A Framework of Justification Criteria for Advanced Manufacturing Technology Implementation in Small and Medium Enterprises

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Abstract

Today in order to stay in businesses and prosper, Small and Medium Enterprises (SMEs) are seeking higher electiveness and competitiveness across the entire cycle of marketing, product design, manufacture, test and sales. SMEs play an increasingly important role in all aspects of competitiveness: both products and production techniques, but also management methods, the organization of the firm and human resources training. One of the ways by which SMEs can achieve a competitive advantage in manufacturing is through the implementation of Advanced Manufacturing Technology (AMT). An increasing number of them have chosen and are choosing various levels of AMT as the solution. Realizing the importance of SMEs, an attempt has been made in this paper to review the application of AMT in SMEs. Also, a framework has been offered for the implementation of AMT in SMEs. Finally, a summary of findings and conclusions are presented.

Keywords: SMEs, AMT, Implementation.

1. Introduction

A unique definition of small and medium sized enterprises (SMEs) is not possible, the concept varies from country to country and from sector to sector. However, in terms of the community's structural funds and leading instruments, it has always been accepted that the SME should not have a workforce exceeding 500, net fixed assets exceeding not more than a third of its capital held by a large firm (Chatwin *et al.*, 1996). In particular, it has been recognized for some 20 years that their dynamism, related in part to the technological and economic changes which have occurred over this period, has made an important contribution to the creation of new jobs, the economic revival of certain regions and also to the technological progress. It cannot, however, be taken for granted that, this dynamism will be maintained in the future in view of trends such as the globalization of markets and technology, the intensification of competition and the acceleration of technological development and change. These factors explain the interest shown by the governments of all countries in the competitiveness of their SMEs which, along and inter-related with that of large firms, constitutes the basis of national competitiveness.

SMEs can gain competitiveness in their products through the implementation of AMT. It is always easy to report, reads and tour successful AMT installations, but it is a rather different task when one's own organization must be converted to this new technology (Gunasekaran *et al.*, 1999). Clearly management education is vital at the appropriate level and at the appropriate time. Haven done all the important learning and preparation work for AMT the next step is to form a team that can create a AMT proposal and a plan that can manage the implementation, measure the results and move the company to the next AMT project.

In SMEs, shop floor tasks which are closely related to production have mostly involved a high degree of human decision making and execution. For example, the operator decides the composition of lots; he transports the raw materials and tools. The foreman decides the order sequence and the machine loading. The positive allowance for decisions of the employee in this form of staff oriented organization is large. With relatively little effort a structure of action can be assigned to the staff which is in good correlation to its qualification. This flexibility can be maintained after the implementation of computer-aided disposition and control devices if the criteria for software design are adapted to these needs and an economically acceptable solution is found. The characteristics of AMT and SMEs are shown in Table 1.

Table 1: Characteristics of SMEs and AMT

Criteria	SMEs	AMT	References
Strategic	High degree of human decision making and execution, ability of customer satisfaction, reduced lead time, improved quality of products, large portion of market share.	Reduce manpower costs, increase capacity, ability of customer service strategy and demand forecasting, reduce product development time, higher product quality, analysing markets and generating forecasts.	King and Ramamurthy, 1992, Sambasiario and Deshmukh, 1994.
Tactical	Efficient and informal internal communication networks, afford a fast response to internal problem solving, ability of project control and technological forecasting, quality control co-ordination.	Greater production control and faster internal communication responsiveness, ability of stand-alone systems for design and engineering technologies, ability of intermediate systems for automated material handling and inspection, higher quality control co-ordination.	Mansfield et al., 1977, Raymound et al. 1996, Udo and Ehie, 1996, Carriere et al., 1998.
Operational	Delivery schedule performance, increase productivity; inventory maintainability; flexibility and quality control.	Ability of customer service, ability to increase productivity within limited resources and improve quality of the product, raw material analysis and control, safety preventive and environmental monitoring, higher quality control ability.	Mather and Garner, 1989, Young and Vesterager, 1990, Marri et al., 1998.
Organizational	Customizability / adaptability to changing conditions, increase internal communication, improve co-ordination between departments.	Real time information across the organization, sharing of information with customers and suppliers, extensive user training, improve decision-making process, improve working capital control.	Nicholas and Lan, 1997, Small and Yasin, 1997, Stefanou, 2002, Spathis, 2006.

Progress in human society has been accomplished by the creation of new technology. The last few years have witnessed unparalleled changes throughout the world. Rapid changes in the markets, demand drastically shortened product life-cycles and high quality products at competitive prices. Customers now prefer a large variety of products. This phenomenon has inspired manufacturing SMEs to look for progressive computerised automation in various processes. Thus mass production is being replaced by low-volume, high-variety production. SMEs have recognised the importance of flexibility in the manufacturing system to meet the challenges posed by the pluralistic market. The literature identifies a variety of strategic, tactical, operational and organizational factors that induce AMT adoption in SMEs such as: reduced product development time, labour costs savings, material costs savings, a need to remain competitive, a need for product change flexibility, environmental, safety or health concerns, increased profitability or plant performance, and customer requirements (Raymound et al., 1996). These factors have strategic impacts on the performance of SMEs and affect virtually every major aspect of the operating environment of SMEs. The justification criteria for the implementation of AMT in SMEs are presented in Table 2.

Table: 2 Benefits for the implementation of AMT in SMEs.

Benefits	Description	References
Increased productivity	Greater output per hour of labour input, higher production rates.	Scheer, 1994, Mechling et al., 1995, Sohal, 1996.
High cost of labour	Increasing labour cost causes higher investment in automated equipment economically justifiable to replace manual operations, machines can produce at higher rates of output, automation results in a lower cost permit unit of product.	Raymound et al., 1996, Attaran, 1997.
Trend of labour towards the service sector	Certainly automation of production jobs has caused some of this shift, there are also social and institutional forces that are responsible for the trend, government employment has consumed a certain share of the labour market, there has been a tendency for people to view factory work as tedious, demeaning and dirty.	Ramamurthy, 1995, Kaiser, 2002.
Safety	Transferring the operator from an active participation to a supervisory role work is made safer, it has also provided an impetus for automation.	Gunasekaran and Thevarajah, 1999, Marri et al., 2003.
High cost of raw materials	The high cost of raw materials in manufacturing results in the need for greater efficiency in using these materials, the reduction of scrap is one of the benefits of automations.	Weatherall, 1992, Morris and Morris, 1994.
Improved product quality	Automated operations not only produce parts at faster rates than do their manual counterparts, but they produce parts with greater consistency and conformity to quality specifications.	Sule, 1994, Gunasekaran, 1997, Marri et al., 2000.
Reduced manufacturing lead time	Automation allows the manufacturer to reduce the time between customer order and product delivery, this gives the manufacturer a competitive advantage in promoting good customer service.	Dyson et al., 1997, Marri et al., 2000.
Reduction of in-process inventory	In-process inventory is of no value, it serves none of the purpose of raw materials stock for finished product inventory, automation tends to accomplish this goal by reducing the time a work part spends in the factory.	Rothwell and Dodgson, 1992, Marri et al., 2000.
High cost of not automating	A significant competitive advantage is gained by automating a manufacturing plant, the benefits of automation often show up in intangible and unexpected ways, such as improved quality, higher sales, better labour relations, and better company image, the companies that do not automate are likely to find themselves at a competitive disadvantage with their customers, employees, and the general public.	Morris and Morris, 1994, Chapelete, 1996.
Management/staff resource	Integrating computerized production planning and control into work practices, devising management time, approving and amending IT and manufacturing strategies.	Harris, 1996, Irani and Love, 2001.
Employee motivation	Being trained to manipulate vendor software and training others, interest in computerized production planning and control increases as time passes, pay increases based on improved employee flexibility.	Irani and Love, 2001, Marri and Sohag, 2004.
Market growth	Improved market growth and success, leader in new technology, improved market share, market leadership, enhanced competitive advantage	Marri et al., 2000, Irani and Love, 2001
Improved shop floor operations	Improved flexibility, response to changes, teamwork, increased plant efficiency, capacity planning, improves data management, manufacturing control and accuracy of decisions.	Marri et al., 2000, Irani and Love, 2001

To stay in the market place it is necessary for SMEs to go for automation in general and implement AMTs in particular for various reasons such as: automated operations not only produce parts at faster rates than do their manual counterparts, but they produce parts with greater consistency and conformity to quality specifications. Also, automation allows the manufacturers to reduce the time between customer order and product delivery. This gives the manufacturer a competitive advantage in promoting good customer service. The past experience of SMEs in adopting AMTs and other automated manufacturing systems is presented in the next section.

An attempt has been made in this paper to study the implementation of AMT in SMEs. The Section 2 of the paper presents the experience of SMEs with automation. Framework for the implementation of AMT in SMEs is offered in Section 3. Finally, the summary of findings and conclusions are presented in Section 4.

2. Experiences of SMEs with Automation

During the mid-1970s onwards many European governments began increasingly to support SMEs. This was based on a growing belief in SME's inherently superior innovatory potential, on their employment creating potential, and on their potential as an endogenous vehicle for regional economic renewal. By the early 1980s many instruments were in place to support innovation by SMEs (Rothwell and Dodgson, 1992).

A survey conducted by Morris and Morris (1994) indicates that almost 87% of the SMEs in the United States are actively engaged in AMT or had plans to do so. Many of the SMEs that are currently using AMT have reported a number of improvements in their performance. Much of the research literature on AMT and FMS systems suggests that SMEs implementing these systems have often gained considerable increase in productivity, reductions in lead time and unit cost, as well as better machine utilization (Goldhar and Lei, 1994). Some of the problems associated with implementing AMT systems resulted from the inherent complexity of automating production process throughout the system. Dean and Susman (1989) note that the software-intensity of AMTs demands more complex and frequent maintenance skills than earlier traditional manufacturing technologies. King and Ramamurthy (1992) point out that many SMEs do not achieve their objectives from AMT investments largely because the analytical methods used to justify these projects often do not capture the richness and underlying flexibility of the new technologies.

The importance of creating a suitable internal organizational structure to implement AMT and FMS in SMEs becomes apparent when one considers the inherent skill and data demand of the system. Although AMT greatly reduces the knowledge work and FMS greatly reduces the amount of physical work needed to manage and operate production processes, the skills and knowledge required for implementing AMT in SMEs on a continuous basis are likely to become more sophisticated over time (Young and Vesterager, 1990). In effect, physical work becomes integrated with knowledge work that increasingly depends upon learning, experimentation and cross-unit co-ordination to share cumulative experiences and insights from analysing and utilizing the data available in a AMT system. AMT systems embody a 'double-edged sword' in that the increased complexity and interdependence entailed to support these investments often demand even greater changes in the SMEs organization design (Zammuto and O'Connor, 1992). AMT's speed and flexibility is derived from integration not only across production processes within a business unit or department, but also among functions, such as design, manufacturing and marketing, and between vendors and their customers (Pierre and Raymond, 2004).

A fundamental hindrance to successfully implementing AMT technologies in many of the SMEs in the US is the lack of commensurate effort to redesign and rework organizational structures and processes to accommodate the vastly improved, data-driven manufacturing processes. Udo and Ehie, (1996) note that the current use of vertically-oriented reporting structures makes it difficult to create the requisite

mechanisms to share information and skills across departmental and divisional lines. Zammuto and O'Connor (1992) argue that control-oriented versus flexibility-oriented values greatly influence the smoothness with which SMEs can implement AMT and FMS technologies. Control-oriented values and structures are though to better support productivity gains within a given product range, while flexibility-oriented values may provide a superior fit to enhancing rapid changes in product variety using the same AMT system.

The needs of customers are now highly specific and continually changing, although they still want to have high-quality and low-cost products. SMEs must respond rapidly to the demands of customers and improve their productivity. They must also provide a suitable product variety in order to survive and be competitive in the market. They attempt to find strong and flexible solutions to this problem. One of the keys for improving productivity and responsiveness of the SMEs is through the implementation of AMTs The automatic generation or preparation of effective and optimal process plans within a short period of time is vitally important in manufacturing, since SMEs have recently become a central part of the manufacturing industry of developing countries (Dereli and Baykasoglu, 2005). The use of new technology and CNC machine tools has dramatically increased in developing countries, while complete CAD/CAM integration through AMTs is still not seen as realizable.

3. A framework for the implementation of AMT in SMEs

Implementing a new technology is a greater burden for SMEs than it is for large companies, which have better resources through a large number of employees and a broader basis of know-how. A framework for the implementation of AMT in SMEs is shown in Figure 1. The issues of implementation of AMT in SMEs are discussed under four perspectives. These includes: Strategic, Tactical, Operational, and the Organizational perspectives. The detail of the proposed model is presented hereunder:

3.1 Strategic Perspectives

Top managers are responsible for making the vital decisions that set the company's overall goals and keep all parts of the company pulling together towards these goals. Decisions that have a long-range impact on the general direction and basic character of a company are called strategic decisions. Through strategic planning, managers evaluate the company's relationship with its external environment and establish the basic directions for the company. Each business unit or a single business company has a business strategy that guides business practices and directs how it will deal with its customers, competitors, and conditions. Major questions that should be addressed at this level are who are our customers? and what are their needs, desires and expectations of the business? As stated by Barady and Gienz (2001) the main barriers to competitive advantages for SMEs are inadequate technologies, as well as inadequate in-house human expertise and poor financial resources. Managerial teams in SMEs are usually heavily involved with the short-term operational problems of their business, which leaves them almost no leisure to utilize their driving energy for strategic improvements. There are certain fundamental strategies that can be employed to improve productivity in manufacturing operations. Since these strategies are often implemented generally by means of automation and particularly by AMT technology. The strategic issues regarding the implementation of AMT in SMEs are: (a) **Business:** Flexibility in meeting customer demand and competitive advantages, technological, economic and demand forecast; (b) **Product:** Easier to fabricate and test prototype, unique, the only one available, better product design, less material handling, shorter assembly time; (c) **Process:** Different structural and managerial practices such as: batch, mass, and continuous process, specifying the sequence of production steps, describing the state of work piece.

The implementation of AMT requires a clear, precise corporate strategy, the success of which will depend upon careful planning of several logical steps namely: prime the corporate culture for change, clearly define expectation, appoint a champion for AMT design and implementation, establish a project team, perform a comprehensive environmental analysis, identify the technology which the

strategy requires, formalise operating policies, establish working partnership with supplier and vendor, and track and report progress.

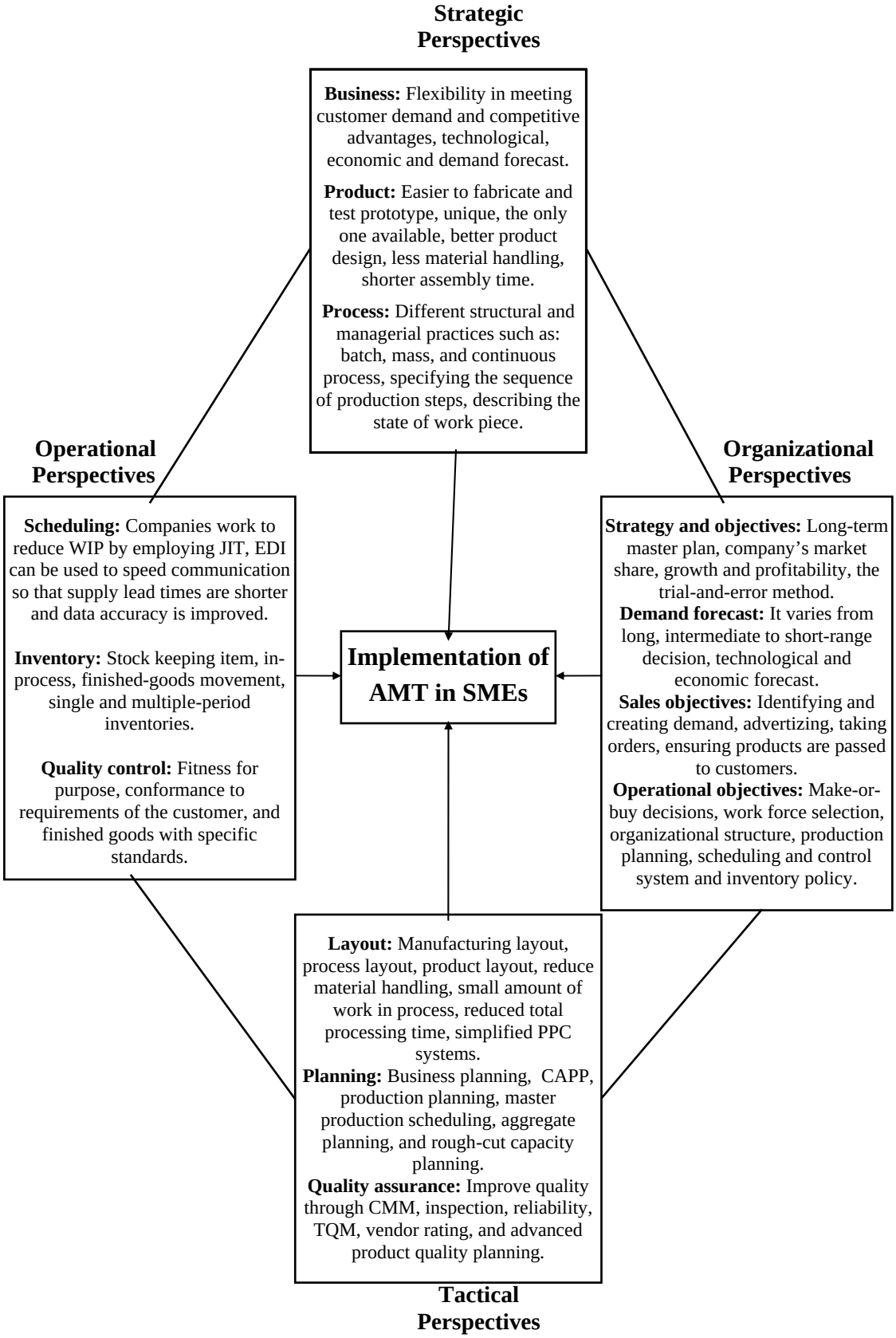

Figure 1: Framework of criteria for the implementation of AMT in SMEs

3.2 Tactical Perspectives

Since managers make decisions about the tasks that other people are to perform, they must understand two major aspects of an organization: they need a basic understanding of the technology with which the production system works, and they need adequate knowledge of the work they are to manage. Technical competence can be obtained through training and experience or through the use of staff specialists and consultants. Today's highly technical processes and the trend toward conglomerates have brought with them an increase in the use of staff organizations specialization in various aspects of operations. AMT is a concept of linking and co-ordinating a broad array of activities in a manufacturing business through an integrated computer system. Its purpose is to enable the SMEs to transform product ideas to high-quality products in minimum time and at minimum cost. AMT goes beyond the scope of FMS or an integrated CAD/CAM system. The concept is to integrate information from the core manufacturing activities and possibly to include information from marketing, order entry, maintenance, accounting, and shipping as well. The core manufacturing activities fall into two major groups: (1) engineering support, which may include CAE, CAD, group technology coding, CAPP, and manufacturing engineering; and (2) operations management, which may include subsystems for master scheduling, capacity planning, material requirements planning, inventory control, purchasing, direct numerical control, shop-floor control, quality reporting, shipping, and distribution. Some of the tactical perspectives regarding the implementation of AMT in SMEs are: (a) **Layout:** manufacturing layout, process layout, product layout, reduce material handling, small amount of work in process, reduced total processing time, simplified PPC systems; (b) **Planning:** business planning, CAPP, production planning, master production scheduling, aggregate planning, and rough-cut capacity planning; (c) **Quality assurance:** Improve quality through CMM, inspection, reliability, TQM, vendor rating, and advanced product quality planning.

3.3 Operational Perspectives

In a company's organization chart, an operation often enjoys parity with the other major business functions: marketing, sales, product engineering, finance, control (accounting) and human resources (personnel, labour relation). Sometimes, the operations function is organized as a single entity which stretches out across the entire company, but more often it is embedded in the distinct, typically product defined divisions into which most major companies are organized. In a manufacturing company, line management frequently extends to the stockroom, material handling, the tool room, maintenance, the warehouses, and distribution, as well as the so-called "factory floor". Support services for line management's operations can be numerous. Within a manufacturing environment, support services carry titles such as quality control, production planning and scheduling, purchasing, inventory control, production control, industrial engineering, manufacturing engineering, and field service. Some of the operational perspectives regarding the implementation of AMT in SMEs are: (a) **Scheduling:** companies work to reduce WIP by employing JIT, EDI can be used to speed communication so that supply lead times are shorter and data accuracy is improved; (b) **Inventory:** stock keeping item, in-process, finished-goods movement, single and multiple-period inventories; (c) **Quality control:** fitness for purpose, conformance to requirements of the customer, and finished goods with specific standards.

The implementation of technical and organizational novelties in SMEs is considerably different from their implementation in large ones for the following reasons:

- Working methods, software, and production techniques must be newly conceived for the specific needs of small companies if they are to be economically applied.
- The dimensions of resources, structure, and organization of the process are smaller.
- Financial resources are limited and/or expenditure is more tightly restricted.

- Because of the smaller number of employees there is not much positive allowance for the development of staff to the new technology in the company.

These difficulties have great impact, especially on optimizing the flow of materials and production control in SMEs, because of the large step from theoretical solution to practical realization. The use of computers to optimize these tasks is state-of-the-art in large enterprises (Chapelet, 1996). In SMEs, suitable developments have been realized only partially. In SMEs, shop floor tasks which are closely related to production have mostly involved a high degree of human decision making and execution. For example, the operator decides the composition of lots; he transports the raw materials and tools. The foreman decides the order sequence and the machine loading. The positive allowance for decisions of the employee in this form of staff oriented organization is large. With relatively little effort a structure of action can be assigned to the staff which is in good correlation to its qualification. This flexibility can be maintained after the implementation of computer-aided disposition and control devices if the criteria for software design are adapted to these needs and an economically acceptable solution is found. To the extent that global and domestic environments differ, we expect that global and domestic SMEs have different objectives for adopting AMT as a means to effectively compete in their respective markets. Whatever the objectives may be, the adoption of any new technology involves uncertainty about achieving the objectives.

3.4 Organizational Perspectives

The conceptualization of the AMT implementation process in SMEs, however, is not an easy task. Process oriented studies have generally claimed that the effective implementation of AMT in SMEs requires a higher degree of organizational integration (Nicholas and Lan, 1997). This integration may be necessary to address a number of issues concurrently which may include: (a) installing and testing the technical system; (b) local workplace design; (c) training and support; (d) organizational change; (e) acceptance of change; and (f) maintaining the volume and integrity of existing activities in ongoing concerns throughout the process of change during the implementation of AMT in SMEs (Small and Yasin, 1997). SMEs should, as far as possible, train its existing staff to take on the new jobs created by the introduction of AMT. This will make the whole project more acceptable to the trade unions but, in addition, staff who have worked for some years in a company know its products and methods which is highly valuable. Some of the organizational perspectives regarding implementation of AMT in SMEs are: (a) **Strategy and objectives:** long-term master plan, company's market share, growth and profitability, the trial-and-error method; (b) **Demand forecast:** it varies from long, intermediate to short-range decision, technological and economic forecast; (c) **Sales objectives:** identifying and creating demand, advertizing, taking orders, ensuring products are passed to customers; (d) **Operational objectives:** make-or-buy decisions, work force selection, organizational structure, production planning, scheduling and control system and inventory policy.

A framework for the implementation of AMT in SMEs is characterized by the following five managerial action modes which cover the various stages of the AMT implementation process.

- ❖ Examine and investigate the strategic and operational needs for adopting AMT. This requires an ongoing investigation of the performance of existing systems in relation to the SMEs ability to remain competitive in the external business environment.
- ❖ SMEs need to ensure that their strategic focus is indeed in tune with their requirements to succeed in the evolving business environment. Organizational goals and performance benchmarks that reflect this strategic focus should be developed. Additionally, SMEs should consider a wide variety of technological and procedural innovations that can assist in meeting their objectives.
- ❖ Modify organizational infrastructure and processes in preparation for the adoption of the AMT, such as: ability to change production lot sizes, variety of part-types produced, average number of tasks per worker, operator output rates, revenues from manufacturing operations, delivery lead-times, overhead costs, product quality, inventory, turnover rates, production changeover times,

time needed for a major design change in an existing product, and time-to-market for a new product.

- The appropriateness of AMT systems should be based on their ability to meet SMEs goals in a cost-effective manner with due consideration being given to required infrastructural changes. This is achieved through a systematic investment justification process.
- Track the operational and strategic efficiency and effectiveness of the implemented AMT systems. This tracking should be performed at two levels. First, the system should be evaluated on its ability to meet the organizational goals that it was implemented to provide cost-effectively. Second, an assessment of the ability of the system to meet revised organizational goals owing to unexpected changes in the external business environment is required.

4. Summary of Findings and Conclusions

An attempt has been made in this paper to present a conceptual model for the implementation of AMT in SMEs. The experiences of SMEs with AMT along with the framework for the implementation of AMT in SMEs are described. Also, the reasons for automation and automation strategies of AMT are widely explained.

There is some reason to believe that the adoption of new efficient manufacturing techniques may be problematic in SMEs. It has been claimed that SMEs frequently lack expertise, time, money, and support to upgrade their current manufacturing operations, introduce new technologies and methods, implement better quality control, and improve work force training. While AMT technologies have the potential to provide significant productivity and quality improvements, they also require relatively steep capital investment, including significant start-up and learning costs. Further, these technologies may require modification and adoption before they can be utilized productively.

The following are some of the findings and recommendations for the implementation of AMT in SMEs:

- The SMEs fall short of achieving those benefits that were perceived as being important in AMT implementation. The reasons for the lack of success includes: technology mania, lack of top management's continued support, poor commitment to shopfloor employees and inadequate managerial training for AMT projects. Further research is required for the success of AMT implementation in SMEs when it becomes a reality that the set of goals and objectives stipulated by the adoption strategy are fully realized.
- The human factors should be given due consideration while designing AMT and there is a need to establish the level of skill and training required in order to implement AMT in SMEs.
- The reasons for the implementation of AMT in SMEs failure are due to the lack of developing an effective support systems, lack of planning for a higher level of system integration, lack of experience with modern technologies and inadequate understanding of new technologies. It is suggested that further research is needed for total system integration rather than stand-alone technologies should be the key requirement for the implementation of AMT in SMEs.
- Large companies often start the introduction of computer-aided technologies with a pilot application in a small department or one operating company. In this way large companies can reduce the consequences of any failures and can use the pilot application as a learning experience, applying any lessons learnt in subsequent applications. Most SMEs are not in a position to adopt this research because of their small size, but increasing modularity and low-cost solutions will make this a more feasible approach in the future.
- Overall, the exploratory action has found lack of awareness of the concept of joint technology and organizational design and its benefits in terms of improved design and implementation processes, better system designs, more appropriate organizational structures and motivated and engaged employees at all levels in the company. Much work clearly needs to be undertaken in the area, both in terms of increasing awareness and developing easy to use supporting methods and tools to

help minimize the risks associated with the implementation of computer-aided technologies in SMEs.

- For the successful implementation of AMT in SMEs, the employees must have a clear understanding of its principles, capabilities, goals and objectives. The literacy factors pertain to those educational efforts which make the employees become more familiar for the implementation of AMT in SMEs and their goals and objectives. This understanding will make it possible for the expectations of AMT in SMEs to be communicated appropriately to all the employees.
- Suitable configuration for AMT in SMEs should be decided before the implementation process which generally centres around the identification of tasks to computerize, the selection of feasible software packages, and improving software compatibility. In order to include flexibility in AMT, manual policies, procedures, and practices should be established.
- A framework for integrating productivity improvement strategy with AMT strategy and the ground work required to facilitate the process of easy implementation of AMT in SMEs such as Just-in time (JIT), Optimized production technology (OPT), and Flexible manufacturing system (FMS) for simplifying the material flow, simplify the logistics and decision making and information processing factors.
- 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 and improvements in infrastructure.

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