance scale with 12 variables was 0.72. Therefore, this performance scale was deemed to be reliable. A composite performance score was calculated for each firm by standardizing the summed scores achieved on all 12 performance variables. To maintain consistency in the analysis of the hypothesis testing results, all hypotheses were tested using only information from the firms that had completed installation of their AMT and had achieved measurable changes in performance levels.

Results and discussion of findings

A discussion of the hypothesis results and findings are presented in the following subsections. First, the relationship between the existence of an MIS department or MIS personnel and the type of AMT portfolio being used by firms is assessed. Next, we evaluate the relationship between the involvement of the MIS department and the type of AMT portfolio being used by firms with respect to planning, justification and installation activities. Finally, the impact of the involvement of the MIS department on software acquisition and on the overall performance of AMT projects is addressed.

Relationship between type of technology and existence of MIS department

As indicated in Table I, the *p*-value for the test of independence between existence of MIS department and type of technology was 0.0017, indicating that there is a strong statistical relationship between type of technology and the existence of an MIS department. Hence, *H1* was supported. Firms with the more complex portfolios were more likely to have dedicated MIS departments or MIS personnel. While 61 per cent of high complexity AMT portfolio projects reported the existence of an MIS department, 50 per cent of the moderate complexity projects and only 10 per cent of the low complexity projects had MIS departments. The fact that 42.6 per cent of all respondents had MIS departments or key MIS personnel is also worthy of note.

Readers should note that the Chi-square test does not address causality. However, it is clear that 50 per cent or more of the firms that were using the high complexity and moderate complexity portfolios have recognized the value of having MIS departments or key MIS personnel to help coordinate the information requirements in systems that utilize integrated process and/or integrated information/logistics systems. The low level of MIS support in the low complexity portfolio firms may be due to the fact that these firms are not yet utilizing the integrated information/logistic technologies. However, further analysis of our data indicated that many of the firms in this category were smaller firms that typically do not have the resources to set up dedicated MIS departments.

Relationship between type of technology and involvement of MIS department

Given the low level of representation of MIS departments in firms in the low complexity portfolio classification our tests for *H2* were restricted to firms in the moderate complexity and high complexity groups. As illustrated in Table I, the *p*-values for the tests of independence between type of technology and involvement of the MIS department in planning, justification and installation activities were 0.7955, 0.9403 and 0.9444 respectively. This indicates that there was no relationship between type of technology being used and MIS involvement in planning, justification and installation activities. Hence, *H2a*, *H2b* and *H2c* were not supported among firms using the high and moderate complexity portfolios. Effectively, there were no differences between the levels of involvement of MIS in these firms at the three stages of the implementation process that could be traced to the type of technology portfolio being used.

It is interesting to note, however, that the high and moderate complexity portfolio firms with MIS departments were more likely to seek the involvement of their MIS departments at the planning stage (95 per cent) and the installation stage (77.5 per cent), than at the justification stage (55 per cent). There should be some concern over the lower level of participation of the MIS department in the justification stage of the project. For it is in this stage that most of the strategic and operational performance objectives are identified.

The hypothesis test results for *H3* are also presented in Table I. This test seeks to determine if firms with more complex portfolios encourage greater MIS involvement throughout all three stages of the AMT implementation process. Our results indicate that the relationship between MIS involvement in the entire adoption process and the type of portfolio adopted was not statistically significant for the high and moderate complexity portfolio groups (Chi-square *p*-value of 0.9349). Hence *H3* was not supported.

Taken as a whole, the results of *H2* and *H3* indicate that, for firms with high and moderate complexity portfolios, there are no significant differences in the level of involvement of MIS departments in implementation activities for AMT projects. This suggests that, without regard to the type of technology being used, firms that have an MIS department or MIS personnel will use them for AMT implementation activities especially in the planning and installation stages. Since the information processing

Integrated Manufacturing Systems
14/5 [2003] 409-422

Table I
Relationship between existence of MIS department and MIS involvement in the implementation process by type of technology portfolio adopted

	High complexity portfolio			Moderate complexity portfolio			Low complexity portfolio			Observed			
Type of technology	Observed count	Column (%)	Expected count	Observed count	Column (%)	Expected count	Observed count	Column (%)	Expected count	Row total	Row (%)	χ^2	*p*-value
Existence of MIS department													
MIS department or personnel	25	61.0	17.5	15	50.0	12.8	3	10.0	12.8	43.0	42.57	19.35	0.0017
No MIS department or personnel	16	39.0	23.5	15	50.0	17.2	27	90.0	17.2	58.0	57.43		
MIS involvement planning stage													
MIS involved	24	58.5	21.9	14	46.7	16.1				38.0	53.52	1.02	0.7955
MIS not involved	17	41.5	19.1	16	53.3	13.9				33.0	46.48		
Justification stage													
MIS involved	15	38.5	13.8	9	31.0	10.2				24.0	35.29	0.38	0.9444
MIS not involved	24	61.5	25.2	20	69.0	18.8				44.0	64.71		
Installation stage													
MIS involved	19	46.3	17.7	12	40.0	13.3				31.0	43.66	0.40	0.9403
MIS not involved	21	53.7	22.3	18	60.0	16.7				39.0	54.93		
Entire adoption process													
MIS (all stages)	12	29.3	11.55	8	26.7	8.45				20.0	28.17	0.95	0.9349
MIS (one or two stages	13	31.7	11.55	7	23.3	8.45				20.0	28.17		
No MIS	16	39.0	17.90	15	50.0	13.10				31.0	43.66		

technologies of MRPII and JIT are common to these technology portfolios it is plausible to assume that it may be the firm's information gathering and processing requirements that drive the existence of MIS departments in these manufacturing firms.

Relationship between sources of software acquisition and involvement of MIS department

The results of the tests for *H4* that are presented in Table II indicate that users of all three types of portfolios were just as likely to acquire at least some of their AMT software from their hardware vendors regardless of the level of MIS involvement. In contrast, firms that had involved their MIS departments in the implementation activities were more likely to acquire some of their AMT software requirements from third party suppliers. Hence, *H4* was supported.

It appears, therefore, that firms that involve their MIS departments in the AMT implementation process have the added advantage of being able to exercise a wider variety of software acquisition options. Undoubtedly, this would be due to the fact that MIS personnel are more likely than non-MIS personnel to have the training, knowledge and skills that are required to investigate and analyze the various software options that may be available to the firm.

MIS involvement and performance

H5 was analyzed using ANOVA-tests as reported in Table III. First, it can be seen that, for the entire sample, firms that were involving the MIS department at all three stages of the implementation process had significantly outperformed those firms with no MIS involvement for all measures except increased product customization. Compared to firms with no MIS involvement, firms that had involved the MIS department in one or two stages of the implementation process had significantly higher levels of performance on the ability to vary production lot sizes and on reducing delivery lead times.

Among firms that were using the high-complexity portfolio technologies, those that were involving their MIS department in any of the stages of the implementation process had, in general, higher mean scores on all four of the measures than the firms with no MIS involvement. However, the differences were only statistically significant for ability to vary production lot sizes and percentage of on-time deliveries. Among firms that were using the moderate-complexity portfolio technologies, the only measure for which statistically significant differences could be discerned was for the variety of products manufactured. In this case, both the firms that were involving the MIS department at all stages of the process and those that were not involving MIS had significantly outperformed those firms that were only using MIS for one or two of the stages. Hence, among firms in the high complexity portfolio group, *H5* was supported for three of the four measures. This hypothesis was not supported for the moderate complexity portfolio group.

Involving the MIS department in the AMT implementation process appears to have paid more dividends to firms that are using the high complexity portfolios. This suggests that MIS departments will have a positive impact on the performance of firms that are seeking to create a strategic technology platform that includes both integrated process technology (such as CIM and FMS) and integrated information technology (such as JIT, MRPII and ERP). MIS involvement in the implementation of such technologies appears to introduce the systematic approach needed to facilitate the effectiveness of the AMT effort.

Conclusion and implications

The results of this study support the efficacy of the research framework advanced in Figure 1, especially as it relates to firms that are using the more complex technology portfolios. The involvement of the MIS department was shown to not only have an impact on the performance of these firms but also on the ability of such firms to seek technology solutions that are not reliant on the vested interests of their AMT hardware vendors. While the findings reported in this study have direct practical applications for management of firms that are using or considering the adoption of the more complex technology portfolios, there are several findings that can assist users of each technology portfolio. The following recommendations are provided for all firms that are interested in pursuing AMT adoptions:

- As firms move along the technology continuum from the low complexity to the high complexity portfolios there will be an increasing need to address information technology issues. In particular, firms will need to address the issue of hiring MIS personnel or setting up dedicated MIS departments.
- Our findings suggest that for firms that are seeking to upgrade from low complexity to moderate complexity AMT portfolios, the major leverage offered by

Table II
Relationship between software acquisition and MIS involvement

	MIS involvement							
	MIS (all stages)		MIS (one or two stages)		No MIS			
Software source	Observed count	Expected count	Observed count	Expected count	Observed count	Expected count	χ^2	*p*-value
Acquired from hardware vendor	13	13.7	17	17.2	44	43.1	0.1880	0.9103
Not acquired from hardware vendor	6	5.3	7	6.8	16	16.9		
Acquired from third party supplier	17	12.8	16	14.7	30	35.5	9.8647	0.0072
Not acquired from third party supplier	2	6.2	8	9.3	30	24.5		

Notes: MIS (all stages): MIS involved in all three stages, planning, justification and installation; MIS (one or two stages): MIS involved in one or two of the three stages of the adoption process; No MIS: MIS not involved in any of the three adoption stages

Integrated Manufacturing Systems
14/5 [2003] 409-422

Table III
Performance by level of MIS involvement

Performance measure	Entire sample A	B	C	D	E	High complexity portfolio A	B	C	D	E	Moderate complexity portfolio A	B	C	D	E
1 Ability to vary production lot-sizes															
MIS not involved	4.2857	0.1365	56	7.3952	0.0010	4.6429	0.2695	14	4.5454	0.0176	4.2857	0.2857	14	0.3570	0.7031
MIS involved at one or two stages	5.0870	0.2259	23		(3-1)	5.4615	0.1831	13		(3-1)	4.7143	0.5216	7		
MIS involved at all stages	5.1053	0.2281	19		(2-1)	5.5455	0.2743	11		(2-1)	4.5000	0.3273	8		
2 Variety of products manufactured															
MIS not involved	4.5357	0.1323	56	1.8597	0.1613	4.3571	0.2695	14	1.5721	0.2219	4.7143	0.2857	14	4.6067	0.0194
MIS involved at one or two stages	4.4348	0.2501	23			5.0000	0.2996	13			3.5714	0.4286	7		(3-2)
MIS involved at all stages	5.0000	0.2023	19			4.9091	0.2846	11			5.1250	0.2950	8		(1-2)
3 Delivery leadtimes															
MIS not involved	4.3036	0.1669	56	7.9840	0.0006	4.7857	0.2998	14	2.7466	0.0780	4.2857	0.4376	14	1.0389	0.3681
MIS involved at one or two stages	5.1304	0.2018	23		(3-1)	5.2308	0.3028	13		(3-1)	5.1429	0.3401	7		
MIS involved at all stages	5.3158	0.2031	19		(2-1)	5.7273	0.1950	11			4.7500	0.3134	8		
4 Percentage of on time deliveries															
MIS not involved	4.4643	0.1323	56	2.326	0.0771	4.4286	0.3588	14	3.6185	0.0373	4.3571	0.2695	14	0.3779	0.6980
MIS involved at one or two stages	4.8696	0.2285	23		(3-1)	5.3077	0.2371	13		(3-1)	4.7143	0.2875	7		
MIS involved at all stages	5.0000	0.2294	19			5.4545	0.2473	11		(2-1)	4.3750	0.3239	8		
5 Composite performance															
MIS not involved	4.3973	0.0769	56	10.5046	0.0001	4.5536	0.1742	14	6.9507	0.0029	4.4107	0.1690	14	0.4554	0.6392
MIS involved at one or two stages	4.8802	0.1706	23		(3-1)	5.2500	0.1941	13		(3-1)	4.5357	0.3107	7		
MIS involved at all stage	5.1053	0.1383	19		(2-1)	5.4091	0.1401	11		(2-1)	4.6875	0.1875	8		

Notes: Scale for performance measures: 1 = Declined significantly ... 7 = Improved/increased significantly; A = Mean; B = Standard error; C = *n*; D = *F*-value; E = *p*-value and 5 per cent significant difference an MIS department may be its ability to better investigate and evaluate potential software solutions including addressing hardware and software compatibility issues. Firms should, however, be aware that the existence of an MIS department will not guarantee higher levels of performance than their moderate complexity counterparts that may not have established an MIS department.

- As firms move from the moderate complexity to the high complexity portfolios (that is as they seek to adopt integrated manufacturing technologies) the existence of an MIS department and its involvement in AMT implementation activities become more important. Our findings indicate that such firms will have an edge on their counterparts in terms of the potential for more extensive options for their software and hardware solutions. Moreover, the firms with MIS involvement in the implementation process had significantly outperformed their counterparts.
- Firms with long-range plans to incrementally move from low complexity to high complexity systems may want to consider setting up a dedicated MIS team early in the process, certainly by the time they are ready to upgrade to integrated information technology. If the long-range plan materializes it will be much easier to upgrade the MIS team to a full-fledged MIS department.
- Firms should also be aware that MIS involvement appears to be most important in the planning stage. Firms that involved their MIS in planning for AMT had significantly outperformed those firms in which there was no MIS involvement in planning. Therefore, firms should minimally seek to involve their MIS departments at the planning stage. The fact that firms that had maintained MIS involvement throughout the entire three-stages of the implementation process had, in general, outperformed all others provides a strong case for MIS involvement throughout the process. Therefore, firms should also carefully consider involving the MIS department in deliberations about the justification of AMT projects.

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