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Touche Ross

A Framework for Computer Integrated Manufacturing

by

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One in a series on Manufacturing Money
from the Proven Professionals.

A FRAMEWORK FOR COMPUTER INTEGRATED MANUFACTURING

INTRODUCTION

Today's increasingly rapid technological advancement and growing competition, both domestically and internationally, are making it more important than ever that companies be responsive in meeting the demands of the marketplace. The ability of manufacturing facilities to adapt and respond to new requirements, additional constraints and developing opportunities will be the major characteristic distinguishing companies that grow and prosper from those that fail or merely survive. Today's success stories, and those of the future, will come from companies whose manufacturing facilities are flexible enough to meet product or design changes with minimum impact on the physical plant or the facility's layout.

Many of our domestic industries are faced with stiff competition from foreign firms with the advantage of more modern facilities, lower labor rates and government subsidies. Further complicating the picture is the relatively high cost of capital that places greater emphasis on foresight, planning, innovation and rapid response capabilities.

One approach to improving a company's competitive posture is Factory Modernization. The ultimate objective of factory modernization is to transform manufacturing facilities into modern, automated plants capable of producing superior products at competitive costs and with reliable production schedules. Effective implementation of advanced manufacturing technologies through a computer-integrated-manufacturing (CIM) system is the cornerstone of factory modernization.

We believe that a company's manufacturing function is either a competitive weapon or a corporate millstone. The connection between manufacturing and corporate success is more than the attainment of high efficiency and low cost. Management must be careful not to select technical modernization projects which, while improving productivity in the facility, could eventually represent a huge investment in obsolete technology. Rather, top management should consider what the industry is likely to look like over the next ten to fifteen years and plan accordingly. While it is not possible to precisely predict the evolution of CIM technologies including equipment, materials and design breakthroughs, the level of flexibility required in physical facilities must be considered in order to be properly positioned to take advantage of new developments.

Often top management is unaware that what appear to be routine manufacturing decisions frequently come to limit the company's strategic options, binding it with facilities, equipment, personnel and basic controls and policies resulting in a noncompetitive posture that may take years to turn around. Unfortunately, in many companies, top management unknowingly delegates a surprisingly large portion of basic policy decisions to lower levels in the manufacturing area. When organizations fail to recognize the relationship between manufacturing decisions and corporate strategies, they become saddled with *seriously* noncompetitive and often inefficient production systems that are expensive and time consuming to change.

To be a winner at factory modernization over the long run, companies will have to merge their strategic business plans with the modernization effort. Many companies lack a concise set of well articulated and thought-out goals and plans. Still others fail to incorporate their plan into their manufacturing decisions. The result is, at best, a manufacturing facility that meets today's needs, but is poorly postured as an effective competitive weapon in the future.

As part of the factory modernization project, the company must seek to develop advanced manufacturing facilities that can help compete in today's as well as in future markets. We believe that it will be useful for management to specifically address critical policy issues that will identify high payoff projects for the company. By so doing, top management can begin to tailor the manufacturing and support activities to the specific needs of the company, thus helping to develop a competitive strategic edge in the marketplace. It does not appear to us to be sufficient to strive for mere technical dominance, if that dominance is not directed at equipping the company with a competitive edge.

A company's manufacturing capabilities should be specifically designed to fulfill the tasks demanded by its strategic plan. However, the linkage between strategy and production operations is sometimes elusive. We find that relatively few manufacturing facilities carefully and explicitly tailor their production systems to perform the tasks that are vital to overall success. Instead of focusing first on strategy, then moving to define the manufacturing tasks, and next turning to systems design and manufacturing policy, most manufacturing facilities are a product of past unfocused manufacturing decisions.

The key to designing a manufacturing facility which is a competitive weapon is to develop an understanding of the strategic implications of the adoption and implementation of each technology. This understanding is developed through a systematic factory analysis which leads to a master modernization plan, as shown on the next page. The scope of the master plan ranges across matters of strategic planning, investment decision making, implementation, and retrospective evaluation. Each technology must be evaluated to determine its potential for meeting the strategic objectives developed early in the master planning process.

As a company goes through a modernization effort it typically identifies numerous individual improvement projects. However, CIM must be viewed as a total system which provides an automatic link between product design, manufacturing engineering, and the factory floor. The methodology selected for screening and prioritizing these individual projects, with consideration of the synergistic effect, is critical — it must provide framework that ensures consistency with the company's strategic objectives.

The approach to establishing this framework is portrayed on the next page. The first step is to develop an understanding of the company's long-term strategic goals and objectives and any fundamental business assumptions in the long-range plan. The second step is to translate these strategic objectives into strategic elements which support the objective. These elements generally form the basis for competition in the marketplace — e.g. cost, quality, delivery, flexibility, technology, etc.

In the next step, each of the strategic elements is reviewed with the functional areas of the company to develop a list of performance measures. This decomposition of the strategic elements into "key success factors" by functional area provides a mechanism for linking operational performance to the strategic objectives. Current and projected performance levels can be measured and operations targets can be developed for overall company performance as well as multiple level for the individual departments and functional areas.

This data can be input to existing company models to develop financial projections under different scenarios to ensure projected performance against the long-range plan. Comparison of projected to targeted performance will assist in determining and prioritizing company needs. The implications on strategy components such as the following can then be evaluated:

- Positioning of the production system
- Capacity/location decisions
- Product and process technology
- Human resources
- Operating decisions
- Suppliers and vertical integration

At this point in the process, a company-specific CIM strategy is identified. This strategy should be defined in terms of both the total system and individual projects. Each project can be examined in terms of its impact on the identified performance measures. Operational improvement impact can be quantified and compared to targeted performance levels. Projects can be ranked in a manner consistent with strategic objectives and an overall framework established for implementation.

A COMPUTER-INTEGRATED-MANUFACTURING (CIM) BLUEPRINT FOR THE FACTORY OF THE FUTURE

A computer-integrated-manufacturing (CIM) system provides an automated link between product design, manufacturing engineering, and the factory floor. Touche Ross has developed a composite view of a theoretical CIM system as illustrated on the next page which should apply no matter what variety of mills, lathes, punch presses, and other machine tools make up the factory. The majority of these technologies are available today; many are currently operating in production facilities and are enjoying growing popularity.

The two major dimensions of a CIM system are:

- Functional integration of the physical production process.
- Information integration of the control of the physical production process.

These dimensions will be described in detail on the following page.

Functional Integration Dimension

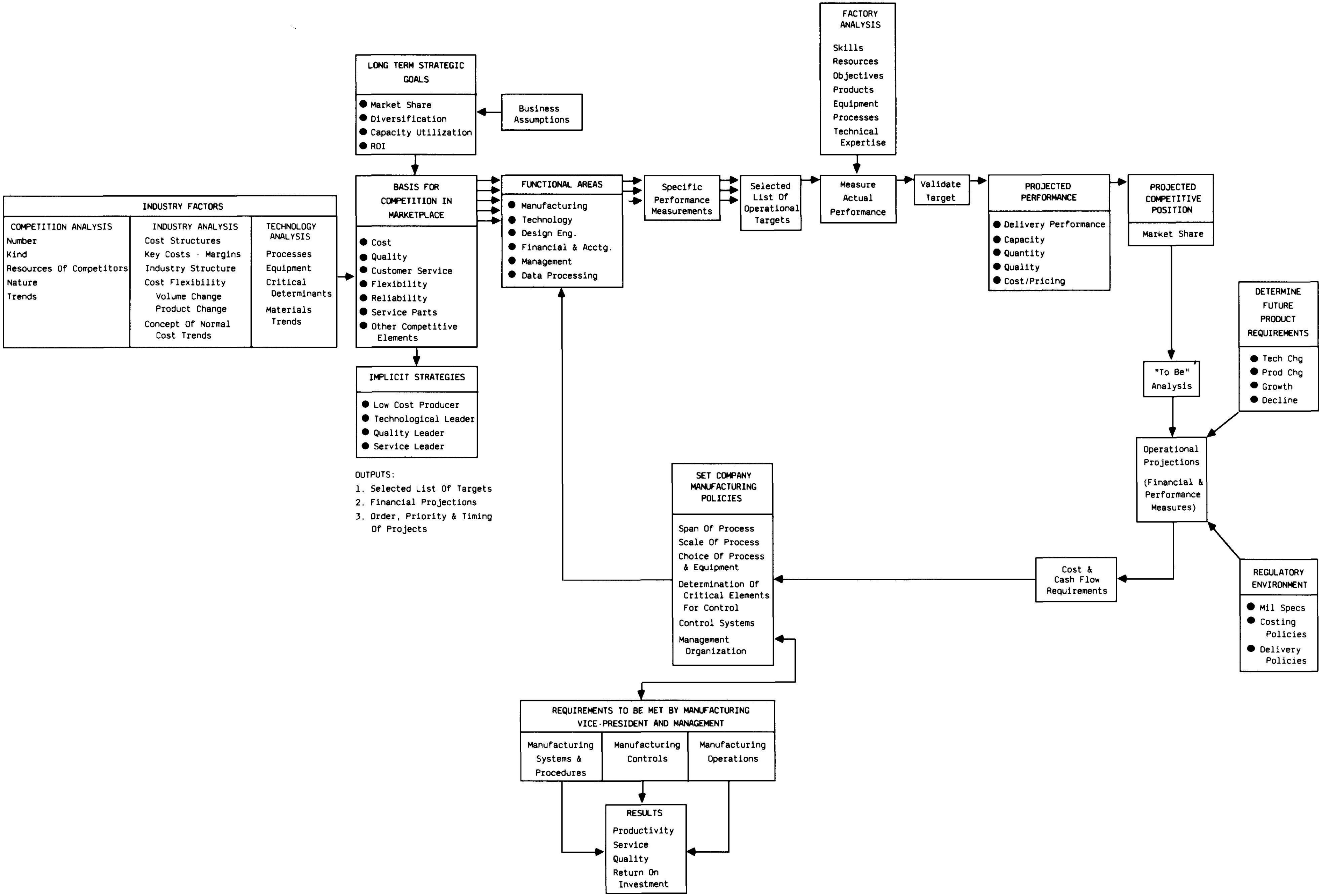
The major components of a CIM system include computer-aided engineering, production planning and control, and an automated shop floor. Each of these components is described in greater detail, as follows.

A. Computer-Aided Engineering

Computer-aided engineering (CAE) includes those hardware and software tools, such as interactive graphics systems, that can be used in the product design and manufacturing engineering functions.

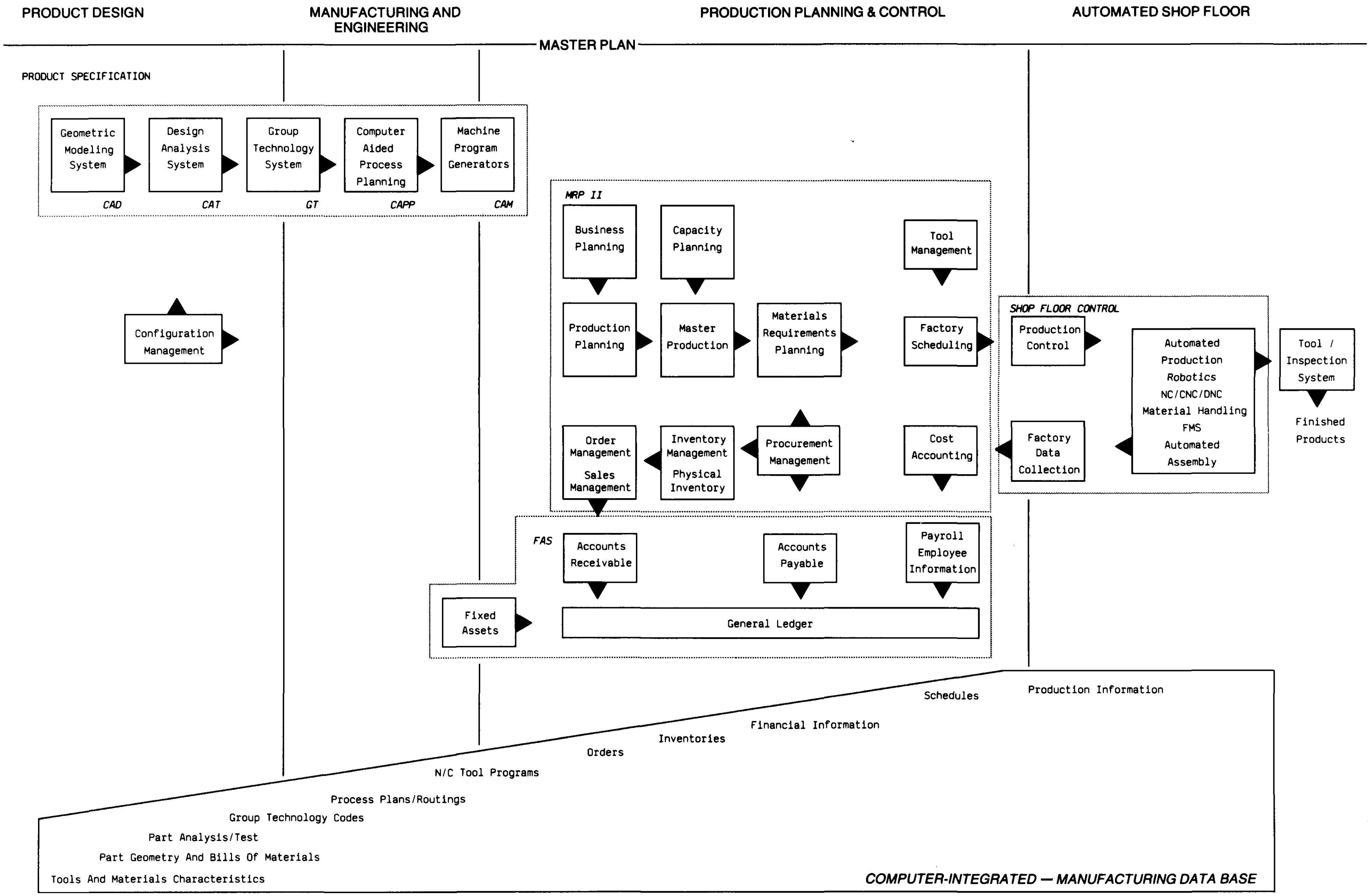
MASTER MODERNIZATION PLANNING PROCESS

STRATEGIC PLANNING ELEMENT



OUTPUTS:
1. Selected List Of Targets
2. Financial Projections
3. Order, Priority & Timing Of Projects

FUNCTIONAL DESCRIPTION OF A COMPUTER-INTEGRATED-MANUFACTURING (CIM) SYSTEM



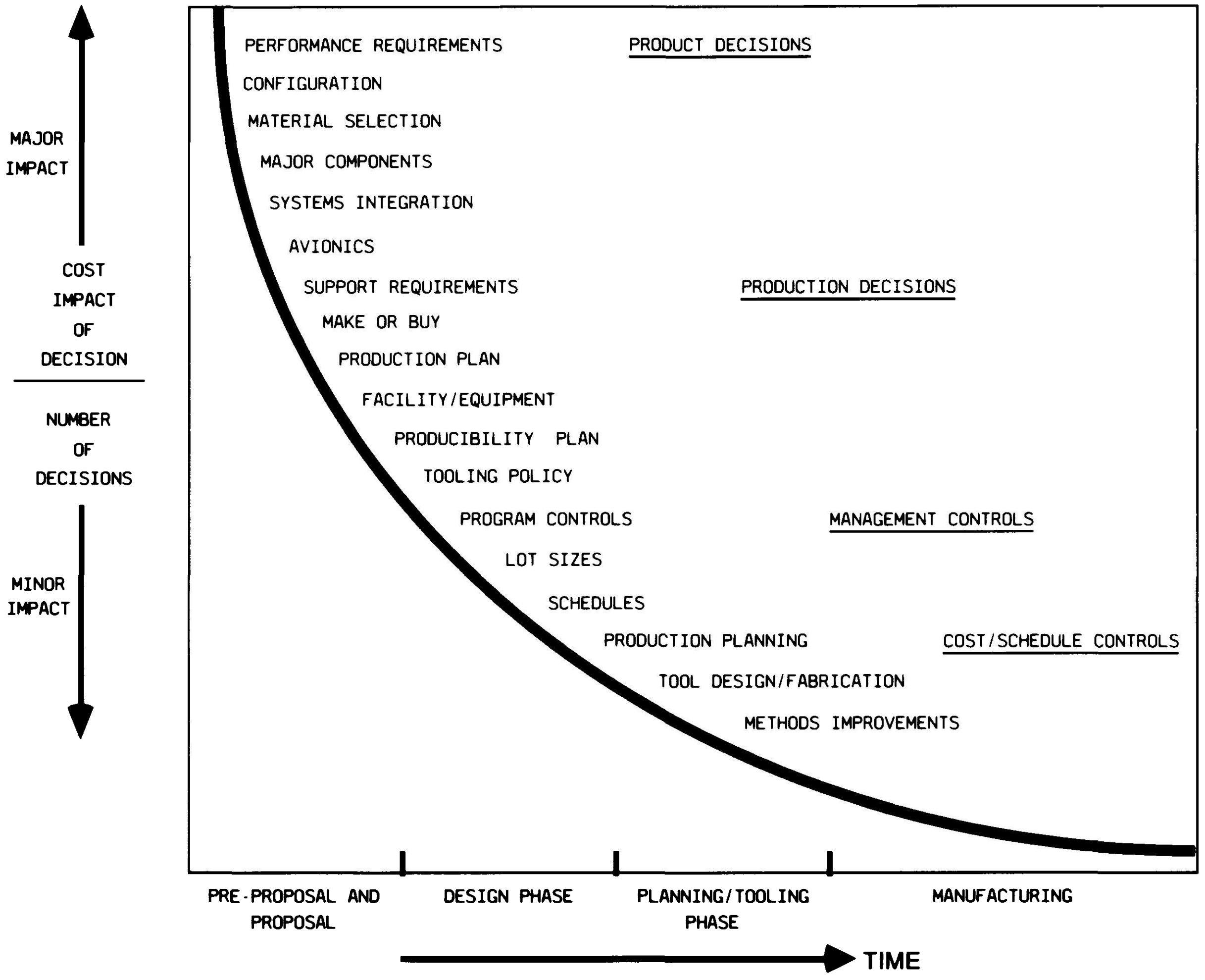
A successful CIM system requires integration of engineering and manufacturing functions for the following reasons:

- Product engineering decisions have a significant impact on manufacturing cost as illustrated in the diagrams on the following page. CIM impacts this area by:
  - — Providing manufacturing engineering with the ability to review designs and ECNs for producibility prior to release, and
  - — Facilitating design of fewer and more integrated components to reduce the number of manufacturing operations and simplify maintenance.
- Decreasing product life cycles have resulted in:
  - — A reduction in the time required for firms to respond to changes in market demand, and
  - — An increase in the number of ECNs.

  CIM can substantially benefit a company in dealing with these decreased life cycles in the following ways:
  - — Coordinating ECNs with all affected manufacturing operations prior to release to determine the impact on schedules and costs.
  - — Increasing efficiency of information transfer from engineering to manufacturing and decreasing time and cost.
- Increasing demand for product quality requires that quality be "designed into" the product. CIM can facilitate increased quality through:
  - — Quality planning
  - — Computer-Aided-Testing (CAT).

The major building blocks of the Computer-Aided Engineering system include:

- Computer-aided design
- Design analysis
- Group technology
- Computer-aided-process planning
- Machine program generators.



IMPACT OF COST VS DECISION

The functional systems associated with CAE require integration of both design and manufacturing data bases. A description of these systems and the required integration follows.

1. Computer-Aided Design (CAD)

Computer Aided Design (CAD) involves the use of computerized tools to improve productivity in the areas of design, drafting and testing. CAD is actually a means of accumulating, manipulating and displaying related graphical data electronically. This graphical data can then be recalled for duplication or modification.

A typical CAD system includes:

- CRT workstations where engineers can create or modify a part by "drawing it" on the screen using a number of different devices, such as:
  - — a standard computer terminal keyboard,
  - — an electronic stylus that the engineer uses like a pen to draw on the screen, and
  - — an electronic sensitive menu tablet of commands that the engineer can select.
- A digitizer that can convert an existing print to X-Y coordinate points which can be stored in the CAD system and retrieved on the terminal.
- Automatic drafting machines that produce high quality drawings from data stored in the system.

A CAD system can provide engineers, designers and drafting personnel with a number of significant benefits:

- Time and effort required to develop designs is reduced because the computer software can be utilized to draw figures, calculate dimensions, rotate or section views, check interferences, and revise existing designs.
- The quality of designs, and their associated products, are improved as the increased productivity of design personnel allows more designs to be modeled, tested and evaluated before engineers select the final, production version.
- The costs associated with the design of tooling and fixtures can be reduced by designing them on the CAD system, in conjunction with the design of the part.
- Communication with engineering and production personnel is improved by taking advantage of CAD's ability to display any view of an object quickly and correctly and provide high quality drawings.

CAD systems coming to market are increasingly powerful, offering more sophisticated capabilities while being easier for design personnel to use. The central reason behind the improvement in CAD systems is the rapid development of computer technology, in both the hardware and software areas. This development will probably continue, perhaps at an increasing rate, into the foreseeable future. The effect of this on companies using CAD will be:

- Significantly increased display speed and pictures/drawings of higher quality,
- More complex designs, tests and simulations which will be made possible through more powerful computers with more real memory, and
- Improved price/performance ratios which will facilitate the support of more workstations, extending the power of CAD to more areas of the company, without significantly increasing costs.

2. Design Analysis System

In most CAD systems, a wide variety of analytical software is available for mathematical testing and modeling of part designs. Computer-aided-testing (CAT) uses a CAD generated model of a product design to simulate the operating conditions and performance of different materials. The design can be interactively improved on the basis of the results of the simulations.

Another important element of a CAD system is the capability to analyze the impact of product design on manufacturing cost. It is extremely important to conduct cost trade-offs early in the design process since it is at this point that most of the production and logistic support costs are locked in, and the economic leverage to reduce cost is the greatest. The manufacturing cost design subsystem should provide the following capabilities:

- Cost comparisons with differing manufacturing processes,
- Performance/manufacturing cost tradeoff information, and
- Cost tradeoffs of materials chosen for the product.

3. Group Technology

Group Technology is a method of classifying parts into families according to similar shapes, or common manufacturing process operations. This is accomplished through a coding mechanism that assigns specific codes to each significant part characteristic. These codes are then combined to form a unique identifier for each part, describing it from an engineering and manufacturing perspective. Thus, Group

Technology facilitates a systems approach to the redesign and reorganization of the factory into a Flexible, or Cellular Manufacturing System.

Such a system consists of a number of work cells, which can be viewed as a cluster or collection of machines designed and arranged to produce a specific group of component parts. Group Technology plays a key role in setting up a Cellular Manufacturing System because it provides a computer oriented tool that the manufacturing engineer can use to identify and design the work cell, and the product engineer can use to determine if similar parts are in existence, thereby reducing the number of parts and process plans.

For standard families of parts, standard routings can be prepared that need only slight modification for a newly designed part. The result is typically faster, more correct routings at less cost. Such standard routings can then be used to group production machines in logical cells dedicated to the manufacture of one or more families of parts. In addition, similar parts or families of parts requiring approximately the same tooling and machinery can be grouped so that production setup time is reduced.

Benefits of Group Technology and related work cells include:

- Reduced machine setup times because work cells are designed to perform the "common" operations identified by Group Technology,
- Less work-in-process inventory because lot sizes can usually be reduced, smoothing the production flow,
- Less material handling because the flexible nature of the work cell allows more operations to be performed within the confines of the cell,
- Easier analysis of production costs of parts in a given family because outliers can be readily reviewed to determine whether the cost is wrong or unusually high,
- Rapid development of cost estimates for new parts based upon the costs associated with other parts in the family, and
- Easier tracing of the effects of price increases on components and raw materials back to the part families, and identification of the associated impact on product cost.

The end result of the work cell approach to manufacturing is increased throughput, lower costs and better cost control.

4. Computer Aided Process Planning (CAPP)

CAPP refers to the method of preparing routings or process plans using computer assistance. Recently, two approaches have evolved for this task. The first and most popular of these is the variant approach where process plans are generated for families of parts that have been classified under the Group Technology concept. In this technique, the process planner calls up existing routings based on similarly coded families of parts. Then, using a "same as-except for" technique, the family's process plan is quickly amended to cover the individual part in question. To create a plan from scratch in the variant approach, the process planner can select from a computerized menu of operations based on part characteristics. Here, the process plan is built, line by line, using company oriented standard text. The procedure is somewhat similar to a manual process but the standard text, of course, is stored on the company's data base ready for retrieval, modification, or hard copy duplication.

The second, far more sophisticated computer aided process planning technique is the generative method. Here, the computer analyzes the part under consideration and, based on part geometry, material, etc., generates a process plan automatically. Not only is the sequence of operations generated, but the computer also selects the company's best suited machine tools and calculates the probable machine time for each operation. From this base, it is a simple matter for process planners to review and edit the plan, and revise time allowances after initial sample parts are run.

CAPP typically increases the product planner's productivity and improves the accuracy of the resulting plans. Both the variant and generative methods use a "building block" approach to developing plans based on common attributes within the part's family, reducing the planning effort and thereby improving productivity. Accuracy is increased because the new plan is "assembled" from pieces of already existing plans, which have been tested in actual production.

The generative method is just beginning to be implemented in U.S. manufacturing plants. The key to its more universal adoption will be the development of better three-dimensional solid geometry modeling software. In addition, much work remains to be done on the logic of process planning based on this part geometry. However, the generative method is an appropriate area for further investigation in modernization programs.

5. Machine Program Generators

Once the part's geometry is defined, it then becomes the basis for future part machining operations. In the past, a design engineer would finish a blueprint, and the NC programmer would have to take that blueprint and redefine the geometry before he could start programming. With an integrated system, the programmer starts with something in digital format.

Machine program generators provide a bridge between CAD and CAM, where designs can be turned into the instructions necessary for computer controlled machines. The programmer does not have to create new instructions from scratch but, as with CAPP, he can build new instructions from the instructions of older family members. This is called family-of-parts programming and increases the programmer's flexibility and his productivity.

B. Factory Management and Control Systems

Factory management and control systems provide for the flow of production information through the integration of data from both engineering and manufacturing functions. The Planning and Control function includes production planning for product families, master production scheduling for customer order promising and shipping schedule development, master requirements planning for component scheduling, and purchasing plans, production activity control for shop operations scheduling, capacity requirements planning for shop loading, priority planning for daily dispatch and inventory planning for material control. These systems address the production questions of when and how many, and facilitate the solution of production problems including machine utilization, control techniques, planning capabilities, quality control, excess work in process, and poor use of skilled labor.

In order to be effective in this area, certain requirements must be met in the areas of planning, facility loading, and dispatching.

1. Production Planning

Production planning translates the dollar goals expressed in the business plan into levels of production for product families. This aggregate level plan is tested against available plant resources through the process of Resource Requirement Planning and represents top management's key "control knob" on the business.

2. Master Production Scheduling

A master production schedule represents a disaggregation of product family production plans into individual end items (or major components when "planning bills" are used).

Master production scheduling must also simulate the resources, including machine types, personnel and inventory levels, required to accommodate the proposed production schedule or product mix. The simulation capability uses forecast workload profiles of each product and projected resource loads for the existing master schedule. Net changes in each type of resource are identified, as are underloads and overloads of existing resource capacities. This process is referred to as rough cut capacity planning.

3. MRP

Material Requirements Planning (MRP) involves computerized techniques for scheduling the replenishment of material, based on the master production schedule and the components needed to build the product. MRP provides the ability to frequently update priorities and schedules while providing suggested start and completion dates for all open and planned work and purchase orders.

4. Production Activity Control

Operations scheduling establishes projected start and completion dates for all activities on open or planned workorders, and is required to automatically verify availability of tools and materials for generating shortage lists. It calls for delivery of required tools and materials when a selected load is released, generates initial shop floor load and identifies bottleneck conditions. This function provides for interactive intervention to undo bottlenecks and a simulation capability for use in interactive intervention.

Production activity control also includes the dispatch function which releases work to specific machines and operators. While the dispatch function can be either automatic or manual, a simulation and optimization capability to assist in assigning jobs and operators to machines is required for either approach. Furthermore, if a manual system is being used, it must have the capability to make detailed recommendations upon request.

5. Capacity Requirements Planning

The information produced in capacity requirements planning is used by manufacturing management, quality assurance management, shop floor supervisors, purchasing, accounting and personnel departments. At a minimum, capacity planning must: access inventory files and process planning files, convert production requirements for personnel, identify overload conditions, and provide the capability to evaluate alternatives.

6. Inventory Control

The activities and techniques of maintaining the stock of items at desired levels, whether raw materials, work-in-process, or finished products is generally referred to as inventory control. These activities involve stocking levels, safety stocks, lot sizes, and focus on managing the company's investment in inventory assets.

7. Purchasing Systems

Purchasing systems serve a dual role. First, they provide information to buyers to aid them in negotiating with vendors and placing/expediting orders. Second, the systems interface with MRP systems to provide feedback of actual order delivery schedules, order quantities and lead times. This information must be both timely and accurate, if MRP is to correctly schedule material replenishments.

8. Maintenance Planning and Control Systems

Scheduling preventative maintenance and collecting maintenance statistics are now computerized. These systems allow the company to monitor such maintenance activities as:

- Mechanic's productivity,
- Work order processing for requested jobs, and
- Requirements for parts and special tools.

These systems also allow the Capacity Planning systems to include scheduled downtime in their calculations and to adjust workcenter loads accordingly.

9. Engineering Database and Change Control Systems

The engineering database is also frequently referred to as the engineering bill of materials. It allows engineers to maintain their product engineering information on the computer in terms of parts lists, specifications and process requirements. The power of this tool is achieved when it is integrated with the manufacturing bill of materials to facilitate engineering changes, and reconciliation of product information.

The engineering change control capability enhances efficiency by maintaining the history of product changes as they are released from engineering. However, its greatest values may lie in its capability to facilitate the incorporation of the changes into the manufacturing bill of materials and its ability to effectively manage inventory investment by controlling effectivity dates.

10. Tool Control Systems

The relationship between planning and controlling production and the need to coordinate tooling requirements is being addressed by many of today's more advanced manufacturing and control systems. Time phased requirements for specific tools are generated, based on production schedules. This information is supplied to the Tooling Design and Fabrication Department to identify the tool requirement dates necessary to support the production schedules.

11. Energy Management

The increasing cost of energy in factories has led to the development of computer software to manage energy resources. These systems can monitor energy consumption, turn lights on and off, adjust heating or air conditioning and provide management with data to include energy costs in their business decisions.

12. Warehouse Systems

Software packages designed to help warehouse managers maximize space utilization, make more efficient use of labor, and improve customer service are now available for a wide range of warehousers. These systems provide a variety of functions including:

- Order processing,
- Forecasting, and
- Finished goods inventory control.

Systems offering these capabilities are available for companies from one warehouse location to a worldwide warehousing network. Systems for the latter generally are capable of playing a coordinating role in the management of inventories and purchasing activities.

Properly implemented, the integrated planning and control system eliminates the problem of missing resources. It ensures that all resources needed to perform a given job are identified, coordinated and available when that job arrives at its workstation. This reduces the amount of work in process, normally held as buffer stock in input queues. Control of material movement reduces the size of the output queues. These capabilities support reductions in the amount of material held as in-process inventory. Flow times for material moving through the production process are reduced accordingly. Utilization rates for machines and workers increase, since the workers are doing productive work rather than waiting for tools, parts and instructions.

One of the major challenges in implementing factory management and control systems is the difficulty in linking together different hardware and software packages. There are currently many vendors and little standardization of technical specifications. Additionally, a company which is modernizing must decide on the value of off-the-shelf versus custom tailored systems. The modernization process should assess projected costs involved in changing existing organizational procedures to fit the software systems being offered, rather than modifying the software to reflect organizational needs.

C. Computer-Integrated Manufacturing Processes

The automated shop floor includes computerized production machines and equipment that facilitate the production process. CIM requires highly automated and intelligent production facilities which are controlled by sensors, minicomputers, and microcomputers. A CIM system has many benefits from the machinists' point of view. Among these are:

- Increased accuracy,
- Increased repeatability (1,000 parts, for example, can all be created alike),
- Decreases in the time it takes to go from a part print to the finished product,
- Decreases in scrap due to better utilization of raw materials,
- Shorter production time frames, and
- Increased machine flexibility.

1. Computer Aided Manufacturing

There are many definitions of CAM in use today. For purposes of this discussion, we define CAM as NC, CNC, and DNC machine tool hierarchies, Robotics, AS-RS, FMS, PCs and related technologies.

a. NC — Numerical control (NC) refers to a category of programmable machine tools. In NC, a machine is programmed with a set of instructions designed for a particular work part or job. Based on the instructions, the machine will move its cutter tool through a series of X, Y & Z coordinates, performing the desired machining operations.

One of the advantages of NC is that, when the job changes, the program can be changed. This feature gives NC its flexibility. Instead of making major changes to production equipment, relatively simple changes are made to a program.

The first NC machines were programmed by a punched paper tape that contained the instructions for the specific job. Many of these machines are in use today and they are well suited for a number of applications.

Advances in computer power have led to an extension of the NC concept to computer numerical control (CNC) and direct numerical control (DNC).

b. Standardized CNC Controls — Computer numerical control (CNC) places a dedicated computer in or alongside the NC machine tool. Paper tapes are no longer necessary and machine tool instructions can be created and stored electronically in the computer's memory or on tape cassettes or diskettes. In modern CNC machines, programs can be created, edited or changed if necessary on the machine. CNC eliminates problems of physical tape storage or deterioration. Thus, CNC machines perform the same function as NC machines although their method of receiving operating instructions is different.

c. Direct NC — Direct numerical control (DNC) offers real time computer control of more than one NC machine at a time. Many NC programs are stored in a central computer's memory, on tape or disk. Not only can the computer control multiple NC machines simultaneously, but it can gather feedback from each machine as to part production rates and machine status. With DNC and CNC capability at each machine, programs can be downloaded from the DNC to the CNC machine for running. This saves the amount of memory needed for each machine and means that the program only has to be created and loaded in one machine (the host DNC) — not every machine that can run the job.

Over the past decade, NC machining has been proven to allow a productivity gain of approximately 3 to 1 in most applications. Other benefits of NC machining are, of course, reduced setup time, better part quality, less scrap and rework, and reduced operator attention.

2. Robotics

Robots are computer controlled devices that automatically perform a programmed sequence of operations. Most industrial robots in use today were designed for specific work such as painting, welding, plastic molding and assembly, and were, for the most part, labor-saving devices utilized solely for the performance of non-complex production work. In addition to such specific-purpose robots, many others perform material handling operations such as workpiece loading/unloading and workpiece transfer in conjunction with other automated machinery.

The benefits of robots include:

- *Cost* — Robots are becoming quite economical relative to the wages of workers they displace.
- *Precision* — Robots have a higher degree of precision than humans, and with proper preventive maintenance can be highly reliable. Precision re-

fers both to the concept of accuracy and repeatability.

- *Availability* — Robots are tireless and can work three shifts with only time off for preventive maintenance; thus, robots are excellent for overloaded or complex structured work.
- *Safety and Environment* — Robots have reduced the exposure of human workers to undesirable environments such as noise, heat, dirt and machine hazards.

The trend in robot technology is toward universality and versatility to produce a standard unit that can handle diverse manufacturing problems. The real future usefulness of robots will be determined by the power of the computers that operate them, the sensors (touch and sight) by which they receive real-time data, and the software that controls them. In the future, as pattern recognition software, artificial intelligence, sensory equipment and adaptive feedback mechanisms become available at even lower costs, robots should be well qualified to perform many assembly and parts selection tasks now commonly performed by humans.

3. *Programmable Controllers and Microprocessors*

Programmable controllers (PCs) are microprocessor based devices that integrate automated machines and equipment to provide a factory with real-time control. Unlike old fashioned, hard-wired, relay-based controllers, PCs are relatively inexpensive, solid state devices that can be reprogrammed quickly to perform new tasks. Better still, different task sequences or programs can be stored in the PC's memory or on tape so that process control changes can be effected with a change of tape cassette or with a typed-in command.

The ultimate advantage of PCs and microprocessors is that any number of them can be controlled by central computers. These devices can then be used to report back on factory floor or process status and can be reprogrammed quickly for different jobs when necessary.

4. *Flexible Material Handling*

Automated material handling systems permit an improved integration of material flow to and within manufacturing functions. Some of the available technologies include wire guided vehicles, smart carts, and dedicated transfer lines. The automated material handling system must be flexible to permit changes in lot sizes, design and product mix.

5. *Automatic Storage — Retrieval System*

Automatic Storage and Retrieval Systems (AS-RS) are computer operated part pickers and stockers. Generally the larger pallet sized systems for warehouses are called AS-RS while smaller stockroom bin sized systems are labeled automatic part pickers-stockers. Working either from direct computer generated and linked pick or stock instructions, or from manually generated pick or stock instructions, these machines either will deliver a batch of parts to an open or random location, while recording the location for future reference, will stock a given part in a preprogrammed location, or will go to a selected location to pick a part.

6. *Computer Aided Inspection*

Computer aided inspection (CAI) is another new use of computerized engineering design data in manufacturing, but this time in the quality control area. In CAI, coordinate measuring machines (CMMs) controlled by software that draws data from the company's engineering design data base automatically measures parts to determine if they have been manufactured to design tolerances specified on the part's drawing. These machines have a probe that automatically moves to a programmed point, takes a measurement and displays or records the result. Some of the more advanced machines, becoming available or under development, replace the probe with a laser, significantly increasing the machine's accuracy. The computer can also print out both the required and actual measurement or dimension and/or the deviation, if significant, for the part under consideration. More importantly, the CMMs also enable these measurements to be stored automatically in a data base, to be used as a basis for further statistical analysis on the part, or perhaps as an early indicator of machine tool wear. This data also serves to record permanently for the company the data necessary to meet traceability requirements and demonstrate that a part was manufactured correctly.

7. *Flexible Manufacturing Systems*

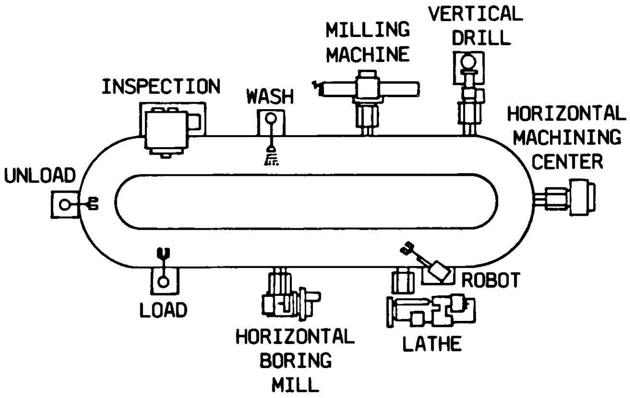
Flexible Manufacturing Systems (FMS) permit the continuous manufacture of different items within a family of parts in small batches within a dedicated machining facility. Flexible manufacturing systems, as shown on the next page, use the concept of integrated raw material storage, part picking, part transportation, and DNC machining that are linked together in such a way that the parts being worked on can travel from raw material storage to finished goods storage in different sequences under the control of computers.

The central FMS computer schedules and tracks all production and material movement in the FMS center. Based on a family of similar parts, an FMS can be reprogrammed quickly through downloaded instructions from a central computer to individual machines, conveyors, and part pickers to perform a new set of tasks. The major benefit of an FMS is flexibility of manufacturing resource assignment along with computer controlled operation.

8. Bar Coding

The expanding role of the computer as a tool for management and production is directly tied to the company's ability to provide it with timely, accurate data. Many businesses are discovering that bar code scanning is the fastest, most accurate, least labor intensive, and lowest cost method for delivering that data. Companies are using bar codes to track work-in-process, aid in physical inventories, control stockroom inventories and lots, and track shipments to customers. Wherever data entry is required by production, shipping, receiving or inventory personnel, a potential application for bar coding exists.

A TYPICAL FLEXIBLE MANUFACTURING SYSTEM



9. Laser Machining

Where extremely precise and/or delicate machining is required, lasers are receiving much attention. Laser machining is capable of maintaining very tight tolerances, in part because they are unaffected by the tool wear inherent in more conventional types of machining. Recent advances in laser machining systems, especially in the areas of laser positioning and process control, have significantly enhanced the capabilities of laser machining. Lasers can be used to machine complicated or unusual shapes, and are excellent solutions to machining delicate components which distort easily, because there is no machine tool contact with the workpiece.

It is important to note one central feature of all CAM applications that we have touched on so far. With CAM, the skill requirement for an operation is transferred from the operator to the programmer who creates all the machine instructions. No longer must a person running an NC lathe be a skilled machinist. Instead, the person can be a less expensive and more readily available machine operator. The same trend is evident in all applications of computers in manufacturing processes.

On the other hand, CIM is promoting the integration of design and manufacturing. With CIM these two previously separate groups work from the same data base almost concurrently in the design process to design the part, the tools and fixtures needed to manufacture the part, the bill of materials for the part, and the process plan for the manufacturing of the part. In fact, some companies have created cells of people who work as a team through 1-3 CRTs to carry out the design and manufacturing engineering process.

Each cell is responsible for a product family or product group. People in each team gain energy from their continuous interaction and not incidentally come to have considerable pride in their group efforts. Such a team approach to manufacturing design and operations is the way some people view manufacturing in the future.

Information Integration Dimension

The proliferation of automation throughout engineering and manufacturing processes is making the factory extremely information intensive. The successful system incorporates software links capable of allowing various systems to communicate directly with each other. This is crucial to the integration of a new system with other in-place systems. The task of processing and controlling information in the factory of the future requires a reconceptualization of the role of data processing and the use of new techniques.

A. Data Base Approach

As companies migrate toward the factory of the future, data bases which support the production processes are becoming more electronic and less paper oriented. Common shared data is a critical element in this process. Much of the potential advantage of factory automation lies in integrating engineering with manufacturing functions. The key is minimizing the need for manual intervention between functions and processes.

1. Data Base Management Systems (DBMS)

File-oriented information systems have been the mainstay of computer applications since their origination. These traditional approaches are inadequate for the factory of the future since they hinder data sharing. The concept of data base management systems (DBMS) is to overcome this limitation by making data independent of application programs.

2. Information Network

While a centralized data base is technologically possible, the factory of the future will probably remain a distributed data base environment due to the nature of the automation process. The advanced manufacturing technology explosion has occurred concurrently with the development of minicomputer and microprocessor technology. This technology, along with local area networking which permits efficient transfer of files between data bases, has provided greater flexibility and responsiveness at the machine and process levels where the transformation process occurs.

The adoption of a decentralized data base concept will not by itself ensure the benefits of this approach. In order to maximize the value of a DBMS, the design of data structures must be organized by logical function rather than by narrow application. The value of a functional orientation is that data can be shared by everyone in the organization, as required.

B. Decision Support Systems

Although very few management functions have been automated, advances in information retrieval, processing, and display technologies have led to significant computer applications that help people perform management functions. Since the purpose of these systems is to support managers responsible for making and implementing decisions rather than to replace them, these applications are often called decision support systems.

Traditionally, data processing systems were designed to expedite and/or automate transaction processing, record keeping, and business reporting. Decision support systems are designed to aid in making and implementing decisions. These systems facilitate development of computer models which reflect "real world" situations, simulations, and answering "what if" questions. In this regard, they allow the manager to assess the impact of a decision before implementing it within the company.

C. Local Area Network Approach

A local area network is a collection of computer hardware and software designed for the specific purpose of facilitating communications between computer devices within an area such as a factory. In a distributed processing environment, the local area network links various devices together, vastly increasing the total available computer capabilities.

1. Distributed Data Processing

One of the key challenges of the factory of the future will be the design of a networking system. As the trend towards distributed automation continues with systems such as CAD and programmable controllers, it will be the role of the local area network to tie these potential "islands of automation" together. Sophisticated users must design the network with enough flexibility to facilitate future factory modernization efforts.

The local area network will allow the creation of a more complete data base. This will be a distributed data base built up through the various nodes on the network, not imposed through a centralized computer system.

2. Data Communications

One of the major problems with designing a local area network system today is that most commercially available systems are closed systems where the equipment that provides the data communications function user vendor specific protocols. This closed system restricts a company's freedom to choose the best possible equipment to meet specific needs.

For these reasons, it is important that the local area networks be designed to maximize flexibility for future expansion.

SUMMARY

We have discussed our view of major components of CIM within the context of developing an understanding of how technology can improve critical performance which contributes to the competitive posture of a manufacturing company.

Simply acquiring technology for the sake of sophistication without establishing performance measures and targets which support strategic objectives is both expensive and foolhardy. We believe that a clear understanding of how advanced manufacturing technology contributes to better performance in terms of cost, quality, delivery, flexibility, reliability and other factors should precede, not follow, consideration of new technology.

Technology without purpose may actually cause deterioration in plant performance through the development of islands of efficiency which only serve to create downstream bottlenecks and increase operating costs. The "top down" approach to modernization planning improves the prospects for logically integrated technology, reduces long run costs, and improves operational performance.

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