Exploiting AMT in small manufacturing firms for global competitiveness

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Introduction

In the last two decades, several factors have forced US manufacturers to make dramatic changes in their products, markets, and manufacturing strategies:

- slowdowns in economic growth have intensified competition for market share;
- saturated markets in many foreign countries have shifted emphasis abroad;
- the increasing capabilities of producers to appeal to consumer appetites for change are shortening product life cycles;
- the rate of technological transfer from development to product, and across products and markets is accelerating;
- perhaps most importantly, the international competitive environment continues to intensify.

Taken together, these factors create a competitive environment which demands a transformation by many manufacturers in how they respond to rapidly changing global markets.

The new role of manufacturing

The market place of the twenty-first century is evolving into one of merging national markets, fragmented consumer markets, and rapidly changing product technologies. These changes are driving firms to compete, simultaneously, along several different dimensions: design, manufacturing, distribution, communication, sales and others. Although manufacturing has not been utilized as a competitive weapon historically, the market place of the twenty-first century will demand that manufacturing assume a crucial role in the new competitive arena.

The authors gratefully thank the Virginia Military Institute Research Laboratories for funding and Wayne Hawkins (Virginia's Center for Innovative Technology) and Chris Caplice (Massachusetts Institute of Technology) for assistance in the collection of data on which this article relies.

International Journal of Operations & Production Management, Vol. 15 No. 2, 1995, pp. 61-76. © MCB University Press, 0144-3577

Japan, for example, has succeeded in world markets by focusing its attention on the importance of superior manufacturing systems and techniques. Thus, manufacturing may be the "sleeping giant" within firms and prove to be a formidable competitive weapon in the global marketplace. One way that firms can achieve a competitive advantage in manufacturing is through the employment of advanced manufacturing technologies (AMT).

Significance of small manufacturers

Small manufacturing firms far outnumber large manufacturing firms, employ a substantial majority of the manufacturing employees in the US, and play a critical role in contributing to the vitality of the US economy[1]. However, past research on AMT adoption and implementation has focused on large manufacturing firms, since large firms have the resources to make extensive use of AMT, and small firms presumably do not.

Unfortunately, little research has addressed the competitive strategies of small manufacturing firms, particularly their motivations for AMT adoption and implementation. This article explores the relationship of AMT to the global competitiveness of small manufacturing firms. More specifically, it identifies reasons why small firms adopt AMT, compares AMT adoption patterns between exporting and non-exporting firms, and examines the relationship between AMT adoption and exporting to global markets. This article consists of five parts: a literature review, the research questions and hypotheses to be tested, the methodology, the results, and conclusions and directions for future research.

Review of pertinent research

The review of the literature is divided into four topics: the changing manufacturing paradigm; advanced manufacturing technologies; factors influencing the adoption of AMT; and the relationship between AMT adoption and exporting.

The changing manufacturing paradigm

The USA experienced strong growth in consumer markets from the 1940s to the 1970s. As consumer demand grew, mass production was the order of the day, and there appeared to be no limit to the size of the US consumer market. Firms employed the "traditional" manufacturing strategy paradigm in which they focused on a limited number of products and made their margins from cost economies of scale. This strategy prevailed through the American growth era and represents the fundamental paradigm of manufacturing: rationalization and mass production of goods.

In business paradigms, just as in science, revolutions often begin with a crisis. The crisis for US manufacturers was a dramatic slowing of domestic population growth, accompanied by continued growth of a diverse and fragmented global population. Instead of the historically homogeneous domestic market, US firms must now compete in multiple markets, supplying multiple products, simultaneously, all over the world. US consumers further exacerbated the problem with decreased brand loyalty, increased acceptance of foreign products, and heightened expectations for service and supplier accountability.

The result of this forced shift in products, markets, competitors and strategy has been profound. Successful global competitors are responding to this shift by simultaneously pursuing multiple "competitive priorities". Thus, a new manufacturing paradigm appears to be emerging in which firms must compete, simultaneously, on a variety of competitive priorities in order to respond quickly to market opportunities and threats. These global competitors reject the "traditional" manufacturing paradigm of tradeoffs among and between competitive priorities such as low cost, time, quality and flexibility.

Recently, some authors[2,3] have suggested a "sandcone" model of competitive priorities where – rather than tradeoffs – competitive priorities are added to a manufacturing environment in a prespecified order. More specifically, they believe that the priorities are added – or stacked – one on top of the other, much like a sandcone is formed as the sand is poured: first quality, then dependability, then cost efficiency, and finally flexibility. They make a compelling argument that time is the next competitive arena[2,3].

This paradigm shift is well recognized in the literature. For instance, Blackburn[4] suggests that the just-in-time (JIT) approach to manufacturing provides firms with the flexibility and speed essential to meet global competition, and that expansion of these principles throughout the firm's product delivery system could result in a powerful competitive tool. He extends this concept of manufacturing flexibility into the context of the global marketplace and suggests that marketing seeks maximum variety in the product line while manufacturing's ideal is to "churn out" the same commodity product in a single colour. Blackburn[4], and others[5,6], argue that increased globalization demands customization of products to fit disparate international market conditions – thus making the ability to produce variety essential.

The evolution of (JIT) production systems has also contributed to the advancement of time-based competition. Abegglen and Stalk[6] state that:

> The JIT system is the key to relieving the ever-present tension between the desires of the marketing organization and the manufacturing organization. The marketing organization seeks greater variety in the product line to pursue growth and higher margins. The manufacturing organization resists increasing variety because the complexity of the plant is compounded: run lengths shrink, inventories swell, and costs rise. But JIT sharply reduces the impact of product line diversity on production costs, thus enabling the marketing organization to obtain needed products at a low incremental cost (p. 93).

Similarly, Stalk and Hout[5] observe that "demanding executives at aggressive companies are altering their measures of performance from competitive costs and quality to competitive costs, quality and responsiveness" (p. 1). These authors[5,6] suggest that time-based competition is the most advantageous strategy in today's marketplace.

Product diversity is increasing, product life cycles are decreasing, and cost patterns are shifting. Global and domestic manufacturers must now include flexibility and time-based technologies in their manufacturing capability. Rather than traditional economies of scale, new strategies must facilitate flexibility, reduce design cycle time, reduce time to market, and reduce order cycle time. For manufacturing to be the new competitive weapon, management must respond with new and agile manufacturing strategies for both the domestic and global environment. The adoption of AMT is one way to respond to this growing need for flexibility and time-based capabilities in manufacturing.

Advanced manufacturing technologies

AMT is a generic term for a group of manufacturing technologies which combine both scope and scale capabilities in a manufacturing environment[7]. Manufacturing strategy has become more sophisticated. As a result, AMT can play a crucial role in making it possible for firms to compete on "traditionally" contradictory competitive priorities simultaneously.

Wiarda[8] suggests two subgroups of technologies within AMT: the traditional hardware technology consisting of systems, devices and stations (SDS); and a second group of technologies, often in software form, which perform integrative and managerial functions – integrative and managerial systems (IMS).

Typical examples of systems, devices, and stations (SDS) include: automated identification station; automated inspection stations; automated material handling devices; computer aided design workstations; computerized numerical control machine tools; numerical control machine tools; programmable production controllers; robots; shop-floor control systems[8].

Examples of integrated and managerial systems (IMS) include: computer aided manufacturing; computer-aided engineering; statistical process control; production planning/inventory management software; engineering data management; computer aided process planning; local area networks; group technology[8].

Both SDS and IMS technologies can be used individually or in combination with other technologies to achieve desired economies of scale and scope. When taken together SDS and IMS constitute AMT. Appendix 1 contains a list of definitions of these programmable technologies.

Factors inducing AMT adoption

To the extent that global and domestic environments differ, we expect that global and domestic (non-exporting) firms have different objectives for adopting AMT as a means to effectively compete in their respective markets (i.e., flexibility, time-based competition, etc.) Whatever the objectives may be, the adoption of any new technology involves uncertainty about achieving the objectives.

In addition to the inherent human resistance to change and innovation, at least two other types of uncertainty are present when adopting manufacturing innovations: technological uncertainty (whether the adoption of the technology will be profitable); and strategic uncertainty (how the decisions of competing firms will adversely impact a decision to adopt a new technology)[9]. Generally, the effects of technological uncertainty can be reduced by research and testing[9]. In contrast, strategic uncertainty is more difficult and problematic to evaluate, frequently relying on speculative efforts to anticipate the decisions of rival firms[9]. Adopting AMT involves both types of uncertainty.

Reducing the technological and strategic uncertainty associated with AMT adoption is critical to firms, both in the acquisition and implementation stages. Firms attempt to identify critical "factors" to reduce these uncertainties and support their strategic objectives. Thus, these factors provide a link between the firm's long-term competitive strategy and its technology. Kantrow[10] calls such factors the "strategy-technology connection".

The literature identifies a variety of technical and strategic factors (reasons) that induce AMT adoption: reduced product development time[11]; labour costs savings[12,13]; material costs savings[13]; a need to remain competitive[11,14]; tax incentives[13]; financing availability[13]; a need for product change flexibility[12,15]; environmental, safety or health concerns[13,16]; increased profitability or plant performance[13]; and customer requirements[17]. These factors have a broad, strategic impact on the firm and affect virtually every major element of a firm's operating environment. For example, these inducements can be grouped into categories associated with five major elements of a firm's operating environment (see Table I).

Adoption of AMT and exporting

Exporters who compete in rapidly changing global markets must be able to reduce their product development time and respond quickly to demands for product changeover[13]. These capabilities depend, to some degree, on the extent to which AMT is linked and integrated. IMS technologies make this linkage and integration possible. Thus, we would expect global competition to drive the adoption of technologies that exploit AMT capabilities. Therefore,

Elements of a firm's operating environment	Associated inducement factors
Ownership	Increased profitability
Customers	Reduced product development time Customer requirements/pressure Need for product change flexibility
Internal management	Labour cost savings Material cost savings
Government	Tax incentives/favourable financing Environmental safety or health concerns/regulations
Competition	Need to remain competitive

Table I.
Technial and strategic factors to induce AMT

exporting firms should have a relatively greater ratio of IMS to SDS technologies than non-exporting firms. We know of no research which has specifically compared AMT adoption patterns in exporting and non-exporting firms.

Relationship between AMT and exporting

Sanchez[13] suggests that firms which export a large portion of their production adopt a greater variety of AMT than domestic competitors. He cites the reorientation to exporting by the Japanese as their motivation to adopt AMT. If this is the case, US exporting firms would be expected to adopt a greater variety of AMT than non-exporting firms.

In the case of small manufacturing firms that export, there appears to be an absence of research which explores the relationship between AMT adoption and the level of exporting. Further, the anecdotal evidence relates only to large manufacturing firms, since large manufacturing firms presumably have more resources to commit to the acquisition of manufacturing systems and technologies than small firms. Thus, it is expected that firm size and AMT adoption are also positively related and may impact the ability of small firms to acquire AMT technology.

Research questions and hypotheses

This study addresses the following three research questions concerning small manufacturing firms: What are the differences between exporters and non exporters with regard to why they adopt AMT? How do exporters and non-exporters differ with regard to how they adopt AMT? What is the nature of the relationship between exporting activity and the variety of AMT adopted?

To address these questions, the authors proposed five hypotheses concerning small manufacturing firms:

H1: There is no difference between exporting and non-exporting firms with regard to their reasons for AMT adoption.

H2: There is no difference between exporting and non-exporting firms with regard to their patterns of AMT adoption.

H3: There is no positive relationship between their exporting activity and AMT adoption.

H4: There is no positive relationship between firm size and AMT adoption.

H5: Firm size has no moderating effect on the relationship between exporting activity and AMT adoption.

Hypothesis 1 relates to the first research question, hypothesis 2 relates to the second research question, and hypotheses 3 through to 5 relate to the third research question.

Research methodology

Sample

In this study, the unit of analysis is the firm, and the population is small manufacturing firms within the State of Virginia. The US Department of Commerce defines a "small business" as having 500 or less employees[18]. Using the *1992 Directory of Virginia Manufacturers*[19] and the *Virginia Business Directory*[20], 3,000 firms, representing 22 standard industrial classification (SIC) codes, were identified as meeting the criteria for inclusion in this research: manufacturing firms with ten to 500 employees. Questionnaires were mailed to these firms, and 552 usable questionnaires were returned for a gross response rate of 18.4 per cent. This response rate is fairly typical in large scale manufacturing survey research[21].

This study requires a critical mass of small firms that are more likely to engage in exporting significant portions of their total output. In addition, in order to eliminate as many confounding effects as possible, a relatively narrow range of manufacturing processes was required. Firms in SIC codes 35, 36 and 37 manufacture industrial and commercial machinery, computers, electrical equipment, transportation equipment and computer-related equipment. Manufacturing techniques within these industries are quite similar, the industries are widespread throughout the world, and firms in these industries frequently engage in exporting. The resulting sample was selected from these three SIC codes, consisting of 108 firms.

Resulting sample profile

The resulting sample profile indicated that:

- A total of 86 firms (79.6 per cent) reported SIC 35, "industrial and commercial electrical equipment" as their primary SIC.
- SIC 36, "transportation equipment" was reported by 12 firms (11.1 per cent) as their primary SIC.
- Ten firms (9.3 per cent) reported SIC code 37, "computer related equipment" as their primary SIC.
- The average age of all firms is 24.5 years old.
- The average number of employees for all firms is 75.5 employees.
- Only ten firms had adopted no AMT.
- For the firms which do employ AMT, the average number of different advanced manufacturing technologies adopted is 4.147 (out of a possible total of 17).
- Of the 108 firms, 56 reported no direct export activity.
- The 52 remaining firms who do directly export, reported that exporting accounts for an average of 16.4 per cent of annual sales revenue.

Questionnaire

Data in this study were collected through the use of a mailed, self-administered questionnaire. A copy of the questionnaire is found in the Appendix 2. In the instrument, firms were requested to: indicate which factors induced them to adopt AMT; identify specific advanced manufacturing technologies they use; and report their level of exporting activity as a percentage of their total sales.

Initial drafts of the questionnaire were reviewed by operations strategy researchers, as well as experts in survey methodology. Subsequently, three sequential pilot tests were conducted. Groups of ten to 12 executives with varied marketing and manufacturing experience evaluated the instrument for each of the three pilot tests. Executives were contacted by telephone after each test, and the questionnaire was revised according to suggestions provided. Further refinement was made based on comments solicited from other academic and professional groups as well.

Based on the literature review presented above, respondents were asked to identify on the survey instrument which of the following factors induced them to adopt AMT: reduced product development time; labour cost savings; material cost savings; a need to remain competitive; tax incentives and/or favourable financing; customer requirements or pressures; a need for product change flexibility; environmental, safety, or health concerns or regulations; increased profitability.

It was possible to check all or none of the possible factors as inducements. The degree to which the factor induced AMT adoption was not considered or measured. Table II lists these nine factors with the percentage of exporting and non-exporting firms who reported these factors as influencing their decision.

Factors inducing AMT adoption: exporting versus non-exporting firms	Percentage of firms reporting factors as an inducement		
	Non-exporting	Exporting	Difference
1. Reduced product development time	18.18	52.83	($p<0.01$)
2. Labour cost savings	61.82	75.47	
3. Material cost savings	20.00	32.08	
4. Need to remain competitive	70.91	71.70	
5. Tax incentives/favourable financing	9.09	3.77	
6. Customer requirements/ pressure	30.91	30.19	
7. Need for product change flexibility	20.00	58.49	($p<0.01$)
8. Environmental, safety, or health concerns/regulations	5.45	3.77	
9. Increased profitability	49.09	62.26	
Sample size	55	53	

Note: Reports only respondents who have adopted AMT

Table II. Percentage of firms reporting factors inducing AMT adoption

Questions 1 and 2 of the survey instrument asked firms to identify the type and number of AMT they had adopted. A firm's breadth of adoption (NUMTECH) is the number of different types of advanced manufacturing technologies used by each firm. The survey instrument identified 17 possible such technologies. Thus, a firm's NUMTECH can range from "0" (a firm which has no AMT) to "17" (a firm which has adopted all 17). Survey responses on NUMTECH fall with that range.

Research models

MANOVA model. The first research question addresses the "differences between exporting and non-exporting firms with regard to the factors that induce AMT adoption". To measure the overall effect, the vector of factors were considered simultaneously, using a multivariate model. The following MANOVA model was used:

$$Y_{ijk} = \mu + \alpha_k + \varepsilon_{ijk}$$

where y_{ijk} is a vector of observations on p dependent variables, μ is a vector of means for p dependent variables, α_k is the effect on an observation of belonging to the kth group from a vector of groups, and ε_{ijk} is the vector of errors. Using the variables in this study, μ is a vector of means for the nine factors which may induce AMT adoption and α_k groups the set of all AMT adopting firms into exporting and non-exporting subsets such that y_{ijk} refers to the ith firm's response to the jth factor grouped either as an exporter or non-exporter. If the vectors for exporters and non-exporters are significantly different, pairwise tests will be used to determine which factor(s) account for the difference in the vectors.

Multiple regression model. Sanchez[13] proposes a model of AMT diffusion which suggests that export sales and firm size are positively related to AMT adoption. He also suggest that firm size is related to AMT adoption and may moderate the relationship between AMT adoption and exporting activity.

In order to establish a causal relationship, adoption of AMT must be a function of expectations of future exporting activity. An adaptive expectations[22] or polynomial lag[23] model could be used to statistically test such hypothesized effects. However, this study uses cross-sectional, rather than longitudinal, data, and the use of causal models is not warranted.

This study will consider only the relationship between a firm's exporting activity and its breadth of AMT adoption. Partial correlations within the regression models will measure the strength of the relationship.

The model to test hypothesis 3 is:

$$\text{NUMTECH}_i = \beta_0 + \beta_1 (XPRT)_i + \varepsilon_i$$

with NUMTECH_i = the breadth of AMT adoption for firm i, $XPRT_i$ = level of exporting activity as a percentage of total sales for firm i, and ε_i is the error term.

To test the relationship between firm size and breadth of AMT adoption, the following model is used to test hypothesis 4:

$$NUMTECH_i = \beta_0 + \beta_1 (EMPN)_i + \varepsilon_i$$

where $EMPN_i$ firm size measured by number of employees.

To determine whether exporting and firm size interact, the following model will be used to test hypothesis 5:

$$NUMTECH_i = \beta_0 + \beta_1 (XPRT)_i + \beta_2 (EMPN)_i + \beta_3 (XPRT * (EMPN) + \varepsilon_i$$

where $XPRT_i * EMPN_i$ = the interaction between $XPRT_i$ and $EMPN_i$ for firm i.

Analysis and results

The analysis portion is organized into five parts, linked to the five hypotheses identified previously. The five hypotheses relating to small manufacturing firms are restated below, together with the analysis associated with each hypothesis:

H1: There is no difference between exporting and non exporting firms with regard to their reasons for AMT adoption.

Table II shows the nine factors that were considered as possible reasons for adopting AMT adoption. Using SPSS/PC+[24] and MANOVA model (M1), the authors first compared the vector of factor proportions for exporting firms (firms that export at least 1 per cent of their product) to the vector of factor proportions for non-exporting firms. Using the Hotelling's T^2 test[25], the vectors were significantly different (p <0.001). Thus, Hypothesis 1 is rejected.

The authors then conducted pairwise Z tests to test for significant differences between each factor. Table II shows two factors to be significantly different between exporting and non-exporting firms: "(A) Reduced product development time" (p <0.001), and "(G) Need for product change flexibility" (p <0.001).

A one-tail test (p < 0.001) further confirms that a significantly larger proportion of exporting firms (compared to non-exporting firms) base their decision to adopt AMT on these two factors.

H2: There is no difference between exporting and non-exporting firms with regard to their patterns of AMT adoption.

Using a two-tail test, the IMS/SDS ratios for exporting and non-exporting firms were compared. The results are shown in Table III.

The ratios are significantly different (p < 0.01) and Hypothesis 2 is rejected. A one-tail test further confirms that exporting firms have a significantly higher (p

Table III.
Comparison of IMS/IDS ratios in exporting and non-exporting firms

	Exporting firms	Non-exporting firms	Ratio differences
IMS/SDS	1.1937	0.8337	0.36 (p < 0.01)
Standard deviation	0.7441	0.7082	NA
Sample size	50	41	NA

< 0.01) IMS/SDS ratio than non-exporting firms. Thus, it appears that exporting firms bias their pattern of AMT adoption more in favour of IMS technologies, relative to SDS technologies, than do non-exporting firms.

H3: There is no positive relationship between their exporting activity and AMT adoption.

Using SHAZAM[26] and Model (1), a significant positive relationship was found between AMT adoption ($NUMTECH_i$) and exporting activity ($XPRT_i$). Therefore, hypothesis 3 is rejected ($p < 0.001$). It also appears that a linear model of this relationship is appropriate and significant heteroscedasticity was not present.

H4: There is no positive relationship between firm size and AMT adoption.

Using SHAZAM[26] and Model (2), a significant positive relationship was found between AMT adoption ($NUMTECH_i$) and firm size ($EMPN_i$). Therefore, hypothesis 4 is rejected ($p < 0.001$). It appears that a linear model of this relationship is also appropriate and significant heteroscedasticity was not present.

H5: Firm size moderates the relationship between exporting activity and AMT adoption.

Using SHAZAM[26] and the fully specified model (Model (3)), both main effects and the interaction effect were tested for significance. Both main effects ($XPRT_i$ and $EMPN_i$) were found to be significant.

Using an hierarchical F test[26], the F statistic ($F_{1,103}$) was less than 0.01. Thus, the interaction effect ($XPRT_i$*$EMPN_i$) was not significant, and hypothesis 5 is rejected. Table IV shows these results, as well as the results associated with Hypotheses 3 and 4.

Thus, it appears that both firm size and exporting are positively and significantly related to AMT adoption. However, firm size does not appear to have a significant moderating effect on the relationship between a firm's exporting activity and AMT adoption.

Model	Partial correlation coefficient ($XPRT_i$)	Partial correlation coefficient ($EMPN_i$)	Partial correlation coefficient ($XPRT_i$*$EMPN_i$)	Mult. R	F stat
Model (1) (df = 105)	0.3789 ($p < 0.01$)	NA	NA	0.3789	17.605
Model (2) (df = 105)	NA	0.4253 ($p < 0.01$)	NA	0.4253	23.188
Model (3) (df = 103)	0.1633 ($p < 0.05$)	0.2550 ($p < 0.01$)	0.0257 ($p < 0.79$)	0.4758	10.046

Table IV. Results of partial correlation analysis for each model

Conclusions

To effectively compete in global markets, firms must be quick and flexible in their response to customer needs. Firms of all sizes find it necessary to compete in these markets in order to survive, and small manufacturing firms play a critical role in our global economy. With their customer orientation and flexible nature, small firms are the logical innovators to adopt the new technologies necessary to enter these markets. Understanding why and how these firms adopt agile manufacturing and time-based technologies can be critical to US competitiveness.

This study provides evidence that small manufacturing firms can respond to customer needs in global markets by exploiting AMT's agile manufacturing and time-based capabilities. Specifically, this study reports three major findings:

(1) When compared to non-exporting firms, small manufacturing firms who export place more emphasis on two factors as their reasons to adopt AMT: reduced product development time, and a need for product change flexibility. These two factors are intuitive and literature-based. These findings suggest that global competitive pressures drive the adoption of AMT, even for the smallest manufacturing firms.

(2) When comparing exporting and non-exporting firms, the ratio of IMS/SDS technologies for exporting firms is greater than the ratio for non-exporting firms. Thus, it appears that higher ratios of IMS to SDS technologies are associated with exporting. This finding suggests that exporting firms appear to more fully integrate and exploit the capabilities of the SDS (systems, devices, and stations) hardware through the use of IMS (integrative and managerial systems) technologies.

(3) Exporting is positively related to AMT adoption. The relationship is still present when firm size is taken into account. That is, firm size does not appear to moderate the relationship between exporting and AMT adoption. These results provide evidence that small manufacturing firms can compete in global markets through the adoption of AMT.

Although this research is exploratory in nature, the implications may be quite profound. For example, small manufacturing firms may indeed be adopting AMT in order to compete globally. Instead of being constrained by less resources, this study provides some evidence that smaller firms are not necessarily as constrained as once thought, and may be responding to global competition through AMT. Indeed, a possible link to this capability may be through the use of more IMS technologies, which integrate and exploit the use of SDS technologies. In the case of exporting firms, the increased ratio of IMS to SDS technologies exploits AMT's flexibility and time-based capabilities. These capabilities correspond with the factors that apparently differentiate global competitors from exclusively domestic competitors: reduced product development time and need for product change flexibility.

Advanced manufacturing technologies and small, technologically-oriented manufacturers combine to form an important link in America's return to competitiveness. Understanding why these firms adopt AMT is critical to this link and worthy of additional research in the future. While these results are encouraging for small manufacturing firms in particular, and small business in general, the findings should be confirmed and further explored.

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Appendix 1: Definitions

AID *Automated identification systems* – recognition systems which use barcodes, radio frequencies, optical chracters, or machine vision to sense and input data into computers.

AIN *Automated (in-process) inspection* – parts presentation and inspection are both performed automatically.

AMHD *Automated material handling devices* – systems capable of automatically loading, unloading, or storing unit loads; parts feeding and delivery devices.

CAD *Computer aided design* – any design activity that involves the effective use of the computer to create or document an engineering design.

CAM *Computer aided manufacturing* – the translation of design data into language which an automated assembly machine or an NC machine can utilize as input to produce a part.

CAPP *Computer aided process planning* – expert systems that capture the knowledge of a specific manufacturing environment along with generic manufacturing principles and apply this knowledge to create a plan for the physical manufacture of a part.

CNC *Computerized numerical control machine tools* – a numerical control system that uses a dedicated, stored computer program to perform some or all of the basic numerical control functions.

EDM *Engineering data management* – computerized data systems used within a company to organize, access, and control information related to its products including CAD data, bills of materials, engineering change data, approval status information, etc.

GT *Group technology* – a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design.

LAN *Local area networks* – a non-public communications system that permits various devices connected to the network to communicate with each other over distances of several feet to several miles. Computers, robots, programmable controllers, barcode scanners, vision systems, and the like are attached to the network.

NC *Numerical control machine tools* – a form of programmable automation in which the processing equipment is controlled by means of numbers, letters, or other symbols.

PLC *Programmable controllers* – a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instruction for implementing specific functions such as logic, sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machine processes.

PPIC *Production planning inventory management software* – a computerized production planning system whose function is master production scheduling, material requirements planning and capacity planning.

RBT *Industrial robots* – a reprogrammable multifunctional manipulator designed to move materials, parts, tools, or specific devices through variable programmed motions for the performance of a variety of tasks.

SFCS *Shop-floor control systems* – the use of computers for shop floor control including, order scheduling and material release dispatching and tracking.

SPC *Statistical process control* – mathematical techniques used to control manufacturing processes within specified limits to ensure that the process is conforming to the desired standards.

Appendix 2: Manufacturing survey form

1. **Please *circle* the abbreviation of any of the following technologies which you have already installed in your plant or have already placed on order for your plant.**

CAE	Computer aided engineering	CAPP	Computer aided process planning
SPC	Statistical process control	CAM	Computer aided manufacturing
PPIC	Production planning/inventory management software	LAN	Local area networks
		GT	Group technology
EDM	Engineering data management		

2. **Please enter, in the spaces provided, the number of each of the following programmable systems, devices, stations, etc. which you have already installed in your plant and the number you have placed on order for your plant. (If none please enter 0).**

AID	Automated identification stations	______ # Installed	______ # On order
AIN	Automated inspection station	______ # Installed	______ # On order
AMHD	Automated material handling devices	______ # Installed	______ # On order
CAD	Computer aided design workstations	______ # Installed	______ # On order
CNC	Computerized numerical control machine tools	______ # Installed	______ # On order
NC	Numerical control machine tools	______ # Installed	______ # On order
PLC	Programmable controllers (for production use only)	______ # Installed	______ # On order
RBT	Robots	______ # Installed	______ # On order
SPCS	Shop-floor control systems	______ # Installed	______ # On order

3. **Do you have plans in place to adopt or expand your use of any of the following technologies – other than those you already have in place or on order? Please circle the appropriate abbreviation(s).**

CAE SPC PPIC EDM CAPP CAM LAN GT AID AIN AHMD CAD CNC NC PLC RBT SFCS

4. **What per cent of your plant's 1990 sales revenue involved the manufacture and/or assembly of parts and/or products? (parts a through c should sum to 100%):**

a. as one-of-a-kind	______%	d. discretely on a line	______%
b. in batches	______%	e. as a continuous flow	______%
c. in cells	______%		

5. **What percent of your plant's 1990 sales revenue was from exports?** ______%

6. **Please check those factors listed below which most influenced your decisions to invest in the technologies listed in parts 1 and 2.**

______ Reduced product development time
______ Labor costs savings
______ Material costs savings
______ Need to remain competitive
______ Tax incentives and/or favourable financing
______ Customer requirements/pressure
______ Need for product change flexibility
______ Environmental, safety, or health concerns/regulations
______ Increased profitability
______ Other

7. **Please check those factors listed below which most impeded or prevented altogether your implementation or investment in the technologies listed in parts 1 and 2.**

______ Inadequate tax incentives
______ Insufficient in-house expertise
______ Lack of favorable financing
______ Insufficient cost justification
______ Other
______ Lack of technical support/ documentation from vendors
______ Equipment incompatible with existing plant layout/work flow
______ Management/labor resistance or union work rules
______ Lack of confidence in these technologies

8. **Please check in the space provided the appropriate range or, preferable, enter in that space the actual amount of your 1990 sales revenue from manufacturing and/or assembly.**

______ less than 2.5 million
______ 2.5 million to less than 10 million
______ 10 million to less than 20 million
______ 20 million to less than 50 million
______ 50 million to less than 100 million
______ 100 million or more

9. **Would you like the Center for Innovative Technology to provide you with further information about their manufacturing technology programs? (Please circle your response)** ___ **Yes** ___ **No**

Your name and position ______________________ **Phone (_____)** ________

Plant name and address ____

Would you like to receive a copy of the executive summary of this survey?

___ **Yes** ___ **No**