Small and medium-scale enterprises (SMEs) are the backbone of the industrialization process of many developed countries and play a crucial role in increasing a country's economy. To be able to survive and grow, SMEs must adopt strategic technologies and innovative management practices to survive. A study on the implementation of advanced manufacturing technologies (AMTs) in SMEs in Malaysia, however, showed that the companies were more concerned with short-term gains, rather than the strategic benefits offered by AMTs. The lack of an organic structure, the lack of understanding of technologies, the inadequate levels of skilled workers and engineers and the culture of the industries are factors that will hinder SMEs from achieving the strategic benefits of AMT and adopting innovative management practices.

Introduction

SMEs are the lifeblood of modern economies. The need for them to remain competitive and produce high quality outputs is important not only at a national employment level but also at industry level, where SMEs are often suppliers of goods and services to larger organizations.1

SMEs comprise about 92.6 per cent of the total manufacturing establishments in Malaysia.2 The Second Outline Perspective Plan3 and the Sixth Malaysian Plan4 clearly laid down the role of SMEs as the backbone of Malaysia's industrialization process.

Globalization, shortening product life cycles, increasingly sophisticated consumers, increasing labour costs and volatility in input prices has created an environment where manufacturers must be flexible, adaptive, responsive and innovative.5 Also, firms must compete simultaneously on a variety of competitive priorities in order to respond quickly to market opportunities and threats. Global markets require that manufacturers have multiple competencies.6

In finding ways to increase competitiveness and productivity, the use of an advanced manufacturing technology (AMT) is one alternative for a small firm to become or remain competitive. An AMT can provide it with the tools and techniques required to accommodate the increasing demands of its customers.7,8,9 It enhances a firm’s ability to simultaneously lower costs, increase quality, and provide rapid delivery of customized products, and therefore has become the cornerstone of many new manufacturing strategies.10
Studies\textsuperscript{11,12,13} have shown that AMTs can be implemented in small firms and that smaller firms have considerable advantages over large firms in AMT implementation. It has also been suggested\textsuperscript{14,15,16,17} that the utilization of AMTs by small manufacturers may improve their competitive position and financial performance. The role of small and medium-sized industries' enterprises (SMIs/SMEs) in supporting the activities of larger companies in Japan, Korea and Taiwan, which has successfully propelled these countries into industrialization, has made Malaysia realize, especially in the aftermath of its economic slowdown in the mid-1980's, that there is a need to promote the activities of supporting industries.

Implementing AMTs in SMIs

The implementation of AMT is a strategic decision. It calls for not only technological change, but to a great extent also operational and organizational changes, where human factors, skills and managing change play as important a role as the technology itself.\textsuperscript{16} In fact, the majority of benefits do not come from the technology itself but from the organizational and methodological changes that are required to be made to support it.\textsuperscript{19}

The implementation of AMTs must be supported by other ‘softer’ improvement programmes, such as quality leadership, training, worker empowerment, the use of small, cross functional groups in order to be successful,\textsuperscript{20} and improvements in infrastructure.\textsuperscript{21,27,18,19}

Zain\textsuperscript{28} suggests that if the introduction of AMT is not merely for economic benefits but also for strategic gains, then the adoption of AMT requires a systems approach. There is enough evidence to suggest a need to involve various business activities in order to achieve overall business effectiveness. Many applications of AMT have not yielded the potential benefits.\textsuperscript{29} Maximum benefits will accrue if there is a fit between the capabilities of the technologies and the firm’s business and manufacturing priorities.\textsuperscript{30}

It is essential for the SMIs in their quest for technology to realize that to be competitive, they have to resort to AMT and that the competitive benefits of AMT implementation can be fully acquired if there is alignment between the technology and organization. Competition is not based on the ability in increasing productivity only, but on increased quality, faster delivery to the markets, and the ability to greater customization, which requires increased flexibility in their operations. AMT can provide this flexibility.\textsuperscript{31}

Factors considered in the study

A review of the literature indicates that the main factors crucial to successful AMT implementation have been categorized into managerial capabilities (understanding technology, planning and innovativeness), organizational structure, level of skills and training and technological capabilities. These factors are regarded as strategic requirements for any company to achieve the full benefits of an AMT.
A questionnaire was designed based on these factors and distributed to more than 1,000 SMIs in Malaysia involved in electronics, electrical, metal-based, and furniture industries. These industries are the major players in the manufacturing sector. The mailing lists were obtained from the Small and Medium Scale Industries Development Corporation (SMIDEC), Federation of Malaysian Manufacturers (FMM) and the National Productivity Centre (NPC). The respondents were required to indicate the level of agreement with the statements using a 5-Likert scale, with 5 as substantial and 1 as nothing.

**Managerial capabilities**

The successful implementation of integrated technologies or AMT requires a manager to devise a strategy that incorporates the business dimension (overall strategic direction and competitive position of the company, which should be addressed first), the technological dimension (installation strategy for investment) and the organizational dimension (review and redesign of the organization at structural and managerial levels). Management plays an important role in evaluating the ability and capabilities of the organization in the context of the AMT chosen. For management to ensure that the implementation of the AMT will be successful, the technology to be used must be fully understood by suppliers and the customer; and the customer must reorganize the company's control system to meet the demands of the AMT and the attitudes of key company personnel.

A deep understanding of AMT involves a careful assessment of the innovation's potential, how it will serve the organization, the effect on the organization and workers, justification of the investment and other factors that will enable successful implementation. Failure of AMT implementation is often the result of inadequate detailed planning. Planning is essential to enable a careful assessment of the innovation's potential, the level of integration required, the functions affected and all the necessary changes required. The pre-planning for AMT implementation should include an understanding of the likely organization and people infrastructure needed to support the technology and the inputs that will contain options for managing a positive infrastructure. Technology, work organization and skill profiles must be well suited to each other and must be designed congruently. Meredith listed some of the implementation problems related to AMT - expensive, complex systems; insufficient internal skills, multiplicity of implementation paths; incremental skill building; and the need for a different support infrastructure.

In this study, the companies were asked to indicate the extent of planning that was carried out when a new technology was considered to be implemented. It was found that the pre-planning carried out in the companies surveyed was not adequate, as all the factors asked were ranked below 3 (less than reasonable). The highest rank factor is financial or cost justification which scored only 2.82, followed by new staff (2.76), the technology operating (2.72), changes in workers' role (2.63), in line with business goals (2.60), improve or solve current problem (2.57), changes in work organization (2.45) and infrastructure changes (2.42) as shown in Figure 1.
The results clearly indicate that the managers have not taken into account organizational adaptation that should go with the technology. These infrastructural aspects are especially important for the realization of flexible organizations and AMT success. A study of FMS installation by Ingersoll engineers found that 40 per cent of the benefits ascribed to FMS were achieved before implementation because of changes in management and reorganization of work. The support and genuine commitment of top management in facilitating major organizational changes that occur is crucial in AMT implementation. This commitment must be reflected in the commitment of resources to the effort, inclusion of managing technology as a component of manufacturing strategy of the firm and a willingness to change.

Another aspect of managers' willingness to change is the approach taken in implementing manufacturing changes. Companies that are marked by a tradition of top-down control, where supervisors are controllers rather than team leaders, may experience more conflict when introducing technological change. This has to be replaced by worker empowerment for quality improvement, supervisors as team leaders and decentralized decision making to accommodate world class manufacturing technologies. The factory of the future requires workers, who on the basis of their job experience play a constructive role in helping to shape technical and administrative innovations. Chang and Lee found that employee participation and bottom-up management were significant factors in improving quality and flexibility.

About 53 per cent of the companies surveyed indicate that a top-down approach is used for manufacturing improvement, with only 9 per cent using a bottom-up approach. Consulting workers for improvement changes is recorded at 36 per cent. The manager's lack of strategic view is indicated by the choice of factors that influence AMT implementation. The need to remain competitive (21 per cent) was followed by customers' requirement (18 per cent) and labour cost savings (17 per cent) as the main factors. Other factors such as reduced product development time, favourable tax incentives, product flexibility, increased profit and environmental safety and health were least influential.
AMTs may have marginal impact on direct labour costs, but they have a significant impact on overall efficiency, effectiveness, and ability to compete. Yet labour cost is one of the most frequent motives for the adoption of AMTs, according to most studies. Increased flexibility and responsiveness are the key benefits of AMTs, but these factors are not influential in decisions by Malaysian companies to adopt AMTs. This indicates that the companies are seeking tangible short-term benefits in AMTs, whereas the implementation of AMT should be strategic. However, it is true that most organizations that adopted AMTs experienced increased productivity (increased machine utilization, decreased WIP, reduced unit cost and shorter lead times) or obtained tangible benefits, but fewer appeared to have increased flexibility.

Workers and skill requirements

The composition of the work force, level of education and the kind of training can influence the implementation of AMT. The number of engineers in a firm has a positive influence on the diffusion of AMTs. Collins et al. found that the most automated firms were those with the most decentralized decision-making processes and the largest number of specialists. In Japan, where more than two thirds of CNC machines went to small and medium sized companies, more than 40 per cent of the work force is made up of college-educated engineers, and all had been trained in the use of CNC machines. A change in the composition of the workforce, where engineers now outnumber production workers three to one in Japan, signals a fundamental change in the environment of manufacturing which many firms may not be able to attain.

The survey found that the current ratio of engineers to production workers is one to ten and only about 10 per cent of the workers are engineers. The companies also indicated that the major problem faced in worker selection, training and recruitment was a lack of skilled workers, followed by competitive salaries and manpower shortage, high turnover rate and, last of all, high training costs.

The survey also indicated that the provisions/training have been less than reasonable to enable positive contribution to AMT implementation, except for work in teams. Work in teams was the highest rank at 3.4 for all industries. Running multiple machines, stopping production when a problem occurs, and communication of organizational goals all scored below three, with participation in idea generation and decision-making the least. Provisions for training should be provided to cater for the various requirements of AMT implementation. The training needs of operators, maintenance engineers, managers/supervisors and other supporting staff should be carried out well before the technology is implemented in an organization. Pre-training staff in the specifics of the technology and in the relevant management issues is an absolute necessity if benefits are to be realized early and maximized.

The use of AMTs increases the demand on workers in terms of decision making, and requires higher knowledge intensity at all levels.

The factory of the future requires workers to play a constructive role in helping to shape technical and administrative innovations thus, the training or provisions
provided must be relevant to their new roles. A higher level of provisions or training in these areas will increase flexibility and competitiveness of the firms, besides increasing worker commitment to and understanding of, the AMTs.

The lack of suitable skills at a number of levels will not only slow down the absolute rate of take-up of the technology, but also limit the range of applications that could be made because of a lack of trained manpower to support the development of sophisticated options in Malaysia.

Countries with higher basic skill levels, such as West Germany or the Scandinavian countries, were able to exploit much of the innate flexibility in AMT and achieve significantly higher productivity and other benefits. Skilled blue-collar workers already experienced with the functioning and operation of AMTs are a rare commodity. To acquire and retain such skilled workers constitutes a formidable challenge for small manufacturing firms. The quest for better qualified and skilled workers require firms to provide not only better wages and salaries but also better working conditions and environments to lure them to work in the firms.

Organizational structure

The organizational structure of a company indicates the role of the top management in the organization, the culture of the organization, the type of structure and the roles of workers in the organization. The use of cross-functional teams, worker involvement and participation, decentralized decision-making and an organic organizational structure are changes that need to be implemented for AMT to function effectively.

An attempt to evaluate the organizational structure of the company for their ‘fit’ with the technology was measured by their response to the type of structure that best described those practised in their companies. It was found that 37 per cent of companies have independent work teams, 21 per cent centralization of authority, and 14 per cent have owner-managers. The more ‘organic’ form of organizational structure suitable for AMT implementation such as cross-functional groups and “management by wandering around” were practised by fewer than 8 per cent of the companies, and only 11 per cent indicated that they had flat organizational structure.

For AMT to be implemented successfully, autonomous, independent work teams and a multi-skilled workforce are essential. Though 37 per cent of the companies indicate their structure as ‘independent work teams’ they do not have the ability to make decentralized decisions in areas related to their work, participate in decision-making or stop production when a problem occurs, as indicated previously. However, in SMIs, there is less formality and each worker’s role is not as clearly specified as in larger companies.

implementation. Decentralized decision making with a high level of inter-functional coordination\textsuperscript{57} can increase the potential for the flexible use of AMT. A positive relationship between the rate of successfully adopted (incremental) innovation and decentralization has been found.\textsuperscript{58} Centralization of authority is 'mechanistic' with formal bureaucratic, autocratic structures regarded as hindrance to obtain the flexibility benefits of AMT.

**Technological capabilities**

A list of 22 AMTs was listed for the companies to indicate AMT already implemented. About 23 per cent of the companies have not implemented any AMT, 29 per cent each are not in the process of, and not planning to, implement any AMT. Among the AMTs implemented, CAD is the highest (25.4 per cent) followed by PLC (25 per cent), CNC (24 per cent), MRP (23 per cent), NC (22 per cent), PPIC (21 per cent) and LAN (20 per cent), as illustrated in Figure 2. The rest of the AMTs had a percentage of less than twenty with the least AMT implemented are AHMD, EDM, CIM, AID and AIM at less than 5 per cent each. The technologies implemented can also be classified as 'stand-alone' or 'level one' AMTs against the 'level four' or 'fully integrated systems' signified by the least common technologies implemented. The 'stand-alone' machines have narrow goals relating to cost reduction and specific improvements in technical performance but the goals of a fully integrated system are more likely to be closely identified with broader strategic goals.

The study also found that the level of computers used in design activities, information processing and transferring information between functions is low. This further indicates the lack of hardware integration between functions and thus the full benefits of AMT cannot be realized.

That a number of technologies have been identified by the companies as not applicable\textsuperscript{59} is a cause of concern as this will decrease the rate of technology 'take-up' among the SMEs. To increase the speed of technology ‘take-up’, a deeper understanding of how these technologies can help the SMEs is required. Though currently there are at least 12 ministries and 40 government agencies involved in the development of SMEs in Malaysia, the companies surveyed showed that government agencies (1.89), universities (1.80), state agencies (1.60) played insignificant roles compared to seminars and trade conferences (2.89), internal expertise (2.64) and consultancy firms (2.31) in disseminating awareness of these technologies. Also, there is a lack of awareness on the various programmes offered by these agencies, which in turn leads to a lack of takers for these programmes.

**Conclusion**

In implementing AMTs, SMIs must take a strategic approach. An AMT is not a 'quick fix' to problems encountered. The extent of changes required, the commitment needed, the cultural and organizational changes and the level of AMT to be implemented must be aligned to ensure that the potential of the AMT is realized. The ability-to incorporate these requirements will ensure that the strategic benefits are achieved in the long term. There is a need for these companies to realize the importance of changing the culture to view supervisors as team leaders, not controllers, and to seek the views and increase the participation and contribution of
their workers in the decision making process. Decisions made by involving those that will be affected most by the changes increase commitment and reduce resistance. After all, as the introduction of new technologies change the nature and number of jobs at all levels, job losses may occur and create new responsibilities and activities. Companies which do not carry out adequate training of their staff (both technical and managerial) and do not restructure and change their production management systems will only achieve partial benefits from their AMT implementation. Studies have shown that, even without the AMT being implemented, these innovative changes in management and organization have resulted in improvements for the organizations.

![Figure 2: Percentage of companies (>20 per cent) implementing AMT](image)

There is also a need for the companies to have a coherent technology strategy to capture the full potential of systems integration, as small firms cannot afford to have radical innovations. The required changes in the work organization's structure and work arrangements have to be made to carefully and consciously manage the timing of adapting new technologies.

Also, the roles of government agencies and academic institutions in Malaysia have to be reassessed, as continuous support from them is required if the performance of SMEs is to improve. Government agencies can play the sponsors role in establishing cooperation between academic institutions and industries.

For AMT projects to be successful, Beatty stated that at least two of these criteria have to be fulfilled: development of an effective champion; planning for a high level of system integration; and use of organizational integration technique. In the SMEs surveyed, none of these criteria were found.
References


