Organizational Considerations for Advanced Manufacturing Technology

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In the last several decades, the United States has experienced a decline in productivity (U.S. Bureau of Labor Statistics, 2001), while the world has seen a maturation of the global marketplace. Nations have moved manufacturing strategy and process technology issues to the top of management priority lists. The issues surrounding manufacturing technologies and their implementations have assumed greater importance in overall manufacturing strategy. Practitioners and researchers have developed strong interest in how advanced manufacturing technology (AMT) can be used as a competitive tool in the global economy to combat the phenomena of fragmented mass markets, shorter product life cycle, and increased demand for customization (Hottenstein & Casey, 1997). The combination of increased production flexibility and higher efficiency contradicts traditional manufacturing strategy. In traditional thinking, efficiency is possible only in the production of large volumes of standard products, while customization is associated with higher costs (Shepherd, McDermott, & Stock, 2000). Clearly, the impact of AMT is redefining the way multinational corporations are managing manufacturing operations; however, effective implementation of AMT has not occurred as rapidly as the development of technology due to organizational considerations. A measure of the global adoption of AMT is reflected in a research project called the International Manufacturing Strategy Survey, which received responses from 556 manufacturers in 18 countries and found that computer-aided design (CAD), material requirement planning (MRP), local area networks (LAN), and computer numerical control (CNC) machines are now the most popular AMTs used in manufacturing (Sun, 2000).

Defining AMT

While the International Manufacturing Strategy Survey was explicit in identifying AMTs to the respondents, there has been some debate about whether AMT represents only the latest cutting edge technology or is it an adopted terminology that classifies a segment of manufacturing? The answer is the latter. AMT involves new manufacturing techniques and machines combined with information technology, microelectronics, and new organizational practices in the manufacturing process. AMT is a key enabler to help manufacturers meet the productivity, quality, and cost reduction demands of competitive global markets (Industry Canada, 2002). Sun (2000) defined AMT as computer-aided technologies used in manufacturing companies. While Industry Canada's definition is comprehensive and Sun's definition is broad, both of these definitions are accurate in describing the integration of AMTs in the modern manufacturing system known as computer integrated manufacturing (CIM). The Society for Manufacturing Engineers (SME) developed one of the first models to illustrate the relationship of AMT to CIM (Goetsch, 1990). This original model contains one business component and four technical components. The four technical components are planning and controlling, information resource planning, product and process definition, and factory automation. Each of these components contain AMTs that can be classified by their level of integration (Bessant & Haywood, 1988) as illustrated in Table 1.

Benefits of AMT

The benefits of AMT have been widely reported and can be classified as tangible and intangible. The tangible benefits, which are easily quantifiable, include inventory savings, less floor space, improved return on investment (ROI), and reduced unit costs. The intangible benefits, which are difficult to quantify, include an enhanced competitive advantage, increased flexibility, improved product quality, and quick response to customer demand (Ariss, Raghunathan, & Kunnathar, 2000). These benefits may still offer many other improvements with respect to organizational improvements and management/worker satisfaction. For example, the process of implementing AMT might lead to better communication, redesigned workflows, or better integration of work across functional boundaries.

Although operational and organizational benefits are often associated with AMT, all AMTs are not the same and do not provide the same benefits. It is known that innovations come in varying degrees of complexity and design. For example, some innovations are extensions to product offerings or improved processes (incremental), while radical innovations involve the development or application of new technologies into previously un-utilized applications. Innovations also involve changes in the core components without altering a product's overall architecture. Also, advancements can be made by linking together the existing technology and components in a new architecture (Noori, 1997). These individual characteristics of product change or process upgrade affect the level and type of benefits derived.

Table 1. AMTs in the Four Components of a CIM System

Level of Integration	CIM Components and Their AMTs			
	Design and Engineering	Plan and Control	Information Management	Fabrication and Assembly
From standalone to integrated	CAD CAE CAPP	MRP MRPII	LAN WAN Shared DB CIM	NC/CNC CAI/T/T FMS/FAS APL/U ATC Robot AS/RS AGV

Assessment and Planning of a Manufacturing System

The first step in planning for AMT generally occurs when an organization recognizes that current processes and procedures are inadequate to meet their current or future strategic needs. The usual response is to investigate current manufacturing processes and available technologies in an effort to accomplish the perceived needs or improvements. Implementing an appropriate new manufacturing system is, however, not a simple matter of purchasing and installing the technology. Great effort must be expended to ensure that the organizational framework is conducive to the successful adoption of such a system.

Innovative technology invariably leads to new relationships with an organization's external environment. Therefore, firms must evaluate the critical aspects of planning for modified relationships with its customers, system vendors, and materials/parts suppliers. One of the most crucial issues in planning for a new manufacturing system is justifying the investment in the new technology.

The prime motivation for installing AMT is to increase the competitiveness of the firm. Since different firms have varying competitive objectives, their expectations from AMT will also vary. Top management must therefore examine the firm's current competitive position in relation to its desired position before deciding on particular technologies that appear to be suitable for its short-term and long-term goals. If it is seeking savings in human and capital costs, the natural choice will be the technology that promises cost efficiencies. If the expected benefits relate to improved product variety, then the technology that promises product flexibility will be preferred. In many instances, organizations have multiple objectives and the choice of technology should be based on that technology's ability to optimize the possibility of attaining both short-term and long-term objectives.

The Role of AMT

The role of AMT can be broken down into three specific categories: operational, marketing, and strategic (Noori, 1997). In its operational role, AMT is often seen as an instrument for achieving economies of scale in small batch production. For mass production firms, the greater product flexibility provided by AMT could result in economies of scope. In its marketing role, AMT is viewed as providing the basis that enables firms to exploit competitive advantages fostered by the technology. In mass production firms, these are expected to gain a competitive edge through their ability to provide a wide range of products at their usual rates of efficiency. Small batch producers can enhance their process efficiencies while maintaining or improving product flexibility. The strategic role of AMT has been related to improving the firm's ability to cope with environmental uncertainty. It has also been viewed as an important factor in the overall improvement of industrial performance. Many believe that in order for AMT to play a strategic role, a philosophy that integrates the computing environment with the factory control system, the corporate planning system has to evolve.

Prime consideration should be given to the benefits that the firm expects to derive from the implementation of the new technology. Only after this determination can an attempt be made to determine the type of technological innovation that will achieve these desired benefits.

It should be stated that not all types of products are conducive to automated manufacturing. Unlike software-based innovations, hardware-based innovations may be rather product/process dependent. For example, with reference to flexible manufacturing cells, there are those who assert that parts which have similar physical configurations or can be partitioned into distinct product families are prime candidates. This accounts for the proliferation of AMTs in metalworking and assembly. The continuing development of robotics is expected to lead to further development of these and other operations. Also, in spite of the increasing number of AMT adoptions, potential users should be cautioned against making premature decisions to adopt such systems because simple practices such as design for manufacturability may be just as effective and cost much less.

Technological Assessment

In order to understand a firm's technological competitiveness, a periodic technology assessment needs to be performed to chart the deterioration of technology and to benchmark a firm's relative position against a competitor. This entails the computation of the organization's "technology index" (a measure of the capability of the firm versus competitors' capabilities), and the comparison of this index with the state-of-the-art firm in the industry. When the firm's index deviates from the industry index by a pre-specified value, a signal indicating the need for technological improvement is triggered. The important factors of such an index should include set-up time, turn-around time, and minimum lot size as key components. Other considerations should be production flow, flexibility of manufacturing facilities and product lines, flexibility of production processes, interdependence of manufacturing segments, and continuity of production. In addition to technical components, the improvements in overall competitiveness and increased responsiveness to market changes should be highly regarded factors in the firm's technological index.

Management Commitment and Organizational Structure

No matter how great the planning or implementation of a process, management's commitment is probably the most key factor of all. This commitment must not be restricted to the support of a concept. Management's commitment should look beyond the technical aspects of a project and to its organizational requirements for a successful implementation.

Training, team building, and the maintaining of employee morale should be seen as its underpinning. A commitment strategy to all personnel should analyze current tasks and skills, anticipate new activities, and determine the fit of skills needed to develop worker involvement or ability and also training programs for appropriate worker selection (Ghani & Jayabalan, 2000). A high level of management commitment should also facilitate the development of a workable strategy that helps eliminate organizational barriers to its implementation of worker delimitation at hierarchical levels and responsibility.

It appears that one of the major barriers to the successful implementation of a new technology is the existence of mechanistic organizational structures. This means that an organizational structure in an AMT firm should be more of an organic nature (Ghani & Jayabalan, 2000). Although the upper levels of management tend to delineate organizational goals based on strategic focus, the importance of a multiskilled workforce cannot be over emphasized. In many instances a reliance on multiskilled workforces and the continued commitment to design has allowed many manufacturers to adopt less complex and less expensive manufacturing techniques. A firm warning should be noted against the "technology first, organization later" approach; strong integration is highly needed. A firm that embraces modernization should first fit the skills of the available personnel into its modernization strategy, while gradually training to upgrade the skills of the employees (Ghani & Jayabalan, 2000).

Process Champion

A process champion is essential to a project success. Projects having a champion are more likely to proceed in an orderly fashion, achieve integration with the wider organization, and meet planned objectives. The roles of the process champion are seen as follows (Hottenstein & Casey, 1997):

1. Creative originator—the source of the idea (not necessarily but "figure head").
2. Entrepreneur—the person who adopts and sells the project.
3. Sponsor—protector and coach.
4. Project manager/overseer—the person who takes charge of planning.

There are also three areas of knowledge and skill required by a champion as shown in the following (Hottenstein & Casey, 1997):

1. Path finding—related to the ability to emphasize the necessity of technological change for future development.
2. Problem solving—related to technical knowledge concerning products and processes in combination with budgeting/planning/monitoring skills.
3. Implementing—requires interpersonal/communication skills.

Although these skills are essential, they are not necessarily sufficient to ensure successful implementation. An organizational structure that supports the work of the champion should be followed here (Hottenstein & Casey, 1997).

Changing Functional Relationships

The flexibility and efficiency obtained in successful AMT operations can lead to substantial strategic marketing advantages. Benefits such as increased market share, reduced prices, improved responsiveness to change in the marketplace, the ability to offer a continuous stream of customized products, faster product innovation, and improvement of the company's image have all been attributed to flexible AMT. New manufacturing technologies should offer many opportunities for innovative marketing strategies. It is believed that the adoption of automated technologies (FMS in particular) allows for a shift in the role of manufacturing from simply supporting marketing to playing a major role in strengthening a company's overall position in a particular market.

In order to take full advantage of the considerable manufacturing and marketing capabilities offered by new manufacturing technologies, there must be a balance between the marketing and manufacturing strategies of the firm. In instances where there are radical changes in manufacturing/process capabilities, innovative marketing strategies are essential. Rapid changes in marketing capabilities or market conditions usually will signal a need for manufacturing strategy changes. In an attempt to develop a shared marketing or manufacturing strategy, companies should determine appropriate order "winners" such as price, delivery, quality, and flexibility for their different markets and needs. For example, AMT with product flexibility built in can relieve the pressure of an increased product diversity as well a fragmented market, while firms with both volume flexibility and mix flexibility incorporated into their AMT can respond better to the threat of unexpected competitors (McClenahen, 2000).

Functional Integration

In addition to facilitating the market or manufacturing interface, the improved process capabilities of an AMT organization can also affect other functional departments of the firm. Of particular relevance to manufacturing is the integration of design and R&D. It has been seen that in the past, the failure to remove organizational barriers between functional areas contributes to integration difficulties that are usually a departmental interfacing problem.

To provide a framework for functional integration, an organizational impact analysis must be completed. This seeks to analyze the importance of the functional departments and/or functions within each department. These usually arise from such analyses that determine the need for vertical or horizontal shifts (Ghani & Jayabalan, 2000), requirements for new departments or new positions within existing departments, changes in the organizational workflow, or required manpower changes in worker qualifications.

To encourage integration between separate functional departments, firms should promote the multifunctional team concept. Other methods to encourage integration include cross training, the formation of autonomous work teams, and the education of personnel in the interfacing departments (Hottenstein & Casey, 1997). The adoption of AMT creates a need for more complex relationships and greater integration within an organization's key environment. It is generally believed that complex projects can only succeed with a greater expenditure of effort in that the combined action of system vendors, consultants, and users are able to capitalize better on the full benefits.

System Vendors

The desired relationship between system vendors and users is a close collaboration over an extended period. Many analysts believe that adopters of such technology lack the technological knowledge to specify the most suitable system for their situation and to operate and maintain the system after installation. In cases where users lack technical knowledge, they have the choice of dealing directly with the vendors or hiring a consultant for assistance. When the users prefer to deal directly with vendors, the vendors should be selected based on technical competence, quality, and dependability, rather than low cost. Users must also recognize that few vendors supply all the components required in any of the new manufacturing technologies and there will most certainly be networking problems in connecting equipment purchased from different suppliers. There will almost certainly be a software problem between the programs written by developers and the hardware to be purchased. Users must be aware that the system vendor will probably require detailed knowledge of business operations in order to design a system that meets the organization's needs. Unless potential users are prepared to provide such information, the solution offered by the vendor might not meet their requirements.

Given the complex nature of interfacing the hardware with the software developers, many potential users should use a consultant. It should be noted that in order for the user-consultant relationship to be beneficial, it is suggested that that the consultant analyze the requirements and resources of the organization. The consultant should be allowed to make suggestions for the development of the internal structure as well as the structure of production to facilitate reduced start-up problems.

Customers and Suppliers

The adoption of AMT has direct implications for the relationship with customers in at least two areas. First, the adoption of AMT requires the firm to shift its manufacturing emphasis from a product orientation to a service orientation. This means that firms should foster tighter links with customers, with the emphasis being on achieving quick response to customer demand. To achieve this, customers should be allowed to participate in product development. Second, the adoption of AMT production should allow the manufacturer to reduce set-up time and produce in smaller lot sizes. Customer response to such capabilities might be to adopt a just-in-time (JIT) approach, thus increasing the number of orders.

As for the relation with suppliers, it is suggested that manufacturing firms work towards a relationship of interdependence with suppliers. Since an AMT is more conducive to JIT, it is believed that AMT users should encourage flexibility in their suppliers. This requires the sharing of sensitive data between producer and supplier (Brandt, 1998).

Economic and Strategic Benefits of AMT

The experience of plants adopting AMT indicates that major economic benefits of AMT include the following (Shepherd et al., 2000):

- Decreased lead times
- Reduced delivery times
- Reduced set-up costs
- Reduced set-up times
- Reduced transportation costs
- Reduced investment in stock
- Reduction in batch sizes
- Improved quality
- Improved reliability
- Improved dependability

Once the expected benefits are determined and the technology required to reap these benefits has been chosen, the firm needs to consider the economic justification for adopting such technology. The major considerations at this stage are the quantification of costs and benefits. While the costs are generally quantifiable, the benefits are often very difficult to quantify. In particular, while major strategic benefits such as early entry to market, perceived market leadership, and improved flexibility are extremely important for the growth and survival of the firm, they are not readily convertible into cash values or numbers. Organizations often seek to justify AMT adoption by showing that the number of people required to operate the production process will decrease. This practice might not be universally applicable due to the fact that the labor cost factor no longer constitutes a large part of manufacturing operations (Ariss et al., 2000).

Budgeting and Assessment Procedures

An issue in justifying investment in AMT has been the inappropriateness of the techniques of financial and accounting analysis in determining the tangible and intangible benefits that accrue from the adoption of AMT. The adoption of AMT usually depresses short-term profits. Since many AMT projects may take several years to install fully, there is a greater danger in setting only short-term financial goals. The payback period appears to be the main criterion used for the economic justification of such projects. A payback period of 1 to 5 years is the generally accepted amount of time to recover the cost of such projects. However, some eastern industrialized giants such as the Japanese use the payback method to serve more as a performance measure than as a rigid financial criterion.

The consensus with respect to accounting for AMT falls squarely on the side of adopting absorption costing, since it is widely accepted that the variable cost component will be reduced substantially while overhead costs rise. There are those who suggest that while firms may continue to use traditional factors in formal financial appraisal of their projects, these factors might not be the main objectives of that particular implementation (Ariss et al., 2000).

Summary and Conclusion

The key to successful AMT planning and implementation appears to be the choice of an appropriate manufacturing system and the attainment of an organizational infrastructure that will offer maximum support to the chosen system. To achieve the desired benefits from AMTs, marketing and manufacturing must work together to ensure that the marketing strategy reflects the manufacturing capabilities of the new technology. Closer working relationships among all other functions of the organization are also required if the firm is to achieve its innovation objectives.

Economic justification of AMT presents significant problems, since many of the touted benefits are difficult to quantify. However, in some instances strategic considerations may override pure financial considerations. This will allow projects with significant tangible and intangible benefits to overcome the rigid payback criterion that has caused the dismissal of many new manufacturing projects at the pre-installation phase.

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