ADOPTING AND IMPLEMENTING ADVANCED MANUFACTURING TECHNOLOGY
Problems, Benefits, and Performance Appraisal Techniques

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Abstract

This article attempts to discuss about the issues on factor inducing technology adoption, some empirical finding on AMT and the role of AMT in manufacturing sectors. There is also growing consensus that many of the failures in adopting AMT are, in fact, due to inadequate planning for, and/or faulty implementation of the systems. The key to successful AMT planning and implementation appears to be choice of an appropriate manufacturing systems and the attainment of an organizational infrastructure that will offer maximum support to the chosen system.

Further, this article presents an overview and guidance for manufacturing companies which are preparing to invest in advanced manufacturing technology (AMT). The purpose of this article is to explain the reasons why the company may encounter problems while adopting AMT, and to look at the many suggestions offered by the relevant literature for improving the performance of evaluation in AMT investment. According to the our major steps in adopting AMT (i.e. strategic planning, justification, training and installation, and implementation) , the research work here aims to assist managers or investors to recognize problems at each step, thus offering appropriate ways to avoid and/or solve those problems. It is believed that improved justification methods will encourage more firms to invest in AMT and to realize the benefits these investments can offer.

Keywords: Investment analysis, Advanced manufacturing technologies, Problems, Benefits, Performance Appraisal Techniques.

Owing to the intense global competition in manufacturing, manufacturers need to increase their level of competitiveness in the global market. Some manufacturing companies, therefore, are forced to undergo a period of transformation in order to compete more effectively. Under these circumstances, advanced manufacturing technology (AMT) is considered as a means of improving competitiveness.

The term "AMT" refers to computer-aided technologies in design, manufacturing, transportation and testing, etc. In general, AMT can be categorized into two principle ways: 1 the classical continuum of basic manufacturing processes which extends from make-to-order manufacturing to continuous manufacturing; and the level of integration of the overall manufacturing system (Hill, 1989). AMT is a generic term for a group of manufacturing technologies, which combine both scope and scale capabilities in manufacturing environment. Since manufacturing strategy has become more sophisticated, as a result AMT can play an important role in making its possible to compete on "traditionally" contradictory competitive priorities simultaneously.

According to Youseff (1993), advanced manufacturing technology can be classified into three groups (1) technology used in the design of the product, (2) technology used in the manufacture of the product or advanced manufacturing technology and (3) technology used in planning, administrating and controlling activities related to the product. In other words, the term AMT refers to hardware-based technology in the design, manufacturing and administration of all the activities that are necessary to produce a product or provide service. Some industrialists and economists (Stainer et al., 1996) believe that AMT has great potential to offer manufacturing companies, with many tangible and intangible benefits. Some examples of the benefits which may be obtained are reduced labour (Hayes & Jaikumar, 1991), improved product quality (Attaran, 1989; Poo, 1990), increased product/ process flexibility (Attaran, 1989; Willis & Sullivan, 1984), enhanced time efficiency (Meredith, 1987a) and shortened time-to market. These benefits are significant but there are several internal and external factors inhibiting the success of AMT investment decisions such as (Stainer et al., 1996): lack of readily accessible and acceptable methods for appraising all the benefits offered by the AMT, inconsistent nature of corporate governance, insufficient level of technological confidence, unclear financial environment, behavior of competitors, and unsuitable time to establish the critical performance measures and performance benchmarks.

Moreover, some manufacturers hold the view that the adoption of AMT involves a high level of investment, and its payback period is usually longer than that traditionally required by business enterprises. Consequently, the investment may initially result in an increase in the cost of manufacturing. Apart from these factors, there is often a lack of sufficient experience with AMT implementation and it is not unusual for organizations that have invested in AMT to discover unexpected areas of application or benefit.

According to the different operating conditions and technological base of individual companies, quoted improvement rates may have been achieved in one company, but cannot be achieved equally in another. For these reasons, management may adopt a rather conservative policy, and hence refuse to consider AMTs, even though they could potentially benefit the firm. Because of the potentially high investments in AMT and the moderate-to high risk involved in adopting these technologies, there should be an adequate economic analysis and justification method to assist companies in selecting the appropriate technology, most suited to their operations and business objectives. Generally, the widespread investment appraisal techniques can be classified into three groups: (1) strategic evaluation approach; (2). economic evaluation approach; and (3) analytic evaluation approach.

In the survey of current research and the applications of existing investment appraisal techniques, this article attempts to provide an overview and guidance for manufacturing companies which are planning to invest AMT. Furthermore, it also reviews the literature relevant to the management aspect of adopting and implementing AMT, and explores the use of appropriate evaluation methodologies from the strategic and economic points of view.

Elements of Successful Adoption and Implementation of AMT

Adoption of Advanced Manufacturing Technology (AMT) promises benefits but are potentially risky. Many firms that have adopted these new technologies have not been able to reap all the potential benefits. Since the technical abilities of the AMT are relatively well proven, there is a growing belief that managerial issues, from planning to implementation, present the major barrier to employing these technologies effectively. Chen and Small (1994) proposed seven elements of successful AMT adoption and implementation:

Strategic planning for the adoption of AMT. The strategic planning approach takes a long term, comprehensive view of both business and technology issues. There is a greater possibility of adoption success if the decision to implement AMT is based on strategic consideration. Whatever the basis of the particular strategy that is adopted, the firm should develop an integrated business plan which provides the vision and sense of direction for each organization unit of the company to meet the strategic objectives.

Match product with process. Companies should first identify the range of product types that are to be manufactured, followed by identifying the technologies and processes required to manufacture this product. In seeking to match product and process, companies should be aware that adoption of AMT can bestow not only operational benefits but also marketing and strategic benefits as well. Benefit such as increased market share, reduced prices, improved responsiveness to changes in the market places, the ability to offer a continuous stream of customized product, faster product innovation and improvement of the company's image, have all been ascribed to the operation of the flexible advanced manufacturing technologies.

Monitoring advanced manufacturing technology. To determine the strategic and operational benefits offered by AMT, firms should continuously monitor the usage and performance of AMT in their core industry. Etlie (1988) emphasized the importance of monitoring technology. He argued that firms must be more innovative in new processing technologies and management practices in order to improve their competitive position and ensure survival.

Management commitment and control. It is critical for the success of AMT adoption and implementation. The lack of an appropriate management commitment and control proves to be the greatest impediment to the effective implementation of new manufacturing technologies. Management should be committed to training during the adoption phase and develop worker selection programs.

Functional relationship. In order to take full advantage of the considerable manufacturing and marketing capabilities offered by AMT there must be a balance between marketing and manufacturing strategies. In the condition when radical changes happened in process capabilities, market strategies must also be innovated. Likewise, rapid changes in market capabilities or market condition will signal a need for manufacturing strategy changes.

Relationship with the external environment. The adoption of AMT requires close collaboration with system vendors, customers and suppliers. During the implementation phase, there is a need for major vendor commitment. Firms should also foster tighter link with customer, with the emphasis being on achieving quick response to customer demand and improved customer service. Wherever possible, customer should be allowed to participate in product development. Further, manufacturing firms should work toward a relationship of interdependence with supplier.

Justifying advanced manufacturing technology. The major considerations in economic justification of AMT project are the quantification of cost and benefit. While the costs (hardware, software, planning, training, operation, etc.) are generally easily quantifiable, the benefits are often very difficult to quantify. Specifically, major strategic benefit such as early entry to market, perceived market leadership, the ability to offer a continuous stream of customized products and improved flexibility, although extremely important for the growth and survival of the firms, are not readily convertible into cash value.

To the extent that global and domestic environment, manufacturing firms are adopting AMT as mean to effectively compete in their respective markets (e.g. Flexibility, delivery, quality, and time based competition). Whatever the objectives may be the adoption of any new technology involves uncertainty about achieving the objectives.

In addition, to the inherent human resistance to change and to be innovative, at least two types of uncertainty emerge when adopting AMT (Mamer & Cardle, 1987):

First, technological uncertainty, which refers to the problem whether the adoption of technology will be profitable, and

Second, strategic uncertainty, which involves the decision to adopt a new technology.

The effect of technological uncertainty can be reduced by research and testing. On the other hand, strategic uncertainty is more difficult and problematic to evaluate. It might be due to the difficulties to anticipate the decisions and actions of the competitors. Mechling et al. (1999) argued that it is difficult to reduce the technological and strategic uncertainty both in the acquisition and implementation stages. The first attempt to identify critical factors to reduce these uncertainties and support their strategic objectives is to provide a link between firm's long-term competitive strategy and its technology (Kantrow, 1980).

Conventional Problems in AMT Investment

It is generally agreed that the competitiveness of manufacturing companies will be potentially improved by implementing AMT. However, the unsatisfactory performance of the manufacturing sector in terms of per capita value added and exports share is also related to the low level of investment in AMT (Wilkes & Samuels, 1991). There are quite a number of practical cases reporting the failure of AMT implementation (Bessant, 1990). It has become a well-recognized assumption that strategic and organizational issues should be considered at an earlier stage prior to the AMT implementation (Bessant, 1990; Gerwin, 1982; Kidd, 1990). However, there are still some implicit questions. For instance:

First, what specific strategic, organizational and technological issues should be considered when investing in AMT?

Second, how could the strategic, organizational and technological issues be interrelated with each other during the implementation of AMT?

Third, when should specific strategic, organizational and technological issues be addressed during the implementation process (Sun and Riis, 1994)?

A survey of related literature indicates that most researchers have only focused on the justification of AMT dealing with the relationships between usage of different justification approaches and the adoption of AMT. Determining the relationships between justification actions and the performance of a project are usually disregarded (Small & Chen, 1995). Excessive attention has been paid to technical development, but not enough to the adjustments needed in the organizations to accommodate the technology. Apart from these, the use of inappropriate appraisal methods may make a company unwilling to invest in AMT (Stainer et al., 1996). Many companies aim to evaluate their chosen technology by quantifying the costs of technology implementation. Although costs such as hardware, software, training, operations, etc. are generally easily quantifiable, many other benefits, for instances quality and flexibility, are often very difficult to estimate (Amoako-Gyampah & Maffei, 1989; Wabalickis, 1988). The most popular capital-acquisition policies, which evaluate the investment in financial terms, have been found to be inappropriate for automation investment decisions (Attaran, 1989; Meredith and Hill, 1987; Roth et al., 1991; Swann and O'Keefe, 1990a, 1990b). For instance, it has been suggested that conventional cost accounting cannot accurately value improvements in quality, flexibility, customer service and other synergistic effects of AMT (Dornan, 1987). Some researchers find that AMT accounting practices reflect external reporting requirements rather than the reality of the AMT production environment (Curtis, 1987; Kaplan, 1984). Many of the problems raised by the introduction of AMT are due to unawareness of the strategic role of AMT, by all levels of management. This situation is caused by the rigid use of a formal budgetary control system, and also due to too much emphasis on piece-by-piece decision processes that are designed to achieve short-term goals (Currie, 1991). Since the benefits are difficult to quantify in financial terms and the decision making process requires a long-term perspective, industry does not invest sufficiently in AMT (Bromwich & Bhimani, 1991).

It is commonly claimed that investment in AMT may result in strategic benefits. However, managers always ignore this advantage as they sometimes consider such investments as an operational or functional decision rather than a strategic one (Toone, 1994). It is suggested that arguments based on comparison with competitors, the retention, attainment or perception of industry leadership, and expected future

Table 1. Proposed AMT Implementation Activities

a. Linking manufacturing to business strategy	l. Emphasizing team work and group activities
b. Coordinating marketing and manufacturing strategy	m. Pre-installation training of all project participate.
c. Developing a long term automation strategy	n. Considering likely impact on suppliers
d. Monitoring AMT being used in the core industry.	o. Considering likely impact on customers
e. Matching capabilities of AMT to benefit expected by the plant	p. Establishing multidisciplinary implementation teams.
f. Ensuring compatibility of AMT with existing production systems.	q. Establishing multidisciplinary planning teams.
g. Ensuring vendor commitment during and after installation.	r. Top management involvement
h. Obtaining the services of knowledgeable AMT consultants	s. Choosing knowledgeable project leaders
i. Hiring or retaining AMT experts on plant staff.	t. Financial investment evaluation prior to installation.
j. Having multi-skilled production workers.	u. Strategic investment evaluation prior to installation.
k. Communicating the likely impact of the AMT to all plant workers.	v. Developing system performance measures prior to installation.

Source: Previous studies.

developments in the industry should be deemed as additional factors for decision makers to approve AMT projects (Vrakking, 1989). Therefore, strategic criteria are considered to be more important than financial criteria in the AMT justification decision making process (Slagmulder & Bruggeman, 1992b).

To address these concerns, AMT investment requires the decision makers to take a strategic perspective (Stainer et al., 1996). Major strategic benefits such as early entry to market, perceived market leadership, the ability to offer a continuous stream of customized products, and flexibility improvement, although they are extremely important for the growth and survival of the firm, they are not readily convertible into cash flow values (Kakati & Dhar, 1991; Meredith, 1988). Therefore, a meaningful justification should require the identification and assessment of all the variables that determine the success of the AMT projects.

The faith in traditional accounting procedures in firms has led some researchers to advocate the justification of AMT on the basis of strategic arguments. Hence, many companies might adopt a hybrid approach which consists of both strategic and economic evaluations in justifying the adoption of AMT. Consequently, researchers do believe that adequate investment appraisal methodologies will encourage more firms to invest in AMT. In addition, managers should realize how AMT investments can offer tangible and intangible benefits to their companies.

AMT: Expected Benefit VS Anticipated Risks

This section is devoted to discuss proposed AMT adoption /implementation activities, expected benefits and anticipated risk based on studies done in developed countries and developing countries. To summarize the results of the previous studies, a detailed list of activities identified most prevalently in the literature as being critical for Amt implementation success is presented in **Table 1**.

Furthermore, based on a lot of studies done on AMT adoption, Tables 2 and 3 summarized the expected benefits as well as anticipated risks and difficulties of the manufacturing firms those adopt, implement and invest on sophisticated technologies.

Based on the above review, it is important to note that many determinants of implementation success, anticipated risks and difficulties as well as expected benefit are actions and conditions that should be in place prior to purchase and installation. Thus the pre installation stage is indeed an essential part of the entire AMT implementation process.

Motivated by this pressing need, this article proposes some stages to help management determine when the adoption of new technology is necessary and the planning procedures to follow and to ensure successful AMT adoption and implementation. For manufacturers to analyze their operational

Table 2. Expected Benefit of AMT Adoption

a. Improved quality	m. Improved integration of management information systems across function
b. Reduced cost	n. Improved working environment
c. Obtaining competitive advantage	o. Reduced change over set up times
d. Increase throughput	p. Improved ability to response variation in supplier lead times
e. Increased flexibility	q. Overcoming skill deficiency
f. Better management control	r. Improved management attitudes
g. Increased sales	s. Enhance company image
h. Improved response to variation in product volume	t. Reduced product development time
i. Improved integration of manufacturing information system	u. Improved ability to implement engineering changes
j. Improved response to variation in product mix	v. Widening product range
k. Reduced work in progress	w. Overcoming production skilled deficiencies
l. Improved workforce attitude	x. Better working environment

Source: Previous studies.

and organizational environment as well as make critical decision about accepting or rejecting new technology development can utilize these stages below.

First, define the company objectives and determine required product/process changes. The need for technological innovation in production processes is often initiated as a result of changing strategic or business objectives, which require an evaluation of current production processes. If existing process are found to be adequate for achieving the firm's business and strategic objectives, the manufacturers will maintain the existing processes, otherwise system changes that could be made in order to obtain the most efficient and cost effective should be considered.

Second, technology monitoring. Monitoring technology is an integral part of the planning process and should consist of the following: a) the development of an awareness

Table 3. Anticipated Risks and Difficulties with AMT Investment

a. Disruption during implementation	g. Production and management skilled deficiency
b. Adverse effect on workflow	h. Opposition by workforce
c. Failure to achieve financial target.	i. Opposition by staff/management
d. Problems with interconnection of equipment	j. Obsolesce of technology
e. Amt skilled deficiencies	k. Lack of integration across system.
f. Lack of integration of information system	

Source: Previous studies.

of available AMT, b) matching of these technologies to the process requirement of the manufacturing concern, c) ensuring the compatibility of the available technology with the plant's existing systems.

Third, operational and organizational planning for the adoption of AMT and financial strategic justification. The stage consists of the development of integrated operational and organizational plans for the adoption of the AMT followed by financial and strategic justification. The operational plan identifies the activities that are needed to ensure the successful adoption of the AMT into existing operating system. The organizational plan details the type of operational structure and human resource changes that will be needed to support the operation of the new system.

A study of Chen and Small (1995) showed that in term of organizational planning activities, successful manufacturing firms expended significantly higher level of effort in following areas:

First, communicating the likely impact of AMT to all plant staff. *Second*, emphasizing team work and group activities. *Third*, having multi-skilled production workers. *Fourth*, pre-installation training for all project participants.

Therefore, it is recommended that these elements be viewed as integral part of organizational planning process of adoption of AMT. In addition, the more successful AMT adopted had exhibited significantly higher level of effort on the following operational activities: *First*, establishing multidisciplinary implementation teams.

Second, establishing multidisciplinary planning teams. *Third*, considering likely impacts on customers. *Fourth*, considering likely impact on suppliers. *Fifth*, top management involvement.

Review of Existing Methodologies

There are four major steps often recognized in adopting AMT. These steps are (Small & Chen, 1995): 1) strategic planning, (2) justification, 3) training and installation; and, 4) implementation of the selected technology. Hence, this article will be guided by these stages to overview the relevant literature as a source of information for industries, which are planning to invest AMT. It should be mentioned that there will be no sharp borderlines between stages. In fact, some of them are partially in parallel.

Strategic Planning

The strategic planning can be divided into five phases: objectives identification, organization infrastructure supporting, management commitment and supervision, performance variables assignation, and technologies identification.

Objectives Identification

The strategic approach takes a long-term, comprehensive view of both business and technological issues. A critical step in the adoption of new technologies is the identification of corporate strategic goals and objectives. According to the various objectives and operating characteristics in each company, the decision on selecting a technology will be different. Besides, the company should point out the problems hindering the accomplishment of the goals, and the contribution of the proposed AMT to these goals. The objectives of the company can be set from self-questioning. For example:

What are the strategic goals of the company? What problems are faced with the current manufacturing system? Will the new AMT encourage the production tasks at operations level and the manufacturing goals? What types of product are going to be produced now and in the future? What is the technology strategy in the near future?

During the strategic planning stage, it should also cover the elaboration of product and manufacturing strategy down to operational or performance variables such as product, volumes, and variants of parts. The clarification of strategic goals is necessary to the success of the AMT implementation (Sun & Riis, 1994).

Supportive Organization Infrastructure

There is a growing consensus that the key to successful AMT planning and implementation depends on the choice of a suitable manufacturing system, and the attainment of an organizational infrastructure which will offer maximum support to the chosen system. In a recent survey, several AMT implementations have been reported as failing to achieve their promised benefits. This is mainly due to problems within the organizational structure (Attaran, 1996; Boer et al., 1990; Hayes & Jaikumar, 1991; Meredith, 1986; Meredith, 1987b; Udoka and Nazemetz, 1990; Zammuto and O'Connor, 1992).

The management level can clarify some ambiguities through the following questions (Sun & Riis, 1994):

Can the current human resources support the AMT? What are the qualifications of the staff needed for the AMT? What is the division of labour? What are the responsibilities and the authority of the operators? How could those people replaced by the AMT be reassigned/redeployed? How could the AMT be integrated with the existing system and other functions?

Furthermore, the firm should also put a great effort into the organizational and operational planning activities (Chen & Small, 1994) such as: announcing the possible impact of AMT to all staff; stressing teamwork and group activities; providing pre-installation training for all project participants;
forming multi-disciplinary planning and implementation teams; and considering likely impact on customers and suppliers.

Management Commitment and Supervision

Top management should recognize the range of product types that are likely to be manufactured, and identify the technologies as well as the manufacturing processes of these product types more effectively and efficiently. Rapid changes in marketing capabilities or market conditions will signal a need for manufacturing strategy changes (Blois, 1986). Top management should be aware not only of operational benefits such as flexibility improvement, but also of marketing and strategic advantages as well. Cash et al. (1988) and Noori (1990) have reported that there are two sets of trends which have an impact on market and manufacturing. Market trends embrace increased new product or process introductions, such as a short product life cycle, fragmented markets and demand uncertainty, etc. Manufacturing trends include inventory reduction, product and process simplification, quality improvement and so on. According to these two sets of trends, stability must be maintained between marketing and manufacturing strategies.

A recent flexibility-uncertainty model (Chen et al., 1992) provides an innovative link between marketing and manufacturing in the new manufacturing environment. The model demonstrates ways of employing different types of flexibility to cope with the various forms of environmental uncertainty that can cause tension between marketing and manufacturing.

A survey of related literature reports that during the AMT justification process, the more the number of functional departments is involved, the more effective it is in explaining project performance. Functional departments involved in justification are (Small & Chen, 1995): production/operations management, engineering/research and development, finance, management information system, general administration, marketing, and personnel.

All departments concerned can identify their expectation from the technology, and seek to determine the time period within which these expectations should be met. Furthermore, the performance of the AMT should be gauged by its impact on all concerned departments, not only on the department where it is installed (Primrose, 1991). This can best be achieved through the use of multi-functional steering committees as well as interdisciplinary multi-skilled teams, and they should assist in fostering inter departmental communication (Falkner & Benhajla, 1990). In order to encourage integration between separate functional departments, the concept of the multi-functional steering committees could be promoted by the firms (Boer et al., 1990). The team should comprise members from various functional areas (Ferraro et al., 1988). This is because manufacturing managers with experience in operations often do not have enough understanding of strategic issues.

And conversely, top management does not have full understanding of operational details. This often results in frustration as operations engineers are expected to meet unrealistic demands of top management. Therefore, the steering committee should create the vision of the project for the company, and know how to convert that vision into reality. System interfaces, database requirements, types of information to be shared and timeliness of the information should also be involved (Attaran, 1996).

Furthermore, some researchers (Beatty & Gordon, 1990) indicated that a champion is the most important figure in AMT implementation. The champion plays both path-finding and problem-solving roles. Without a capable and skilled champion in companies, the implementation would proceed very slowly, and remain restricted to a small corner of the organization, or, more importantly, would not achieve the objectives expected at the outset (Beatty, 1990). Therefore, the most useful support is to officially appoint the champion as the leader of the AMT implementation project, to give him or her enough authority to carry out the implementation, and to provide the necessary financial resources. Moreover, good coordination of all parties provides strong support for the champion which is a critical success factor (Sun & Riis, 1994).

Performance Variables Assignation

Another essential issue is the timing of the establishment of the performance measures, and the performance benchmarks. Some authors state that the correct time for establishing these criteria is during the planning stage, especially during the financial and strategic justification of the technology (Chen & Small, 1994; Gold, 1988). If the performance variables can be established in good time, the plant will be better able to monitor progress during and after installation of the AMT and make adjustments to project goals and objectives. The performance variables which are considered generally can be listed as follows:

Time needed for a major design change in an existing product Compatibility with existing machine, machine breakdown, utilization, the average number of tasks per operator, production lot sizes, operator output rates, work morale, human integration, cost product cost, maintenance cost, labor cost material cost, plant revenues from manufacturing operations, flexibility, changeover times, variety of part-types or products manufactured, design change accommodation, capacity growth.

Then, routing and scheduling flexibility, market responsiveness, quality Scrape value, rework, product conformance and consistency, delivery Time scheduling, delivery time, lead time from receipt of order to delivery, transportation, customer services, inventory/work in progress, innovativeness Research and development, and introduce product variation.

Technologies Identification

The advanced manufacturing technologies are broadly classified into seven sub-groups. The classification scheme adopted here is similar to the US Department of Commerce (1989) Survey of Manufacturing Technology. The findings of some researchers show that the technologies are also cross-categorized as stand-alone systems, intermediate systems, and integrated systems (Meredith & Suresh, 1986). This classification scheme links technologies that have similar benefits and costs. The advanced technologies are classified into three main groups, and seven subgroups are further divided as shown below (Small & Chen, 1995):

***First*, design and engineering technologies:** Computer-aided design (CAD) and Computer-aided process planning (CAPP).

***Second*, fabricating/machine and assembly technologies:** NC/CNC or DNCmachines, Materials working laser (MWL), Pick-and-place robots, Other robots, Intermediate systems.

***Third*, automated material handling technologies:** Automatic storage and retrieval systems (AS/RS) and Automated material handling systems (AMHS).

***Fourth*, automated inspection and testing systems:** Automated inspecting and testing equipment (AITE) and Integrated systems.

***Fifth*, Flexible manufacturing technologies:** Flexible manufacturing cells/systems (FMC/FMS).

***Sixth*, computer-integrated manufacturing systems:** Computer-integrated manufacturing (CIM).

***Seventh*, logistic related systems:** Just-in-time (JIT), Material requirements planning (MRP), Manufacturing resources planning (MRPII)

Companies must ascertain which technologies can fulfill their objectives and identify the selected technologies belonging to a system (i.e. stand-alone, intermediate or integrated systems), since it will affect the following justification methods chosen. For stand-alone systems where the purpose is the straightforward replacement of old equipment, even if some economic benefits not usually considered are obtained, the standard economic justification approaches can be used.

However, for the linked systems, flexibility, risk and non-economic benefits are expected, more analytical procedures are needed. In such cases, subjective estimates of probability distributions are obtainable and can be included in the analysis. Lastly, with systems approaching full integration, clear competitive advantages and major increments towards the firm's business objectives are usually being obtained.

In such cases, strategic approaches are needed to take these benefits into consideration, although tactical and economic benefits may arise as well. Each of the justification categories spans a number of approaches. In the following sections, we will describe these approaches and discuss their pros and cons. Justification methodologies As mentioned before, evaluation techniques can be partitioned into three groups, i.e. strategic, economic and analytic justifications.

Strategic Justification Approaches

Strategic approaches tend to be less technical than the economic and analytic methods, but they are frequently used in combination with them. Performance approaches is their direct tie to the goals of the firm. A disadvantage is the possibility of overlooking the economic and tactical impact of the project, myopically focusing entirely on the strategic impact. However, if a strategic approach is used, the economic and analytic implications should also be checked, simply for a clear understanding of the impact of the project (Meredith and Suresh, 1986). There are several commonly used strategic approaches.

Technical importance. This approach is based on the concept of technical importance which means the project is a prerequisite for a crucial follow-on activity. It may have negligible returns, or even disadvantages, but later, more desirable work cannot be attempted without implementing this activity first. It is common for activities such as these to be grouped with the desired follow-on project in a ``package" that is approved en masse by the approval board.

Business objectives. Through the business objectives justification approach, a firm can check whether the project achieves the firm's business objectives or not.

Competitive advantage. In the competitive advantage justification approach an opportunity may exist for the firm to gain a significant advantage over its competitors by implementing this project. The advantage may not belong to one of the strategic business objectives of the firm but it is very important for the company to press on. The opportunity may have arisen from a unique set of circumstances or may be an outgrowth of a slight competitive advantage the firm already holds. This situation occurs frequently in all areas of technology. A firm may hold a crucial patent that allows it to build on an existing base for a significant advantage over its competition.

Research and development. Treating a project as an R&D investment admits that it may fail but it holds sufficient strategic promise to justify the investment. The point is that one of many such projects will eventually come through and provide returns to the firm to reimburse all the failures. Without risk, nothing is gained. The R&D approach can be evaluated through the pilot project, setting up one group technology line, or one manufacturing cell to observe how well it works, what it costs, its problems, and its benefits (Meredith & Suresh, 1986).

Swamidass (1987) pointed out that planning for manufacturing technology requires the assessment of the deterioration of technology over time. In this connection, an ``organization technology index" (i.e. a measure of the capability of the technology being used by the firm) will be calculated and compared with the index for the state-of-the art firm in the industry. When the firm's index deviates from the industry's index by a pre-specified value (labeled the ``modernization point"), a signal indicating the need for technological improvement will be triggered. Recent studies show that the manufacturing strategic map (Krinsky & Miltenburg, 1991) can be used to simplify the strategic analysis. It is a set of plans and policies from which manufacturing industry seeks to provide six types of manufacturing output (i.e. cost, performance, quality, delivery, flexibility, and innovation) at target levels, to the rest of an organization. Thus, appropriate plans and policies are designed for some or all decision areas (i.e. production capacity, facilities, process technology, supplier relations, planning and control, measurement, work force, quality and structure policies) within manufacturing. It shows precisely what the manufacturing function will provide (specific outputs at specific levels) to the rest of the organization and indicates how the manufacturing functions provide such outputs.

Economic Justification Approaches

Economic justification calculations will commonly be made in combination with strategic considerations, but analytic evaluations are rarely included. This is because analytic approaches always require a lot of time and trouble. Some newly industrialized countries have a relatively low labour cost but highly motivated workforce and generous supply of raw material, so it often makes economic justification of projects difficult (Zhao & Co, 1997). There exist a number of formulae and approaches that companies use for the economic justification of equipment. They are concerned with simple economic functions such as payback (PB), return on investment (ROI), internal rate of return (IRR), net present value (NPV), and so on, used in situations where they are assuming no uncertainty (Fotsch, 1984; Rosenthal, 1984; Schall et al., 1978).

One school of thought is that return on investment (ROI) and payback calculations cannot identify potential AMT improvements, since these techniques only assess financial feasibility of the technology (Attaran, 1996). Many researchers (Kakati and Dhar, 1991; Kaplan, 1984; Park and Son, 1988; Primrose, 1991) consider the use of discounted cash flow (DCF) techniques to be critical for AMT investment. However, recent studies (Baldwin, 1991; Cole, 1987) show that DCF is inherently biased against technological capital investment; furthermore, some skeptics believe that the widespread use of these methods has led to a decline in the level of capital investment. In addition, DCF techniques have some drawbacks such as conceptual weakness, inability to evaluate strategic investments with future growth opportunities, and especially biased against long term projects (Krinsky and Miltenburg, 1991). Although these techniques are not inherently flawed, the main problem is that the investors do not recognize the value of a wide range of competitive commitments. When an organization invests in a new product or process that decreases the value of existing products, it is said to be cannibalizing its business. This kind of cannibalization can be overcome by the capital budgeting systems. Through the calculation of NPV or IRR, the investment which may decrease the organization's value can be avoided (Stainer et al., 1996). However, there are still some loopholes when employing the capital budgeting systems.

For example: They support decisions that are sensible when viewed in isolation. They do not always indicate the best action within an inter-related set of decisions, and they are inherently incremental so that long-run survival cannot adopt.

Apart from these, some authors mention the possible source of error in investment appraisal procedures to which the investors should pay more attention (Cole, 1987), such as: employing unreasonably high discount rates, failure to identify all the costs of new investment, neglecting crucial benefits from new investment, employing short payback periods, adjusting inappropriately for risk, comparing investments with irrational continuation of status quo alternatives, and putting stress on incremental rather than global opportunities.

It should be highly recommended that if the previously cited possible hazards can be avoided, discounted cash flow analysis is a powerful and valid tool where benefits can be properly quantified. On the other hand, some scholars suggest that all projects can be appraised through a single evaluation approach which uses sensitivity analysis to compensate for the risk associated with evaluating the intangible benefits (Primrose, 1991; Smith, 1983). Sensitivity analysis encourages identification of variables that might be disregarded in the assessment of uncertainty. The key variables that are likely to affect the result of investment would probably include such elements as unit variable costs, fixed cost, market share, market size, and unit price achievable. These would be adjusted in turn, and the overall effect on NPV or IRR would be calculated. To alleviate the problems inherent in using purely financial or purely strategic appraisal approaches, recent studies have promoted hybrid financial and strategic appraisal approaches (Boaden & Dale, 1990).

Analytic Justification Approaches

The analytic techniques are largely quantitative but more complex than the economic techniques. When intangible benefits are taken into consideration, the analytic investment appraisal techniques for investment are required. It is because they can collect more information and frequently consider uncertainty and multiple measures and effects. The superiority is that they are more realistic, taking more factors and subjective judgements into account, and hence better reflect reality as understood by knowledgeable managers (Meredith & Suresh, 1986). Even though a computer can be used for the complex analysis, it is still time consuming to collect data for analysis.

Several Commonly Used Approaches are Described Below

The analytic hierarchy process (Sullivan, 1986) structures a complex decision into a hierarchy of elements. The attributes are compared pair-wise, relative to the company objectives. The pair-wise comparisons are based on judgments about the relative differences among comparable elements. The relative weights are then set by the eigenvector method and combined to derive a single overall rating for each decision alternative.

The advantages of using hierarchies are that: they can describe how changes in priority at upper levels affect the priority of elements in lower levels; They also provide a great detail of information on the structure and activity of a system in the lower levels and give an overview of the actors and their purposes in the upper levels; and natural systems assembled hierarchically, i.e. through modular construction and final assembly of modules, decision making evolves much more efficiently than those assembled as a whole (Saaty, 1990).

Nevertheless, they also have some flaws which are: the absence of a theoretical framework to model decision problems into a hierarchy. The pair-wise comparisons are based on subjective judgments. The estimated relative weights are set by the eigenvector method, and without formal treatment of risk (Zahedi & Fatemeh, 1986).

The linear additive model (Sullivan, 1986) can be applied to justify long-term and short-term manufacturing investment alternatives. Each alternative is ranked by combining the information from independent criteria. The score for each alternative is the summation of the rating assigned to each decision factor multiplied by the weight of that factor relative to a weight of one for the most significant decision factor. The alternative with the highest score will eventually be preferred. It seems to be easy for the decision makers to use because it has produced a rank ordering which appears to correspond closely to their actual ultimate choices (Morris, 1977). Since the alternatives considered are not really independent in reality, the model may have some difficulties in implementation (Soni et al., 1990).

Profile charts and symbolic scorecards (Sullivan, 1986) offer a visual aid for the analyst to choose between alternatives with a summary of intangible performance criteria. The charts themselves make no attempt to rank importance, so subjective judgment is needed to determine the relative importance of the criteria presented in the graphical display. Hence, profile charts are very useful in the decisions where only a simple visual indication of the desirable criteria is desired. Generally, there are a number of programming models which are based on the equation given for the weighted factor scoring model. Integer programming is used; 0-1 variable to represent each project. The project is selected when the set of project total weighted scores is maximized, subject to resource constraints such as capital and facilities (Meredith and Mantel, 1985). Goal programming is used to show the different factors as goals to be attained, subject to resource constraints. Again, weights are used on the goal deviations to give importance to each of the factors (Ignizio, 1976). Linear programming technique is used to assist decision makers to allocate limited resources, such as company money, to the investing technologies while considering their interdependence (Kuei et al., 1994).

The risk analysis approach is to simulate the projects under consideration to determine the variables of interest, such as benefits, costs, yields, and capacity etc., and to describe the outcomes statistically or graphically. In general, cumulative distribution functions are always used to determine each variable of interest. In risk analysis, there are two broad approaches. First, the probability of a particular outcome is defined by a reasonably familiar concept, such as gambling. The probabilities of a series of outcomes are established which seem straightforward. Second, a specific outcome is defined as value to the decision maker by the concept of utility. A survey of recent literature highlights that there are two prime risks having a profound impact on decision making behaviour (Sitkin and Pablo, 1992).

They are: 1) The probability of variance in the cash flows which are initiated by the project. 2) The probability of variance in the time taken before such cash flows occur, and in the case of the development of some new technologies, whether they would be feasible, acceptable and suitable. The use of risk analysis, therefore, provides management with extended risk-adjusted capabilities for assessing the feasibility of the project.

Training and Installation

During this stage, the company should consider several aspects which have impacts on the overall performance: to select a suitable site for installation, to test and install the equipment piece by piece before they were integrated, to select and train the operators and maintenance staff; and to take into consideration human resource allocation.

A survey of literature indicates that management must realize the critical nature of proper training and education, as experience has shown that between 25 per cent and 40 per cent of the total cost of a project will be spent on education and training (Mize, 1987). Furthermore, the company should conduct a complete skill assessment of the workforce. For example, it should determine what skills are needed and what changes have to take place.

Besides, it should ensure that the human element is prepared for the new equipment utilization, before any equipment is installed. Support is needed at all stages for those who are being trained on new equipment (Attaran, 1996). Recent researches claim that training and involvement of managers, accountants and technologists at all levels can minimize the uncertainties and enhance the effectiveness of AMT investment (Zhao and Co, 1997).

Implementation

After the equipment haa been installed, a reasonable period of time is needed for the managers and workers to gain sufficient organizational and technical experiences for the normal and continuous operation of the AMT. here may be some strategic changes that arise from environmental alternations, such as technology, economy, customers and competition, after the installation of AMT. Unpredictable and inevitable uncertainties always occur both in technology and organization. For instance, Meredith (1987) reported a case where the AMT implemented forced the top management to reconsider their strategy. Therefore, all departments are able to monitor the whole implementation progress via the inter-departmental teams as mentioned before. Whenever any environmental change occurs, the top management can respond quickly and make necessary adjustments to project goals and objectives.

Conclusion and Recommendations

The advent of AMT has given manufacturing organization a new dimension on which to compete. Product-base competition must not be driven by cost alone. In 21st century, management must move beyond cost and quality as the only dimensions on which to compete. Agility, quick responses to customer needs, timeless in all manufacturing activities necessitate the use of time as a new metric or dimension for competition.

In order for organization to be more flexible and responsive to customer needs, it is necessary that proper environment for implementing AMT is created. For the environment to exist, we suggest the following: *first*, top management must be convinced about the synergistic impact of these technologies. *Second*, the motive for implementing AMT should be of a strategic nature. *Third*, the integration of these technologies beyond the design of the product.

The implementation of AMT is a complex process whose success depends on myriad aspects of the organization structure, systems (formal & informal) culture and environment.

There is also growing consensus that many of the failures in adopting AMT are, in fact, due to inadequate planning for, and/or faulty implementation of the systems. The key to successful AMT planning and implementation appears to be choice of an appropriate manufacturing systems and the attainment of an organizational infrastructure that will offer maximum support to the chosen system. The achievement of desired benefit from AMT requires systematic and integrated operational planning prior to the adoption of new systems. Such planning requires the identification of likely product and the matching of these products with efficient AMT processes. In addition the processes should be matched with the organizational structure and worker's skills to allow for organizational infrastructure changes, which might be needed prior to adoption of the technology. Closer working relationship among all functions of the organization will be required.

Finally, planning for AMT must be seen as a critical step in the implementation process if up front planning for the operational and organizational aspect of the AMT project is performed, the likelihood of encountering installation will be greatly reduced. Management to continuously meet organizational objectives and determine when the adoption of an innovative technology is warranted can use the three stages that we propose in this article.

A common belief is that the implementation of advanced manufacturing technologies involve large initial investments. If these investments can be fully justified, it will lead some companies to be willing to invest. Moreover, some of the benefits, such as tangible and intangible, are difficult to quantify in financial terms and require long-term considerations. Our review of literature indicates that achievement of the desired benefits from advanced manufacturing technologies requires systematic and integrated planning rather than the adoption of new systems. Generally, AMT adoption can be divided into four major stages: strategic planning, justification, training and installation, and implementation.

The article presented here is followed by these four major steps to offer a systematic guidance for decision makers via the relevant literature. It also points out what factors should be considered and what conventional problems the company will encounter. As revealed by the literature survey, some technology evaluations are based on the weighted averages of expert or decision maker judgments. All of these judgments must be measured in numerical and exact values. We do believe that there is a need to consider both subjective and objective factors during the selection of technologies.

Subjective factors are commonly evaluated by the experienced decision makers or experts. It is most appropriate and convenient for them to express their opinions on the comparative importance of various factors in linguistic variable scales, i.e. very high, high, medium, low and very low, since the decision makers or experts feel comfortable in giving relative weighting in linguistics (Prabhu & Vizaykumar, 1996). It will be better and meaningful to convert these linguistic variables into fuzzy numbers to evaluate the technologies by using fuzzy multi-criteria methods. For these reasons, further development will be needed to study its advantages, limitations and accuracy compared with the conventional evaluation methodologies.

As evidenced by the literature review, it shows that most companies are only using one (i.e. strategic, economic or analytic alone)or hybrid evaluation approaches (i.e. strategic and economic or economic and analytic) to decide AMT investment. And thus, integrated approaches (i.e. strategic, economic and analytic) are recommended to quantify the tangible and intangible benefits throughout the technology investment. Since each individual evaluation technique can rectify another's deficiencies, a more accurate management decision can be made. ■

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