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Abstract: This paper presents factors in the process of adopting advanced manufacturing technologies. The process is believed to result in the Agile Factory of the future. The adoption process is analyzed in five phases: definition of the future factory, planning for future factory, selection of the right technologies for the future factory, implementing the future factory and preparing the workforce of the future factory. An annotated bibliography is also provided.

Factors in Adopting the Advanced Manufacturing Technologies: Transition to the Factory of Tomorrow

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EMGT 606 INDEPENDENT STUDY REPORT

FACTORS IN ADOPTING THE ADVANCED MANUFACTURING TECHNOLOGIES: TRANSITION TO THE FACTORY OF TOMORROW

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ABSTRACT

This paper presents factors in the process of adopting developing advanced manufacturing technologies. The adoption process is believed to result in the Agile Factory of the Future. The adoption process is analyzed in five phases : definition of the future factory, planning for the future factory, selection of the right technologies for the future factory, implementing the future factory, and preparing the workforce of the future factory. An annotated bibliography is also provided.

The second part of this paper is an annotated bibliography of approximately 100 research papers in this and related fields. The papers included are obtained both from academic and trade journals from the 1980's forward. The bibliography is recommended to the researchers in this and related fields as a base for their initial investigation. It should also be of benefit to the practioner considering adopting new manufacturing technologies.

1. FUTURE FACTORY

This section will introduce the factory of the future to the reader. The descriptions from previous research will be presented. The similarities and the conflicts between these studies will prove the need of better understanding of the future manufacturing environment.

1.1 INDUSTRIAL AUTOMATION

Odrey et al [C17,pp 3-5] segments industrial automation in three categories : fixed automation, programmable automation, and flexible automation.

The automobile industry is a place where good examples of fixed automation can be observed. Highly integrated transfer lines are employed for machining operations on engine and transmission components.In fixed automation the cost of the special equipment can be divided over a large number of units and the resulting per unit costs of equipment acquisition are low relative to other forms of production. However, there is a certain risk involved. Since the initial investment cost is high, if the volume of production turns out to be lower than anticipated, the unit costs become greater than the initial projected value. Another problem in fixed automation is that the equipment is only designed for a specific product which causes the equipment to be obsolete after the product's life cycle is finished.[C17,pp 3]

Programmable automation is generally employed when the volume of production is relatively low and there are a variety of products to be made. The production equipment in this case is designed so that it can be adapted to variations in product configuration. This adaptability is attained by operating the equipment under the control of a program of instructions which has been prepared especially for the given product. Because of the programming feature and the consequent adaptability of the equipment, various products can be manufactured economically in small volumes.[C17,pp 4]

The third category between fixed automation and programmable automation is called flexible automation. Flexible systems possess some of the features of both types of automation. It has to be programmed for different product configurations but the variety of the products is limited when compared to programmable automation and this allows a certain amount of integration to occur in the system.[C17,pp 5]

1.2 FACTORY OF THE FUTURE

Groover [C6,pp 776] claims that computer integrated manufacturing, CNC machines, robots, and flexible manufacturing systems are all directing the technology of manufacturing toward the fully automated factory of the future. Certain trends are occurring in manufacturing that will shape the factory of the future. These trends include ; shorter product life cycles, increased emphasis on quality and reliability, more customized products, new materials, growing use of electronics, pressure to reduce inventories, outsourcing, just in time production, point-of-use manufacture, greater use of computers in manufacturing. These trends are leading the way toward the computer integrated factory of the future. [C6, pp 776]

The "factory of the future" is thought to be a place where gleaming robots continuously monitoring and adjusting computerized machinery, rolling perfect, customized products down the assembly line. The excitement of the computerized "factory of the future" has captured the imagination of many people. As Meredith [A6, pp 27] describes Visions of robotized factories come to mind, whirring away in the dark throughout the night with only "ghost crews" to oversee them, or perhaps even totally unmanned, "lightless" factories.

Today's factories are not lightless factories, and will not be in the near future. These factories are full of managers, workers, supervisors, staff and support personnel. Therefore it is important to consider the human side of manufacturing strategy in order to implement the latest in computer integrated manufacturing to make the factory of the future a reality.

As Maleki [C11,pp 256] states, the factory of the future not only requires the implementation of advanced manufacturing technologies, but also totally depends on the kind of workforce that is knowledgeable about those technologies and has a high degree of motivation. This type workforce does not come easily and requires the attention of managers within different levels of organization.

Defining the elements of the factory of the future will help to identify the occurring changes. Meredith [A6, pp 31] classifies the current and emerging technologies into three groups: CAE; Computer Aided Engineering, CAM; Computer Aided Manufacturing, MRPII; Manufacturing Resource Planning. He later groups those technologies in three functional areas : Engineering Techniques, Manufacturing Techniques, Business Techniques. Even the techniques listed in this 1987 paper are becoming obsolete. Terms like total quality management, concurrent engineering, synchronous manufacturing, single minute exchange of dies, rapid prototyping, optimized production technology and agile manufacturing are becoming hot topics. Agile Manufacturing Enterprise Forum based in the Lehigh University claims that a new competitive era is emerging which they call Agile Manufacturing. According to the forum Agile Organizations will supersede mass/JIT/lean competitors.

"Agility is achieved in part by using science and engineering to leverage the information skills and decision making capabilities of the workforce for the success of the enterprise. This represents a major shift from our previous focus on using science and engineering to leverage the muscles, physical skills and dexterity of the workforce." [from the Agile Manufacturing Workshop 1993 brochure]

It can therefore be claimed that the factory of the future is not just a collection of a few hot buzz words, but rather a dynamic environment which is flexible in all dimensions. In a sense, the factory of the future is a way of thinking, rather than a way of operation. Although the future work place is expected to be full of surprises and requires full flexibility, the main elements and the possible changes to occur can be roughly estimated. Clancy [E4, pp 49] has done a very good job in highlighting the major differences occurring and having a high tendency to occur in his paper.

In the factory of the future, a manufacturer uses fewer suppliers, located in close proximity to the plant. Manufacturers schedule frequent smaller deliveries to eliminate inventory control costs. Few parts are stored centrally. Inventory is delivered, inspected, and stored where it is used. The shop floor is designed into cells to create several small assembly lines. Each cell has the machines required to build a complete product or component. The work in process is reduced due to fewer bottlenecks. There are several shorter assembly lines where workers control and perform many functions. Robots perform many manual tasks. Products are inspected as they move along the line. Workers are responsible for quality within their cells. Quality is built into the product. The percentage of wasted work and scrap is low. Finished products are shipped quickly and regularly. Workers are responsible for machine maintenance within the cell and conduct regularly scheduled preventive maintenance checks on all equipment.[E4, pp 49]

In the factory of the future, there are few layers of management. There are few job descriptions in which workers perform a variety of related tasks. Cross training is required to increase flexibility. The pay plan is pay for knowledge and skills based on training completed or skills acquired. Incentive compensation is based on group performance in such areas as production, quality, and innovation . Decentralized decision making and problem solving exist. Power is shared with workers in each cell as well as with management. Relationships are collaborative.[E4, pp 49]

2. STRATEGIC PLANNING

Meredith [A10, pp 229], reports that the difficulties and complexity of implementing the factory of the future are so well publicized that the major problems now have their own terminologies such as islands of automation, short term management attitudes, conducting the "as is" study, and so on. Meredith [A10, pp 229] also reports that the failure rate for implementing manufacturing resource planning systems is 80 percent. According to the same study [A10, pp 229], achieving a strategic goal of implementing a computer-integrated manufacturing facility will be accomplished neither quickly nor soon. Another study by Meredith [B14, pp 50] indicates that the broad extent of change required for CIM goes far beyond that required for previous manufacturing projects such as installing a robot or NC machine. The coordination needed, not just for the manufacturing functions, such as purchasing, quality control, and scheduling, but also all the other company functions - engineering, finance, marketing, accounting, human resources - is at least an order of magnitude greater than ever needed before, particularly for manufacturing projects.

Gerwin [A5, pp 90] in his 1988 paper developed a theory of innovation processes for computer aided manufacturing technology. The model had three stages: adoption, preparation and implementation. In this paper the major function in the adoption stage is believed to be the planning operations. According to Gerwin innovation in manufacturing processes is traditionally considered to have objectives such as improved productivity, better quality, or faster delivery time. It is also a tactic which, in the long run, handles uncertainties affecting technical core. Process innovation, however, threatens to pierce the core with new uncertainties in the short run during adoption and implementation as indicated by Gerwin [A5, pp 90].

2.1 DETERMINING THE MANUFACTURING STRATEGY

Gerwin [A5, pp 90] identifies three uncertainties in the process of introducing new manufacturing technologies:

"*technical uncertainty* refers to difficulty in determining the precision, reliability, and capacity of new processes, and whether still newer technology may soon appear to make the equipment obsolete; *financial uncertainty* includes whether return on investment should be the major criterion and whether net future returns can be accurately forecasted; *social uncertainty* is exemplified by questions concerning the nature of the required human support system, and by the possibility of conflict."

According to Gerwin [A5, pp 90], the tension created between the core's need for certainty and new equipment's generation of uncertainty is likely to account for many of the problems that arise during the innovation process. He [A5, pp 90], suggests that a good deal of human behavior can be analyzed in terms of efforts to deal with these problems by developing coping strategies which either avoid, adjust to, reduce, or take advantage of uncertainties. His theory describes behavior in terms of coping strategies and the problems which give rise to them.

During the adoption phase in Gerwin's model [A5, pp 91], the initial need for change is recognized and a decision is made on whether to install the innovation. The participants in this stage deals with the most uncertainty. Those participants are vendors who are according to Gerwin [A5, pp 91], are a critical element of the innovation process. Other group members are the focal organization's innovating group, as well as its technical task force, which includes the new technology's champion. All these individuals make recommendations on hardware, software, and vendors.

Meredith [A10, pp 229], describes the champion to be the one who perceives the potential future in a new process and adopts the successful implementation of the process as a personal crusade, inspite of the possible risk, not only to the project, but also to his/her own career. According to Meredith [A10, pp 229], the champion typically has a vision of the firm's future were it to adopt the process innovation and strives to make this vision a reality.

Gerwin [A5, pp 91], introduces the concept of performance gap which is the positive difference between aspirations and performance on some dimension relevant to the organization. Gerwin claims that financial uncertainty is at the heart of the technology selection process. He suggests two coping strategies to deal with this uncertainty: short term policy orientation which will attempt to avoid uncertainty by stressing a short run time horizon, financial control, and profit maximization in decision making; and long term policy orientation which will attempt to live with uncertainty by emphasizing a long run time horizon, adaptive planning, and minimizing the chances of disaster.

Gerwin draws to major propositions [A5, pp 92-93]:

" 1. The more strategic management's basic values reflect control and efficiency ,the more advanced is the technical core's stage of development and the greater the manufacturing technology's technical complexity, then the more likely is strategic management to adopt a short term policy orientation.

" 2. The more confident the task force appears to be in its recommendations, the less it biases them and the greater the champion's reliability, then the greater will be strategic management's confidence in the recommendations."

Soska et al [A11, pp 13], provides a list of suggestions for factory automation :

" 1. Begin your automation plan by looking at the overall strategies of your business, then work your way backwards into the factory.
2. Plan from the top, then implement from the bottom.
3. Avoid tendency to consider individual pieces of automation equipment in isolation from the total business equation.
4. Straighten out the information flow, before you purchase equipment.
5. Straighten out the material flow before you purchase equipment.
6. Aim for "pay as you go" automation. Prioritize and sequence your action plan so you can pay for automation as you go.
7. Don't make direct labor the prime target of automation
8. Be prepared to redesign your product.
9. Communicate every step of the way
10. Get on with it! "

What Soska et al [A11, pp 13] suggests is actually an integrated automation rather than piecemeal automation.

Grant et al [B8, pp 53], stresses the fact that each business is unique in terms of its goals, resources and product market conditions. As a result, there is no best process technology: programmable robots are not necessarily superior to manual assembly, JIT production is not necessarily superior to push systems replete with buffer inventories between production stages. The appropriate manufacturing technology for a business depends critically on the circumstances of that business with regard to its strategic goals, its resources, the resource availability within its regional and national economy, and the characteristics of its product-market environment.

The critical requirement for sustainable competitive advantage is that manufacturing seek dynamic rather than static optimization. The critical decision variables are the size of technological increments and the priority that the firm gives to different areas of manufacturing technology.

2.2 EVALUATING OF THE MANUFACTURING STRATEGY

Wheelwright [B22, pp 82], deines three primary levels of strategy in a manufacturing firm : corporate, business and functional, corresponding roughly to the organizational units charged with formulating and pursuing each level of strategy.

" Corporate strategy specifies two areas of overall interest to the corporation: the definition of the businesses in which the corporation will participate, and the acquisition of corporate resources and their commitment to each of those businesses. Business strategy refers to two critical tasks carried out by each strategic business unit or strategic planning unit. First it specifies the scope of or boundaries of each business in a way that operationally links the business strategy to the corporate strategy. Second, it specifies the basis on which that business unit will achieve and maintain a competitive advantage. Functional strategy must be developed and pursued if each function is to support business strategy. A business might have four functional strategies : a marketing strategy, a manufacturing strategy, a research and development strategy, and an accounting strategy. A functional strategy specifies how that function will support the desired competitive advantage and how it will complement the other functional strategies."

According to Wheelwright [B22, pp 84], a manufacturing strategy has 8 dimensions:

" 1. Capacity - amount, timing, type
2. Facilities - size, location, focus
3. Technology - equipment, automation, connectedness
4. Vertical Integration - direction, extent, balance
5. Workforce - skill, level, pay. security
6. Quality - defect prevention, monitoring, intervention
7. Production Planning - computerization, centralization, decision rules
8. Organization - structure, reporting levels, support groups "

The overall evaluation of a manufacturing strategy based on Wheelwright's study [B22, pp 85], can be based on :

a. Consistency
   1. between the manufacturing strategy and the overall business strategy
   2. among the manufacturing strategy and the other functional strategies within the business
   3. among the decision categories that make up the manufacturing strategy
   4. between the manufacturing strategy and the business environment

b. Emphasis on competitive success factors
   1. making trade-offs explicit, allowing manufacturing to prioritize activities
   2. directing attention to opportunities that fit the business strategy
   3. promoting clarity regarding the manufacturing strategy throughout the business unit

Branco [A2, pp 36], developed a similar model. His model suggests a set of corporate and a set of manufacturing success factors. The corporate success factors are : 1. getting new products to market quickly at low cost, 2. creating a pervasive cost orientation throughout the organization, 3. achieving and maintaining a work environment where people can be most effective, 4. hiring and maintaining quality people, 5. finding and implementing manufacturing processes and practices that achieve cost superiority and systems that provide manufacturing capacity and increase responsiveness.

Based on the corporate success factors Branco [A2, pp 37] suggests the following manufacturing success factors:

"1.achieve cost superiority, 2.product/process focus, 3.cost orientation, 4.group/process technology, 5.reduce design/delivery cycle, 6.reduce material costs, 7. people work environment, 8.hire/retain quality people, 9. promote integrated approach"

As seen in both models, success is measured based on integration. The focus should be measured not in success of individual projects but rather in the contribution and integration of all units.

2.3 DETERMINING THE START POINT

The problem of deciding what to automate is one of function allocation. Given that the system must perform certain basic functions, which ones should be performed by a machine and which should remain a job for the human operators ? Boyd [A1, pp 3] suggests that first the system purpose must be defined in general terms. The next step he suggests is to derive concrete specifications to which the system must conform. These are actually operational requirements which describe what the system must do to accomplish the mission. Operational requirements serve as a criteria by which the performance of various design options can be evaluated. The next Boyd [A1, pp 5], uses is setting the operational constraints which are the real world restrictions.

Based on the operational requirements and operational constraints, the pre-identified functions can be allocated. Bailey is reported by Boyd [A1, pp 7-9] to identify five different strategies for this last step of function allocation: 1.*Comparison Strategy* - is based on a comparison of human and machine capabilities and limitations. This strategy focuses almost totally on performance and it assumes that people will be willing to do those things which the machine does not do well, and will be willing to give up those functions at which machine excels. 2.*Leftover Strategy* - is automating everything and letting human operators get the functions that are leftover. This kind of strategy may require huge initial capital outlays and it may take longer to get the system operational. 3. *Humanized Strategy* - tends to justify jobs, taking full advantage of human capabilities, while compensating for human limitations. 4.*Economic Strategy* - focuses on cost as a central basis for allocation decisions. 5. *Flexible Strategy* - assumes that the operator is in the best position to make the decision whether or not the machine should take over.

Elavia [A3, pp 19-21], suggests a comprehensive model which has two stages. The first stage called "as is" needs analysis, includes six major tasks: project initiation, functional analysis, cost analysis, improvement analysis, improvement prioritization, needs analysis report. The second stage called the "to be" conceptual design includes two major tasks: analyzing productivity drivers and any barriers to them, defining technology needs.

Consequently it is seen that organizations need a link that will connect the manufacturing strategy to technology selection. Several models which have been developed are presented in the next section.

3. SELECTION AND JUSTIFICATION OF THE RIGHT TECHNOLOGY

Traditional capital investment decisions performed by engineers dealt primarily with the replacement or retirement of obsolete equipment in manufacturing firms. Today, rapidly changing technology and shortened product life cycles lead to an uncertain economic environment.

Mansfield [C12, pp 158] suggests that the use of flexible manufacturing systems is spreading relatively slowly. Non-users of these systems, particularly in the United States, have tended to require higher minimum rates of return to justify investments of this sort than users. In the United States , where users on the average required a minimum rate of return of 27 percent, nonusers of 34 percent.

3.1 TRADITIONAL COST JUSTIFICATION

Traditional cost-justification techniques are based on comparing the potential return from a particular project to the return that could be gained from other investments. In this section four basic techniques are discussed:

The payback period - divides investment cost by net annual savings to determine the time required to recoup the investment [B16, pp 45] . If the investment can be recovered below the company's target payback period, the investment is justifiable. Airey et al [B1, pp 52] report this is the simplest and most commonly used method of investment appraisal. It is an easy concept to understand and is extremely useful as a first financial check on a new project to see whether it is likely to be financially viable. However, this technique ignores income after the payback point, is biased against investments with the highest return in the later years of the project and is inadequate for rigorous analysis of all the variables and for systematic comparison purposes[B1, pp 52]. Payback can be considered a proxy for risks, however, in particularly where short product life cycles are dominates.

Return on investment - calculates the rate of interest required to make future savings equal to the investment cost. If the rate exceeds a set hurdle rate, the investment is justifiable. According to Airey et al [B1, pp 53], the ROI concept can provide a useful yardstick for measuring the past performance of a business, but it is less useful for assessing future projects because it ignores the project life, takes no account of either the timing of the investment or its benefit, and is unsuitable for optimising investments.

Discounted cash flow - is concerned with the flow of money and its timing over the life of a project. Airey et al [B1, pp 53], point out there are several different applications of the basic DCF technique two of which are internal rate or return and net present value.

3.2 EVALUATION OF THE ADVANCED MANUFACTURING TECHNOLOGIES

As Hill et al [B14, pp 49], illustrate the difficulties of justifying new manufacturing systems are becoming legendary. The system's most important benefits are often strategic and difficult to quantify. Noble [B16, pp 46] suggests three types of justification for computer integrated systems: *Strategic Justification* - For strategic justification, three types of evaluation are required: strategic planning, market assessment, and functional analysis. *Cost Justification* - Costs should be broken down in as much detail as possible to compare alternatives. Costs often overlooked in justification calculations include indirect labor, inventory, quality control and floor space. *Benefit Analysis* - Strategic and cost justifications focus on feasibility and tangible cost savings. Benefit analysis can be used to assess intangible benefits and CIM's overall ability to meet strategic objectives.

Meredith et al [B14, pp 58], classified the cost justification according to the level of integration of manufacturing system technology. This model recommends the traditional economic techniques which are payback, ROI, NPV, and cash flow only for the stand alone level. For the next advanced level the existence of cells, the model recommends portfolio techniques such as: *programming models*, include linear, integer and goal programming formulations. Each project can be represented as a 0-1 variable in an integer program selecting projects that maximize a set of weighted scores; *scoring models*, which let the manager determine a set of relevant factors and then assign each project a score for each factor which are then summed up to calculate the total score; *growth options* which consider future investment opportunities.

For linked islands of automation types, Meredith et al [B14, pp 54] recommend analytic techniques which are value analysis and risk analysis. Finally for full integration the model recommends strategic techniques Those are factors such as thr *technical importance* of the project for other favored projects, the appropriateness of the project to *business objectives*, and *competitive advantage* that will come with the project.

Troxler et al [B21, pp 180], recommends a different concept called manufacturing System Value for evaluating the advanced manufacturing technologies. System Value has four attributes: *suitability, capability, performance,* and *productivity*. Suitability is a measure of compliance with corporate strategy. The determining factors of this attribute are investment, growth, technology position, market position, employee relations, workforce composition,

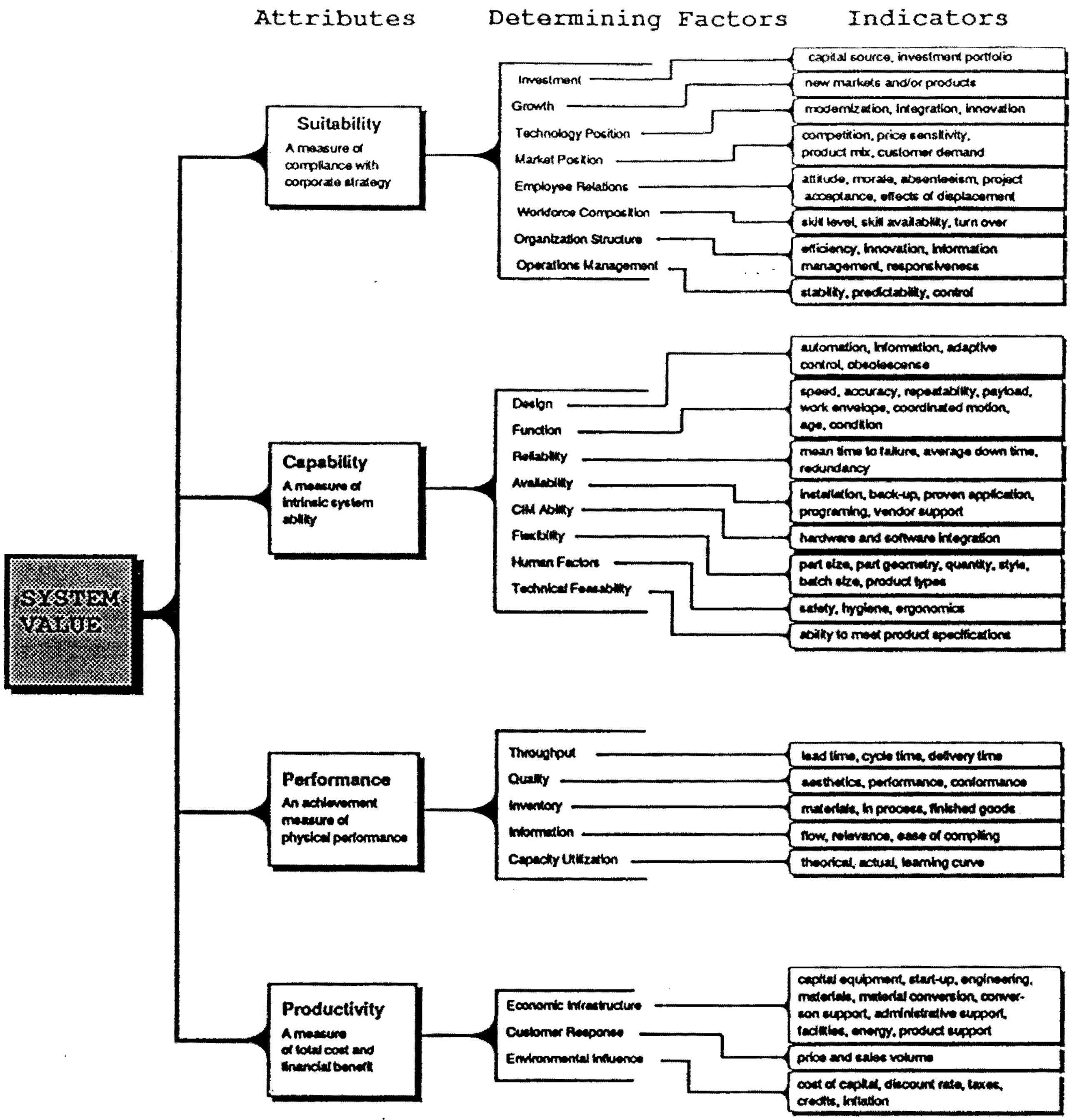

Figure 1. Representation of Manufacturing System Value [B21, pp 179]

organization structure, and operations management. Capability is a measure of intrinsic system ability. The determining factors in this case are design, function, reliability, availability, CIM ability, flexibility, human factors, technical feasibility. Performance is an achievement measurement of physical performance. The determining factors of this attribute are throughput, quality, inventory, information, and capacity utilization. Productivity is a measure of total cost and financial benefit. The determining factors are economic infrastructure, customer response, and environmental influence.

Swamidass et al [B19, pp 184], have identified five major groups of justification methods: discounted cash flow, cost and benefit analysis, scoring methods, risk analysis, computerized approaches and methods measuring the strategic value of flexibility. This study [B19, pp 181], has reviewed twenty-six other research reports to identify the benefits of new manufacturing technologies. Those benefits are reported to be decrease in workforce, in processing time, in lead time, in various costs, in work-in-process, in number of machines, in set up time, increase in quality, in productivity, and in output.

3.3 FLEXIBILITY CONCEPTS AND MEASUREMENTS

Gupta et al [B9, pp 119], reviewed the literature on flexibility concept and measurements. The general definition of flexibility provided was flexibility being the ability of a manufacturing system to cope with changing environments or instability caused by the environment. Brown et al, is reported by Gupta et al [B9, pp 121], to describe manufacturing flexibility in terms of the following eight characteristics:

" *Machine Flexibility* : The ability to replace worn out or broken tools, change tools in a tool magazine , and assemble or mount the required fixtures, without interference or long setup times.

	This is the ease of the system in making changes required to produce a given set of part types.
Process Flexibility :	The ability to vary the steps necessary to complete a task. This allows several different tasks to be completed in the system, using a variety of machines.
Product Flexibility :	The ability to change over to produce a new product, within the defined parts spectrum, economically and quickly.
Routing Flexibility :	The ability to vary machine visitation sequences and to continue producing the given set of part types.
Volume Flexibility :	The ability to operate an FMS profitably at different production volumes.
Expansion Flexibility :	The capability of building a system and expanding it as needed, easily and modularly.
Process Sequence Flexibility :	The ability to interchange the ordering of several operations for each part type
Production Flexibility :	The ability to quickly and economically vary the part variety for any product that an FMS can produce.

Nelson [B15, pp 347], suggests a model for identifying, evaluating, and prioritizing manufacturing modernization projects. The model is a linear combination of five terms.

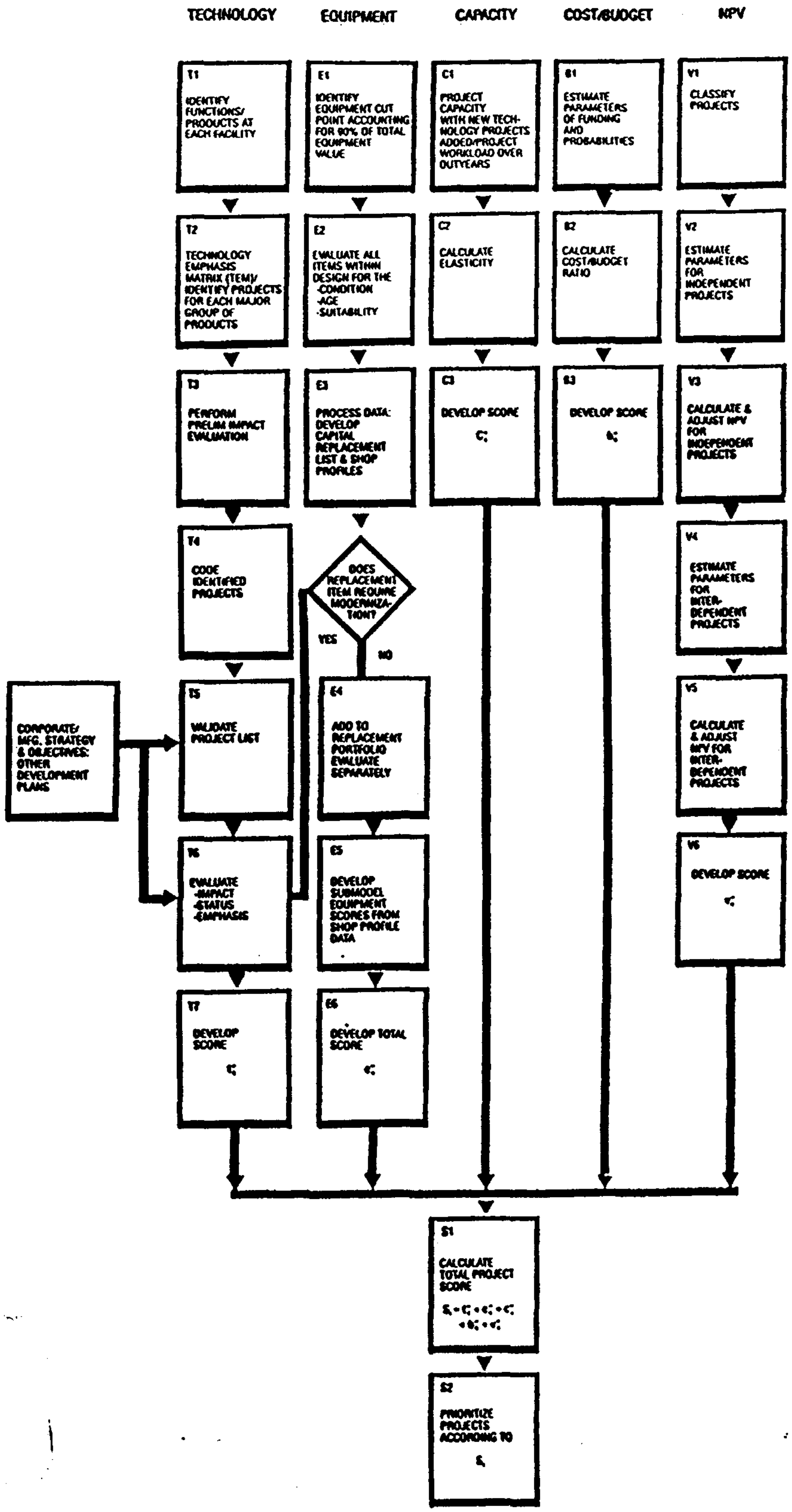

Figure 2. Generalized Score Development [B15, pp 348]

The Technology assessment score, t_i is for project identification and evaluation. This score is made up from three scales: an emphasis scale which measures the concept of strategic need from a local facility view, a status scale which measures the state of knowledge of the proposed technology and its use in the market place, and an impact scale which measures the benefit directly attributable to the proposed project. *Equipment evaluation score,* e_i is a measure of the need for modernization from a survey of existing equipment. *Workload elasticity of capacity score,* c_i is dependent on the ratio of the percent change in capacity divided by the percent change in workload, based on point estimates of these variables for each outyear of the planning horizon. *Cost / budget ratio score,* b_i measures the degree to which total estimated project investment is within the limit of estimated funding. *Net present value score,* v_i is a result of complex formulation which is actually adjusting for risk and interdependencies. s_i is the total score expressed by the following equation.

$$s_i = t_i + e_i + c_i + b_i + v_i$$

Arbel et al [B2, pp 608], developed a hierarchical performance evaluation model for flexible manufacturing systems. Three major bases of evaluation are economic, production and organizational issues. The next level of evaluation includes line efficiency, performance, process, volume and configuration control issues. This method has been useful in the incorporation of various levels of expertise into an integrated framework.

All these studies agree that advanced manufacturing technologies require more complex evaluation compared to the evaluation of the existing technologies.

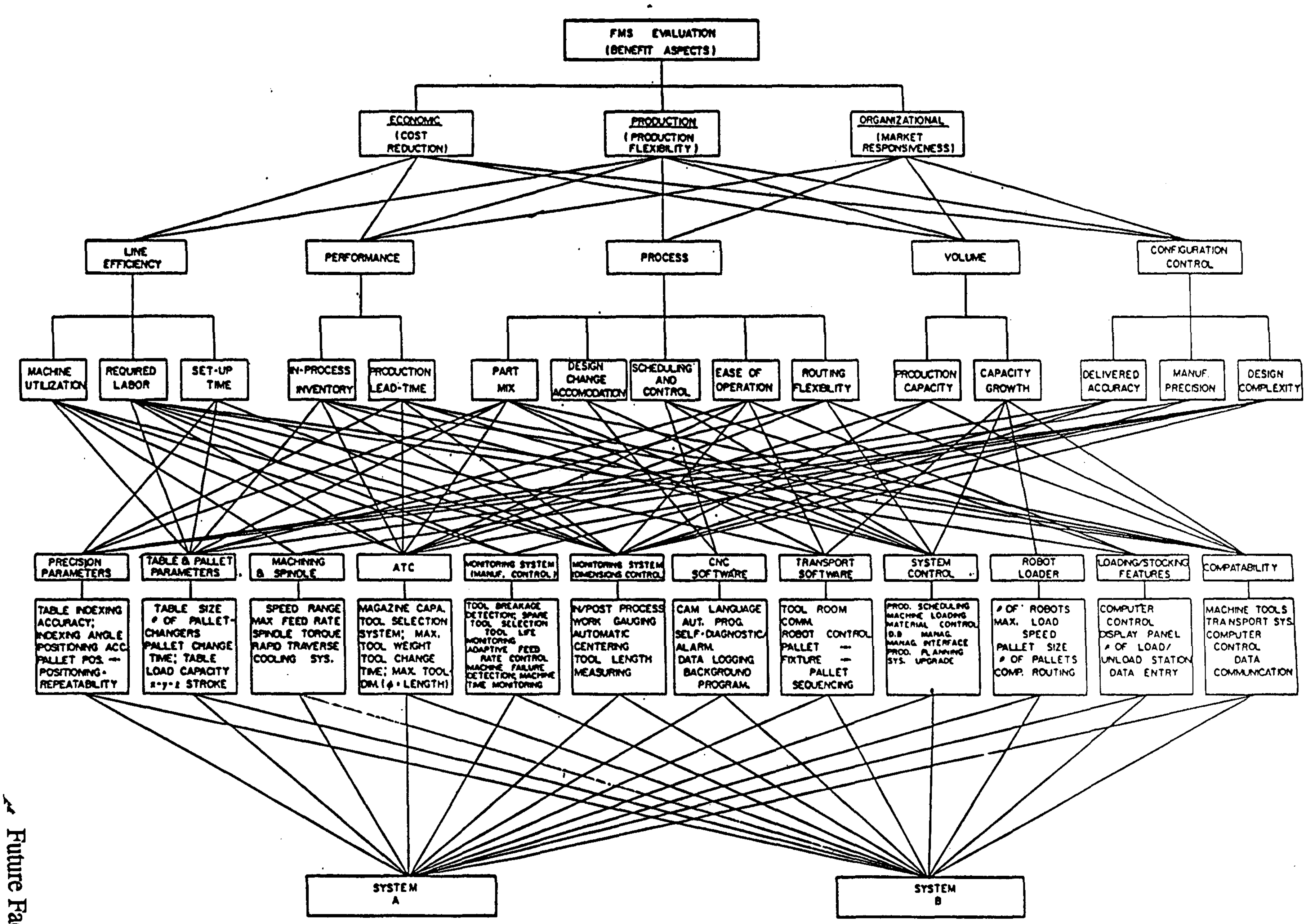

Figure 3. The Performance Hierarchy [B2, pp 610]

4. IMPLEMENTATION

Many researchers and executives have been studying the concept of the factory of the future and recommend to implement it with advanced manufacturing technologies. King et al [D6, pp 139], in their 1992 paper focused on the objectives that are set by manufacturing companies when they start on implementing advanced manufacturing technologies, and on their perceptions of the extent to which they believe they have achieved the stated goals. Their results [D6, pp 140] indicate that manufacturing firms in the US are currently more concerned with addressing micro-level operational issues through advanced manufacturing technologies rather than the more strategic benefits that these technologies are capable of enabling.

As King et al [D6, pp 140] reports, despite the fact that these investments had the significant support of top management in the initial stages of the adoption decision, the firms in the study fell short of achieving even those objectives they perceived to be important.

Kunnathur et al [D8, 376] in their 1992 paper provides an implementation plan for flexible manufacturing systems based on their analysis of five distinct FMS installations:

* DO's
  - include input from functional units on an on-going basis,
  - encourage MIS participation for analysis of software capabilities and limitations,
  - set up a master plan for initiating and monitoring automation projects,
  - use evaluation criteria tailored to automation projects,
  - build infrastructure needed for automation projects in the long term,
  - plan for integrating automation into the portfolio of manufacturing facilities,

Don'ts

- evaluate FMS projects as one time occurrences,
- bundle software and machinery acquisition decisions,
- contract for turn-key installation,
- create islands of automation "

Gerwin [A5, pp 95], suggests the chances for successful implementation depend upon the expectations which have been developed for the innovation, the performance of the innovation and the extent of intraorganizational conflict. Gerwin [A5, pp 96-97] discusses six major propositions for the implementation process:

" 1.The greater the scope of the problem definition, the greater the level of expectations for the innovation.
2.The greater the scope of the problem definition and the greater the product's recency, then the greater the ambiguity of expectations. The greater is technical complexity and the lower is the infrastructure's sophistication, then the greater is the ambiguity of performance measures.
3.The greater the innovation's technical complexity and the lower the sophistication of the infrastructure, the lower the level of performance.
4.The greater the divisibility of the innovation, the less its technical complexity.
5.The greater the increase that has occurred in the infrastructure's sophistication and the greater the ambiguity of expectations and performance, the greater the intraorganizational conflict.
6.The greater the performance gap, then the greater the adjustments in the innovation, the infrastructure and in expectations in order to reduce the gap. "

4.1 IMPLEMENTATION STORIES

Although the United States still currently lead the world in developing automation technologies, Japan has been more successful in implementing them. Huang et al [D4, pp 102] in their 1990 paper, summarized the approaches utilized by the Japanese firms:

" 1.Very few Japanese companies were concerned about the potential negative impact of factory automation (FA) on short term profit.
2.The Payback period method is, by far, the most popular financial justification technique employed by Japanese companies to evaluate FA investments.
3.FA system design and vendor selection were typically conducted by company employees, not outside consultants.
4.Most surveyed companies spent two years or less to complete a typical automation project.
5.System design and software development were identified as the two most time-consuming tasks in an FA project.
6.Reduced labor cost, improved quality, and increased flexibility were the three apparent benefits of FA.
7. Exorbitant cost, increased need for technical expertise, and lack of adequate software were identified as the most serious difficulties which Japanese companies have experienced. " [D4, pp 103]

Meredith [A8, pp 1] points out that many companies in U.S. are reluctant to install advanced manufacturing technologies, and those who do frequently are not reaping the advantages the technologies can offer, largely because of the difficulties of implementing these expensive, complex systems. Meredith [A8, pp 2] identified the difficulties or so called implementation barriers to be :

" 1.*Insufficient internal skills*: Highly complex , frequently computerized advanced manufacturing technologies challenge the knowledge of the oldest manufacturing manager as well as the experience of the youngest.
2.*Implementing computerized systems*: When there are numerous interfaces with the rest of the organization, implementation of computerized systems becomes an extremely difficult task.
3.*Multiplicity of implementation paths*: Implementing factory automation entails even further difficulty because of the multitude of apparent potential paths available to the firm.
4.*Limiting or multiplying synergy*: Adopting one technology or system at an early stage can limit a firm's options at a later stage. Similarly a wise choice of technology at an early stage can significantly multiply the benefits achieved at a later stage.

5.*Incremental skill building*: Mistakes are an extremely expensive way to gain experience with these technologies, therefore, moving slowly and deliberately will often pay dividends in the end.
6.*Different support infrastructure*: Technologies require an infrastructure of supporting policies, systems, and procedures considerably different from what exists in most firms today.

Marks [D10, pp 165] reports, based on a survey of CIM directors in U.S. companies, that the overall needs for integration cut across at least three dimensions of the organization. Marks [D10, pp 165] identified those dimensions to be : inside to outside, which is a dimension focusing on customer; beginning to end which is a dimension focusing on the communication between functions like engineering, manufacturing, and even procurement; and top to bottom, which is dimension focusing on the communication among the levels of management. Those three dimensions are actually three different levels of integration that the CIM directors have been targeting.

4.2 IMPLEMENTATION OF AMT IN SMALL COMPANIES AND DEVELOPING COUNTRIES

From the descriptions of firms implementing high technology manufacturing programs it would appear that only large companies can benefit from these new manufacturing technologies. Meredith [D11, pp 249] argues that small firms are just as well, or better equipped to implement and benefit from these technological advances. Knowing that almost 80% of all manufacturing firms employ less than 100 employees [D3, pp 39], studying implementation in small companies can be considered as a vital issue for the manufacturing sector in U.S.

Meredith [D12, pp 10] points out that the new technologies seem to offer the types of benefits that small firms are already used to competing with: fast customer response, quick production, more customization, greater variety, and so on. Yet these technologies are a major commitment for small firms. Selective investment at critical points in the production process will be the key factor for small firms, not massive investment in greenfield plants.

Meredith [D11, pp 258] estimates the critical point to be in either design (CAD), or engineering (CAE), or manufacturing (CAM). But wherever it is applied, the small firm must be able to capitalize on the new technology's benefits to provide a significant competitive advantage over others in its market.

The situation in countries other than the US and Japan can be viewed as similar to implementation in small companies. The results of a survey done in Germany by Kohler et al [D7], indicate that the utilization of CIM components and their integration is limited. The authors point out that the chosen strategy for implementing CIM components and systems plays an important role in determining the direction of technological and organizational change in companies.

Margirer [D9], thru series of interviews has identified that as a result of the slight improvement in industrial investment in France, the diffusion of FMS is beginning to pick up, although the size of these systems is smaller than before. The results of the interviews indicate that industrialists have learned from the non-optimal performance of large systems whose complexity constitutes an obstacle to efficiency.

5. PREPARING THE FUTURE WORKFORCE

There has been a significant change in business methods and technologies employed in the manufacturing industry in the last 10 years. This change has experienced a very high acceleration. This volitile rapid process has naturally affected the labor force. The strategy for management of human resources during this critical period determines the overall performance of the company. The key to the success in implementing new technologies depends very much on human factors and considerations.

" American industry has been at the leading edge of new techniques and technologies. However, for a number of years, this industry has been trailing in implementing these new techniques and technologies. Why? Most of the focus has been on the tool and has, for the most part, ignored how the worker will use the tool" [C11, pp 256]

Vanderspek while describing the challenge in the manufacturing sector claims that "many chief executive officers and general managers are not prepared to deal effectively with the question of whether, when, how, and to what extent their manufacturing operation should be updated by the introduction of totally new methodology and equipment" [C27, pp 6].

Both studies cited above agree that both line workers and managers need to be educated so that the workers will perform their best without any doubts and managers will know what to expect from them.

As it can be induced from the results of many surveys and research effort, all the workforce involved with manufacturing has been affected by changes in manufacturing technologies and business methods. The important point to be kept in mind is that the workers on the floor are not the only ones who should be ready for the changes.

The strategies of managing operations, managing and leading human resources and perhaps managing the whole business should be reevaluated. Management should prepare for the changes, they should go over the past mistakes and develop new dynamic strategies. The question is, How?

Managers can use a number of methods related to the human infrastructure of organizations to anticipate and implement new factory technology successfully. These methods include selecting employees with skills needed to handle the new technology, structuring programs to meet increased training needs, and using personnel policies, such as equitable compensation and job security , that facilitate automation. Majchrzak [C10, pp 149] develops a "human infrastructure impact statement" that addresses many of these issues.

5.1 ASSESSMENT OF THE WORKFORCE

The introduction of any new technology will change the way in which organizations recruit their employees. According to the study done by Crocker and Guelcker [E5, pp 31], in the past employees entered businesses immediately after they left school and then set about working their way to the top. Today, however, recruitment is geared to the employee who possesses a strong technological background and interaction and communication skills - skills not generally gained in high school or university programs. One of the findings of Crocker and Guelcker [E5, pp 31] study was since there is a shortage of people who can cope with the demands of robotics and are willing to begin their careers doing basic clerical jobs, personnel departments will have to work harder, both in their actual recruiting and in ensuring that conditions within the organization are geared to attract such people. Lack of motivation may be a significant problem; change naturally causes resistance, and managers will have to expect delayed schedules, decreased performance, and sabotage. [E5, pp 31]

Crocker and Guelcker [E5, pp 31] identify several reasons that a decrease in motivation may occur. With automation, pay increases may be rare. In some cases, take-home pay will decrease. Since human labor is relatively expensive, human services are replaced by those of the machine. Upward mobility will be harder to achieve. One of the reasons Crocker and Guelcker [E5, pp 31] identified as a source of demotivation is that clerical workers will have more trouble getting promoted to professional and managerial positions due to the large number of professional and technical employees. Thus career planning will be more difficult and less predictable. The problems involved in implementation of robotics will be considerable, and employees who assume the responsibilities for these activities will expect to be rewarded. Salary increases for these employees might have an ascending effect. To obtain the required specialists, personnel departments may have to recruit outside their own organization which generally demoralizes those who are currently employed at that organization. Psychological problems will be created for workers because the new technology will break up existing social interactions and will result in worker isolation. This could cause workers to feel more alienation. [E5, pp 31]

Another issue is that automated systems can seriously reduce job opportunities for the young, the unskilled, older and less mobile employees, women, African Americans and other minorities. According to a study conducted by the International Labor Office in Geneva ; technology in banking resulted in a great deal of job loss. It diminished the need for low-skilled clerical jobs; and it resulted in a specialization of tasks that in turn led to increased depersonalization in the work area.[E5, pp 32]

One of the interesting conclusions made by Crocker and Guelcker [E5, pp 32] was that organizations might also experience an increase in employees' social and emotional problems resulting from displacement and the stress of coping with the robotic mentality. Computers currently accumulate employees' second-by-second behaviors and performances: When management utilizes this monitoring information to control workers and make personnel decisions , greater stress and anxiety over careers will result. Some employees will undoubtedly feel that they are slaves to the robots they monitor. When problems occur, they will be of greater magnititude and will present a greater challenge. Those who can not cope will feel increased stress.[E5, pp 32]

Many surveys [C20, pp 142] indicate that greater motivation may also result from introducing new technologies. According to the Japanese Management Association many workers have a much better attitude toward their jobs since automated systems have been introduced into work processes; that there has been an increased interest in jobs; and that workers have become more alert of, and careful toward, the work processes in which they are involved.[C10, pp 142]

5.2 ASSESSMENT OF THE MANAGEMENT

Gerwin [A5, pp 90] reports: "A good fit is the result of a company having developed not only a coherent strategy but also a human and technical infrastructure to support its manufacturing equipment..."

Gupta [E7, pp 34] in a study where he focuses on human aspects of flexible manufacturing systems, points out the issues management has to consider . First, management should analyze the skills and experience of the workers and find out if they would be capable of carrying out their tasks after the new system is implemented. Management should figure out the new tasks that will emerge after implementing the new system. The fit between the workers' abilities and the new tasks that will be created should be analyzed. Involvement of the workers in the system design is another positive factor which facilitates the new system's acceptance.[E7]

When introducing robotics, management should analyze the concerns of the workers about the change. According to a study done by Argote, Goodman, and Schkade [E1, pp 39] from Carnegie Mellon University, workers are likely to be most concerned about job security and pay. Introducing robots before resolving such questions is likely to reduce the effectiveness of the introduction.

The organization itself should also be analyzed. This is a critical issue and will help the managers be aware of future problems that are likely to appear after the introduction of robots, such as job loss or new job activities. In the case of robotics, worker involvement is also necessary. This involvement is likely to increase understanding about the robot and may perhaps lead to greater commitment to the change process. In introducing robots demonstrations that illustrate the operations of a robot can be a powerful communication technique. A feedback mechanism is also vital in monitoring communication effectiveness in introducing a new technology. [E1, pp 39]

Researchers from Carnegie Mellon [E1, pp 40] believe that first line supervisors should be given the information about the robot and support from upper management in dealing with workers' reactions to the robot. Workers, in times of change , are likely to go to their supervisors more frequently for information and advice. The behaviors of supervisors have a large and critical effect on the success of the robot introduction. Management should do a careful analysis of the new job activities that has been created with the introduction of the new technology so that they can maximize the fit (mentioned above) ,between job characteristics and the personal characteristics of the worker. A poor fit between a job and a particular worker may have a dysfunctional effect on both the individual and the organization. The question is not just whether the worker can do the new activities but whether the worker can do and prefers these activities. In the case of a poor fit, an alternative selection process should be considered.

5.3 SELECTION OF THE WORKFORCE

New technologies are having and are going to have numerous impacts on the workforce. The tendency now is to increasing the level automation. This will cause a gradual decline in the number of employees just as the number of agricultural workers has dropped as a result of farm mechanization.

Vanderspek[C7, pp 117] estimates that this decline will be offset to a substantial extent by an increase in demand for employees in other economic sectors that interact with manufacturing.

A study done in Germany by Lahner [E9, pp 286] demonstrates that by implementing new technologies, jobs are created to a very limited extent. However, new technology is used to economize on labor, so that these effects virtually cancel each other out. New jobs are more likely to be created by companies wanting to expand - in other words, changes are predominantly based on the positive development of demand, rather than on new technologies.

According to Majchrzak [C10, pp 145], after identifying the skill requirements needed for advanced manufacturing technology jobs, careful selection of workers for these jobs becomes essential. There are three questions to be answered to approach the solution of this problem:

1. How many workers are needed ?
2. Where do they come from ?
3. What is the criteria for selection ?

Based on a number of surveys Majchrzak [C10, pp 146], found that many times the direct labor replacement factor provided by vendors is used in estimating the number of workers required to operate the new equipment. The problem with this method however is that there is no information about the indirect labor replacement.

The production rate at which the plant will be running after the new equipment is installed will not be the full capacity rate. Due to poor planning, the initial rate may be less than the full capacity. Initially there may be a need for a fewer number of workers, but it should be kept in mind that this number is going to increase. Planning the implementation process appropriately will enable the project people to estimate the right speed of installation. In similar cases the number of workers stays surprisingly constant[C10, pp 147]. This is because the organization as a system has enough time to absorb additional workers into other production environments, create market niches, and control for seasonal fluctuations in inventories. Design of jobs will affect the number of workers, too. Job designs that are very rigid and narrowly defined may require more people than flexible job designs that allow workers to share job tasks. Identifying the pool of workers is the next step in the selection process. Lay offs are a choice prefererred in some cases. It has been observed, however, that lay offs affect worker motivation in a negative way and also cause union problems. Management's philosophy about retraining determines the pool of workers. The last step is to set the selection criteria so that the number of workers can be determined. The traditional ways are so called seniority and skimming of the cream. Seniority is selecting the workers according to the number of years they have been working. This will form a group of old workforce having a few years to retirement or having the probability of getting an early retirement. Skimming off the cream is the selection of the best workers, without regard to seniority or service. This may not be possible under some labor contracts or viewed as fair in some labor settings.

5.4 CRITICAL NEED FOR TRAINING

Clancy [E4, pp 49] claim that training is a major factor in creating competitive advantage. The factory of the future uses flexible automation where the shop floor is organized into cells. This results in several short lines instead of a few long ones. Each cell can run a specific product or a major piece of a product or they can all run the same product. Within a cell, machines found in many departments now work together under the control of the cell supervisor. As a result, workers in each cell must have the skills to operate a variety of machines, the ability to control the manufacturing requirements of diverse products and the knowledge to manage people, the process, and the various product requirements.[E4, pp 49]

As Helfgott [E8, pp 69] also claims that getting ready for the factory of the future is a time consuming process but the training is an immediate requirement for the sake of the success of the implementation of new technology. Early action is needed for training. The project team that will implement new technology is the first group of personnel that has to get this initial training.[E8, pp 69]

A number of researchers [E2,3,12,13,15] agree that prior to preparing the training program, the risks in implementing new technology should be analyzed so that the priorities in training can be determined. Getting top management's support will help to expand and fund the training program. Again, the involvement of workers in defining the new jobs will lead to a good integration.

According to Osborne [E13, pp 65] when selecting people to train, volunteers are the ones that should be considered. Major efforts to learn new skills will be needed. Highly motivated individuals are a must for doing the hard work, especially during the start up. The people needed have to be initiators. Middle managers should have direct responsibility for training because they are the ones that know enough about the unique requirements of their own customized systems and interfaces to manage the training close enough.[E13, pp 65]

Rosato [E15, pp 72] points out that in running a training program, a training team where a work sharing environment exists, is a must. Trainers have to look inside as well as outside the organization, especially for people who have done training before. During the transition period, it is important that trainers look for simple solutions. Especially since many things are completely new, trainers should look for solutions that have worked in their organizations as well as in other organizations. In order that the management and the workers can understand the training risks, trainers should be able to speak the language. This means that they have to make themselves familiar with the technology and the software. Scheduling the training program is another vital issue. Management will want to see the factory running in a very short period of time. Even with this pressure, the trainers should not plan to climb a mountain of learning in a short time. Realistic expectation levels should be set.[E15, pp 72]

The factory of the future provides training professionals with the opportunity to manage change in their organizations as well as the opportunity to expand their training skills. In fact, training is one of the key functions in implementing the factory of the future. To succeed, training departments must take the lead in preparing for change. Technologic improvements will result in heavy requirements for upgraded training. This continuous improvement implies the necessity of continuous training and higher level of restaffing by hiring in new employees trained elsewhere.

5.5 INITIATING THE TRAINING PROGRAM

Since many different types of people with different levels and types of education are targeted to be trained, researchers agree that the training program should consist of different levels. These levels may be; extensive technical training, simple technical training, operation training, features/economies training, and awareness training.

The extensive level training will enable the trainees to repair and to actually maintain the robot. This may not be necessary if there is a service contract with the vendor. Simple level technical training will be for developing skills such as the precursory repair of the robot and its ability to interact with other equipment.[E10, pp 85]

Operational training includes such features as the programming of the robot and the daily operation the robot will undergo when it is in use. Features/economies education may include the ability of various robots to accomplish the different user tasks of the user and the relative merits the robot has for the economic operation of the plant. Awareness training will be a simple explanation of the facts about robots that will allow everyone to judge a robot on its true features.[E10, pp 86]

According to many researchers [E2,10,15], training is probably the most abused and misunderstood tool in the industrial tool kit of strategies for achieving greater strategies. Training programs may end up as failures due to similar reasons as the ones listed ; a knowledge gap in the individual/group which was not identified prior to training, a language barrier, poorly designed training, poorly presented training, training during commissioning of equipment by engineers who are not trainers, very little understanding of the fact that training is forward planning to a sophisticated degree, the trainee rejected the needs for training and was not properly committed.

Discussion held between the training department, engineers, local training resources and suppliers should be done at the earliest possible opportunity to establish possible training requirements, the resources required and to identify the population needing this training is suggested to be the first act to overcome the above mentioned barriers. The next steps recommended are : discussion with the people requiring training, visit to, or by, the supplier to establish outline requirements and/or a visit to the local training resources if the needs are beyond our internal capability, outline requirements can be established using learning objectives as a means for discussion, training plan produced, pilot training course implemented, make changes as necessary, introduce mainstream courses.[E2, pp 100]

6. CONCLUSION

The key to strategic utilization of advanced manufacturing technologies is to ingrate them with other functional units. One of the major reasons causing the failure of an advanced manufacturing technologies adoption is the lack of planning before the technology is acquired.

All the researchers and case studies discussed in this paper agree that there is no best process technology. The right technology for a business is related to the strategic goals, the resources, the resource availability and market environment of that business.

Rapidly changing technology and shortened product life cycles lead to an uncertain environment and thus traditional cost justification methods become inappropriate for new technologies. In the literature [B15,21,9,19,22], flexibility concepts are introduced and different ways to measure it are explained. Measurement of flexibility is an appropriate way of monitoring the performance of advanced manufacturing technologies.

During the implementation there may be some problems. There may no be a sufficient skill set. Implementing computerized systems may be a complex task. There may be multiple implementation paths, limiting or multiplying synergy, or the system may need different support structure. The managers should make sure that their system is ready to encounter such problems.

A critical issue in the future factory is the human factors. Proper training is a must for a successful implementation. Managers should never forget that the future factories are not unmanned and lightless.