BARRIERS TO ADVANCED MANUFACTURING TECHNOLOGIES IMPLEMENTATION IN THE SMALL AND MEDIUM SCALES INDUSTRIES OF A DEVELOPING COUNTRY

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ABSTRACT

The small and medium scale industries (SMIs) are the backbone of the industrialization process in developing and developed countries. They play a crucial role in increasing the country's economy. With globalization and free trade agreements, the SMIs are under increasing pressure to adopt advanced manufacturing technologies (AMTs) to be competitive or simply to survive. Even though studies have shown that AMT can be implemented in smaller firms and are more successful than bigger firms, the implementation of AMT requires the SMIs to adopt new ways of thinking and doing work. The successful implementation of AMT will require the companies to have a workforce with higher level of skills, a flexible organizational structure and inculcate a new culture in managing, training and planning of the manufacturing industries. A study was conducted using survey questionnaire to investigate the ability of the SMIs of Malaysia to implement AMT successfully. The results of the survey showed that the main factors preventing the SMIs from obtaining the strategic benefits of AMT are the lack of an organic structure and understanding of the technologies, planning, the level of skilled workers and engineers and the culture of the industries. To increase competitiveness and flexibility of the organizations, a flexible structure is required. There is a need for the SMIs to increase the number of engineers and training provided in the companies to enable a positive contribution to AMT implementation. The ability of the workers to run multiple machines, stopping production when problem occurs, communication of organizational goals, and participation in idea generation and decision- making are important in achieving the flexible benefits of AMT. The SMIs have to increase the educational and training needs of the workers and also have a higher understanding of the technology to realize its potential.

Key words: *AMT Implementation, SMIs, Developing Country, Organizational Structure*

INTRODUCTION

The small and medium scale industries play an important role in both developed and developing country economies. They are often the vehicles that facilitate the birth and expansion of large- scale industries. In the developed economies, they are seen as reflections of entrepreneural spirit, generators of employment and potential sources of increasing total savings in the economy. SMIs/SMEs are the lifeblood of modern economies. The need for them to remain competitive and produce high quality outputs are important not only at the national employment level but also at the industry level where SMEs are often suppliers of goods and services to larger organizations [1].

The Malaysian government has earmarked the SMIs to be the engine of growth for the economy as it moves from agriculture to a manufacturing-based economy. The development of the SMI sector into a global player is considered important in achieving the newly industrialized countries (NIC) status. Thus, the SMIs of Malaysia must play similar roles as the small and medium sized industries/ enterprises (SMIs/SMEs) of Japan, Korea and Taiwan in supporting the activities of larger companies and successfully propelling these countries into industrialization.

However, global competition stresses on the firm's ability to innovate, to capture global levels of manufacturing efficiency and to understand international marketing and the diversity of the world's market[2]. For the SMIs to survive in the face of global competition requires technology to assume an increasingly important role in all aspects of production as well as management. The globalization of markets, new computer and communication technology, growing inter-linkages of economies and increased interdependence amongst players are changing the conditions of competitiveness. The pattern of economic competition has changed. Traditionally, competition was static, and success or failure hinged on production factors. Modern competition is dynamic where new technology, new products, new markets, and new management concepts are constantly emerging.

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Dimensions of non-price challenge such as increasing demands for variety and customization of products and services, better and more customized design, more rapid new product introduction, high quality, fast and reliable delivery and an overall high level of responsiveness against price challenges are forcing firms to recognize that the current highly competitive environment demands that they find ways of resolving these apparent contradictions. A way of dealing with these increasing challenges is to employ advanced manufacturing technology [3],[4],[5]. Properly executed this improved capability results in greater customers satisfaction and lower manufacturing operating costs [6]. Godwin et al. [7] emphasized that these manufacturing technologies have the potential to improve production performance dramatically and create vital business opportunities for companies capable of successfully implementing and managing them. AMTs can also provide distinctive advantages in cost and process leadership. Although AMTs can help manufacturers compete under these circumstances they often impose organizational challenges.

For the small and medium scale industries (SMIs) of Malaysia, the implementation of AMT is necessary to face the challenges of globalization and to ensure their future survival. However, the implementation of AMT has long- term implications to the whole organization. Several studies have highlighted that there is a clear need for organization to change alongside the technology, and failure to effect this will likely result in inferior system performance [8],[9] . As the full potential of AMT can only be realized if it is properly executed and managed, a study was conducted to examine the barriers of successful implementation of AMT in the small and medium scale industries. Rosnah et al. [10] reported the level of AMT implemented in the SMIs are low and maybe due to the lack of understanding of the ways in which AMT can help them.

Barriers to successful implementation of AMT

Many applications of advanced manufacturing technologies (AMT) have not yielded their potential benefits frequently because the implementation has not been carried out in relation to strategic objectives [8],[11]. Maximum benefit will accrue if there is a fit between the capabilities of the technologies and the firm's business and manufacturing priorities [12]. According to Voss [9], many firms that implemented AMT achieved technical success (the technology is running) but not business (increased competitiveness, quality) success. Voss also identified that many important determinants of successful implementation are actions and conditions prior to investment and there are risks involved as many companies that have implemented AMT report failures and that perceived benefits of AMT have not been achieved. For SMIs adopting AMTs, must realized this critical organizational issue in their implementation process, otherwise they may not achieve the benefits promised by AMT.

Studies also found that the majority of benefits do not come from the technology of AMT but from non-AMT factors, (organizational changes, training, changed marketing and product strategy etc.) which are required to support it. Hence, these benefits cannot be separated to take into account individually for AMT and non-AMT factors. It is therefore, desirable to treat them together, considering the investment in both AMT and non-AMT factors [13]. Investing in one or several technologies should be associated with simultaneous investment in supportive mechanisms Flexibility arises not only from the equipment and software used, but also from changed working practices, skills disposition, interfunctional relationships, planning and control procedures, such as changed work organization and preventive maintenance policies [14]. If competitiveness and flexibility of the firms can be increased, then the full potential of AMT is realized.

The benefits obtained from AMT can be classified as tangible or intangible [7],[8],[15],[16]. The intangible benefits are the strategic benefits [15] that are harder to justify through traditional accounting methods. The strategic benefits of AMT are the benefits that will increase flexibility and competitiveness of the firms and can be achieved if proper planning for AMT is carried out. These are long-term benefits that should justify the implementation of AMT.

The strategic benefits or success of AMT implementation are achieved with a suitable organizational structure [17],[18],[19],[20] such as teamwork, flat organizational structure, cross-functional groups [21] decentralization and 'manager by wandering around'. Decentralized decision making with a high level of inter-functional coordination [22] 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 [23]. Having independent work teams with the ability to make decentralized decisions, at least in areas related to their work, participate in decision making and stop production when problem occurs are positive contributors to AMT implementation.

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The organizational structure reflects the organization's primary purpose. As the needs of organization change, the structure of organizations is modified to accommodate such changes. To implement AMT, the ability of the organization to accept and fully utilize the new technologies has to be examined by considering the appropriateness of the current structure and culture. The organization's ability to integrate new technology with existing technology and its ability to support new technology so that it is fully utilized and its full potential realized determines the speed of the implementation and the degree of integration [24]. A firm's resource base can constrains its technological choice, attractive new technologies cannot be adopted unless the firm has the skills and resource to implement new technology [22]. Also, a variety of environmental, structural, technological, individual, and task-related factors in a firm's operating environment can facilitate or inhibit adoption, implementation, and successful management of AMT [25].

The motivation for AMT investment decision in the SMIs should be for competitive advantage with flexibility as its essence. The SMIs should carefully assess why they are considering adopting AMT. Zammuto and O'Connor [19] are of the opinion that if firms are only interested in productivity gains, or if they want the flexibility benefits but estimate that the cultural and structural changes needed to enhance flexibility are unlikely, they are better off adopting fixed automation.

METHODOLOGY

The purpose of this study is to identify the possible barriers hindering the SMIs from achieving the strategic benefits offered by AMT. Though numerous factors have been identified as necessary to obtain the strategic benefits of AMT, the study focuses on the organizational structure and culture, the availability of the right workforce, planning and understanding of the technology and level of computer integration.

The study was conducted using a structured questionnaire where the factors have been identified through literature review. The questions used a Likert scale of 1 to 5, with one as nothing and five as substantial, indicating the extent each element is being practiced or available in the organization. A mean weighted average value is used to evaluate the responses. The lower mean average values indicate the greater the barrier to implementing AMT successfully.

The questionnaires were sent to more than 1000 small and medium scale industries, comprising of electronic and electrical, metal and furniture industries. The mailing lists of the industries were obtained from the National Productivity Center (NPC), Small and Medium Scale Industries Development Corporation (SMIDEC) and the Federation of Malaysian Manufacturers (FMM).

RESULTS AND DISCUSSION

A total of 1182 questionnaires were sent to manufacturers all over Malaysia. Out of these only 136 companies or 12% responded. Based on the response of these companies, the following analyses were carried out.

Changing the Organizational structure and culture

Studies have shown that the majority of AMT benefits do not come from the technology of AMT but from the organizational and methodological changes that are required to make to support it [13], [26], and by improvements in infrastructure [18],[21] [27], [28],[29],[30]. Companies that want to squeeze performance improvement from AMT need to adapt technology to new organizational forms and emerging managerial practices. There is evidence and agreement that successful changes in companies over the past few years were more organization-driven than technology-driven, though AMT often provided strategic support for organizational restructuring [31]. For the SMIs to achieve greater flexibility of AMT, changes in their organizational structure to incorporate more of the 'organic' structure should be considered

It was found that 37% of the companies indicate that they have independent work teams, and 21% centralization of authority, and 14% owner-manager. The more 'organic' form of organizational structure suitable for AMT implementation such as cross-functional groups and management by wandering around were practiced by less than 8% of the companies and only 11% indicate having flat organizational structure. The lack of an organic structure is detrimental to the success of AMT implementation. An organic structure allows employees to have

broader defined jobs, enhanced communication and decentralized decision making increase the potential for the flexible use of AMTs. Decentralization of authority in organic organizations increase the total pool of available ideas, keeps decisions close to the source of variation or need, improve the chance that compatible technologies will be proposed and adopted, and increases the acceptance and commitment to change. Organizations with low behavioral formalization maintain flexible organizational roles and work units [32].

The organizations must be structured for flexibility before AMT benefits of flexibility can be achieved. Though independent work teams were cited by most of the companies, they lack the autonomy ascribed to AMT as shown later in the limited roles played by the workers.

The different organizational structures vary in their capacity for change because of the patterns of social action that those structures encourage. A highly mechanistic structure where conditions and problem resolution occur at higher levels within an organization hierarchy can hinder AMT implementation. This is evidenced by the low response for the use of bottom-up approach in implementing manufacturing improvements in the organization surveyed. About 53% of the companies indicate that a top-down approach is used for manufacturing improvement, with only 9% using bottom-up approach. Consulting workers for improvement changes is recorded at 36%. The level of 'bottom-up' approach used in manufacturing improvement maybe detrimental for the success of technology implementation. 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 [33].

Level of Education, Training and workforce skills

AMT requires workers to be equipped with a variety of new skills at various levels. A variety of environmental, structural, technological, individual, and task related factors in a firm's operating environment could facilitate or inhibit adoption, implementation and successful management of AMT. The operating and technical people responsible for running, maintaining, and organizing the new technologies require new skills, attitudes, system procedures, and social structures. The use of AMTs increases the demand on workers in terms of decision-making [27], [28]. Higher knowledge intensity is required by workers in automation, even low level jobs will require more responsibility for results, more intellectual mastery and abstract skills and more carefully nurtured interdependence [27], contrary to the general belief that automation will lead to deskilling. Qualified skilled labor is an indispensable precondition of future factory structures to ensure sufficient flexibility, availability, and, thus, productivity of the complex installations [33]. The increase task complexity linked to integrated manufacturing requires employees to expand their scope of attention and process significantly more information. Their technical knowledge must extend well beyond their own functions to encompass aspects of adjacent and even distant stages of a production process [34]. These changes have placed additional burden on the skill demands of the entire workforce, not only at the shop floor level, but also at higher levels. But these changes are necessary as the competitive advantage of AMT hinges on the creation of a flexible, multi-skilled, knowledgeable workforce.

The SMIs must be able to recruit and maintain such a workforce. However, the survey on the Malaysian SMIs found that the current ratio of engineers to production workers is estimated at one to ten. Most of the engineers are degree or diploma holders. The number of skilled workforce is also low, mostly are certificate holders or obtained secondary level of education. The number of engineers in a firm and skilled workers has a positive influence on the diffusion of AMTs. Collins et al. [32] found that the most automated firms were those with the most decentralised decision-making processes and the largest number of specialists. In Japan, where more than two thirds of the CNC machines went to small and medium sized companies, more than 40% of the work force is made up of college-educated engineers, and all had been trained in the use of CNC machines. In the U.S. companies studied, only 8% of the workers are engineers, and less than 25% had been trained on CNC machines. Training to upgrade skill was three times longer in Japan than in the United States. The efficiency of labor is part of the reason that smaller companies in Japan have been able to use the FMS technology so effectively. The largest manpower reduction is in manufacturing overhead causing a change in the composition of the work force: engineers now outnumber production workers three to one. This signals a fundamental change in the environment of manufacturing [35] which many firms may not be able to conform to.

Flexible automation and CIM make intensive use of capital and require sophisticated engineering skills, adaptable and well-trained production workers, and communication and collaboration skills. These resources are relatively abundant in Japan with its high savings ratio, low cost of capital, highly educated workforce, cultural homogeneity, and emphasis on consensus and harmony. The availability of technical and engineering skills are scarce in Malaysia. Since the workers in the SMIs are less educated and literate, they are likely to be less

adaptable to new technology. The SMIs surveyed also indicated that the major problem faced in worker selection, training and recruitment was the lack of skilled workers. Thus, the implementation of AMT may not achieve its full potential in the Malaysian SMIs due to the workforce composition of low skilled and less educated workforce. A firm's capacity to assimilate technology depends on its capabilities [22].

The ability of the companies in providing, developing and changing the organization's culture in incorporating the workers new roles and skills required by AMT have been less than reasonable to enable positive contribution to AMT implementation. Based on a 5-Likert scale, with 5 as substantial and 1 nothing, some efforts have been made in the areas of teamwork (3.68), communication of organizational goals (3.20), training, initiative and motivation (3.11), able to do maintenance on their own (3.07) and workers are able to stop production when problem occurs (3.06). Little to reasonable efforts were made in the participation of workers in idea generation (2.98) and participation in decision- making (2.66). The training of workers in increasing their ability to run multiple machines is at 2.98. The training needs of the operators, maintenance engineers, managers/supervisors and other supporting staff should be carried out well before the technology is implemented in the 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 [36].

Though most companies cited their organizational structure as independent work teams previously, the findings here indicated that workers autonomy is very limited, and decision-making is centralized, thus, decreasing the potential for the flexible use of AMT. Empowerment has been identified as one of the initiatives that support the improvement in manufacturing strategy and the business strategy [37] and for the realization of a flexible organization [14].

The lack of suitable skills at a number of levels will not only slowed the absolute rate of take-up of technology, but also of limiting the range of applications which could be made because of a lack of trained manpower to support the development of sophisticated options. Countries with higher basic skill level 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 [8]. The efficient use of new technologies requires skills and abilities of the workforce, especially in an increasingly interconnected application, which by far exceed the traditional workers' virtues in conventional in-plant training such as careful handling of means of production, sense of order, of punctuality and diligence. Workers should acquire competence in technical, managerial, social skills and flexibility and willingness to learn [33].

The skill demand of AMT is a formidable challenge for the small manufacturing firms to acquire and retain. The strongest determinants of the level of AMT adoption are by far the technical skills of blue-collar workers followed by the influence of customers and vendors. White collar workers who are experienced with computer-based information technology may have little knowledge of manufacturing technologies, integration of information and production technology is not yet a reality in smaller firms. Skilled blue-collar workers already experienced with the functioning and operation of AMTs is a rare commodity. SMEs/SMIs must invest heavily in on-the-job learning whereby blue-collar workers acquire skills and capabilities with technology through ongoing exposure to and use of the more sophisticated machinery. This may not translate into longer term benefits for smaller firms, since a significant percentage of these skilled blue-collar workers prefer to leave for the better paying jobs and improved conditions offered by larger firms [38].

Planning and understanding the requirements of technology

A deep understanding of the technology is required for appropriate planning to be carried out. The reasons why the AMT is being considered should be clear. The capability of the new technology must match the firm's competitive strategies and the need of its customers. The technology must match a firm's operating procedures and the skills of its personnel. The information of the relevant technology, which is to be implemented, must be adequate to facilitate the preparations of installation. Though they are aware of the potentials benefits of the AMT, firms lack an understanding of the specific ways in which the technology can help the businesses. The lack of awareness of particular needs to which the technology might be applied and the lack of understanding of the specific ways in which the technology could benefit their business have been identified in a number of studies and represented a major barrier to widespread take up of AMT amongst smaller firms in particular [8].

Not much effort has been put by the companies surveyed in the areas of planning and understanding the demands of the new technology on the organization. The items ranked were financial cost justification (2.84),

new staff required and training needs to operate the technology (2.70), and the technology operating and business objectives identified (2.64). The need to redefined workers role and responsibilities (2.45), infrastructure changes (2.36), changes in work organization (2.36), whether it is in line with business goals (2.27) and improve or solve current problems (2.05) have not been investigated or studied vigorously for AMT considerations. The emphasis on cost or financial justification of AMT implementation is an indication that AMT investments are treated like any other capital investments, justifying based on tangible benefits rather the intangibles. The lack of planning in the SMIs clearly indicates that the AMT implemented is not for strategic gains but for short-term benefits. Thus, the full potential of AMT will not be realized.

Planning is essential for AMT [9],[15],[17],[39] to enable a careful assessment of the innovations potential, the level of integration required, the functions affected and all the necessary changes required. Careful planning helped to facilitate top management support. Planning for the long term on how the new technology will integrate into the system and for the short term on how the project of implementation will be managed is required. Thus, for wide ranging investment in AMT to be successful, a carefully defined plan is required which includes financial and non-financial, long and short-term performance indicators. . Changes to work organization should not occur by default through AMT but by careful planning. Planned organizational changes will minimize the risks of failure, reduces workers resistance, and that the planning for changes have been carefully thought off. The purpose of planned change is to improve the ability of the organization to adapt to changes in its environment and to change employee behavior [40].

CONCLUSION

AMT can provide the SMIs with the tools and techniques to meet the customers changing needs, increase flexibility and competitiveness. However, the SMIs must meet the demands of AMT in providing a more 'organic' structure, develop the skills of the workforce and carry out detailed planning so as to derive the full potential of AMT. Under the existing conditions in the SMIs, AMT will not work, thus, organization-driven changes should be initiated. It is less likely that these changes can be made without AMT. AMT will provide the impetus for the improvement benefits through a better-managed plant. Since investments in AMTs are high, the SMIs must plan to gain the strategic benefits of the technology. If the AMTs were purchased to solve only certain problems, then the investments will fail to contribute significant improvements to the organization.

Thus, the SMIs should assess why they are considering adopting AMT. If they are only interested in productivity gains, or if they want the flexibility benefits but estimate that the cultural and structural changes needed to enhance flexibility are unlikely, they are better off adopting fixed automation [19]. Companies that are applying advanced technologies to improve their competitive position must learn to embrace change [41]. The very structure and organization of the support net is affected by the implementation of high technology. It will change the nature of tasks and their performance, interconnections and nature of physical, energy and information flows, the skills required, the roles played, the styles of management and coordination, even the organizational structure. Managers cannot incrementally buy AMTs, than follow up at a later date with investments in training, leadership, and empowerment. These investments must be made in concurrent, not an evolutionary manner [42].

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