ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Title:	Computer Integrated Manufacturing: "A Strategic Tool"
Course:	
Year:	1991
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Report No:	P91002

ETM OFFICE USE ONLY	
Report No.:	See Above
Type:	Student Project
Note:	This project is in the filing cabinet in the ETM department office.

Abstract: Computer Integrated Manufacturing (CIM) has emerged as a powerful tool to help firms continue to produce the highest quality products at the lowest possible prices in increasingly competitive business environments. Although CIM provides one method of control over the manufacturing process, attempting to use this tool by itself will probably result in failure unless the systems are supported by a solid management philosophy and other techniques such as Just-In-Time and/or MRP processes. This report identifies CIM as a strategic tool which provides competitive advantage to companies in the global market when used in conjunction with advanced manufacturing techniques. A discussion of industrial robots, and their relationship to a facility's CIM implementation is explored. The concept of "islands of automation" versus a fully integrated factory is presented. Finally, applications of CIM-based technology specific to the manufacturing environment and their impact on product quality are described.

COMPUTER INTEGRATED MANUFACTURING

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EMP-P9102

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Computer Integrated Manufacturing

by

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PSU 510D -- Manufacturing Management II

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Spring, 1991

OUTLINE

A. Executive Summary

Computer Integrated Manufacturing (CIM) has emerged as a powerful tool to help the firm continue to produce the highest quality products at the lowest possible prices in increasingly competitive business environments. Utilizing computer-controlled, automated processes helps to reduce manufacturing costs by reducing the amount of direct labor required to actually process the product through the various manufacturing steps, and by helping to control the amount of work in process (WIP), thereby keeping a tighter lid on both labor expense and inventory levels, while offering maximum responsiveness to the market. Although CIM provides one method of control over the manufacturing process, attempting to use this tool by itself will probably result in failure unless the systems are supported by a solid management philosophy and other techniques such as Just-In-Time and/or MRP processes. This strategic outlook will promote the global optimization of the factory, and not limit the firm's effectiveness by generating conflicting local optima at the expense of lost opportunities on the larger scale. The effective integration of computer control on the factory floor, and communication to that toolset by other organizational entities can continue to help the corporation maintain the highest quality standards for its products. Unquestionably, use of CIM techniques can help the company establish and maintain a competitive manufacturing edge in the global arena.

B. Introduction

This paper identifies computer integrated manufacturing (CIM) as a strategic tool which, when utilized in conjunction with advanced manufacturing techniques, provides competitive advantage to companies in the global market. CIM technology can play a key role in supporting essential goals of the company and offers an alternate method of reducing manufacturing costs, increasing company efficiencies, and achieving the greatest levels of customer satisfaction through high quality products. Some examples of these benefits include facilitation of:

- Faster (product development) time to market.
- Increased design for manufacturability.
- Better market responsiveness.
- Reduced amounts of work in process (WIP) inventory.
- Higher utilization of factory capital equipment.
- Reduction in direct labor expenses.
- Elimination of non-value added functions.
- Information management, availability, and accuracy.
- Automated functional control on the factory floor.

While employing this technology may help to increase throughput and reduce both operating expense and inventory costs, there are several potential pitfalls to its successful implementation. A fundamental barrier is the use of a traditional mindset when performing financial analysis of the CIM project. Failure to acquire top management support can also hinder the efforts of the operation. Another basic consideration is in selection of an appropriate-sized project which maximizes the opportunity for success (usually a smaller-scoped undertaking), yet is significant enough to provide good visibility of the results to help leverage backing for future efforts. Further, the social and cultural impacts of adopting automation as a course of action has major implications for company management.

A discussion of the use of industrial robots is made, and their relationship to a facility's CIM implementation is explored. The concept of "islands of automation" versus a fully integrated factory is presented, with implications addressed for the various tradeoffs examined. Finally, applications of CIM-based technology specific to the manufacturing environment, their impact on product quality, and future roles of the worker are described.

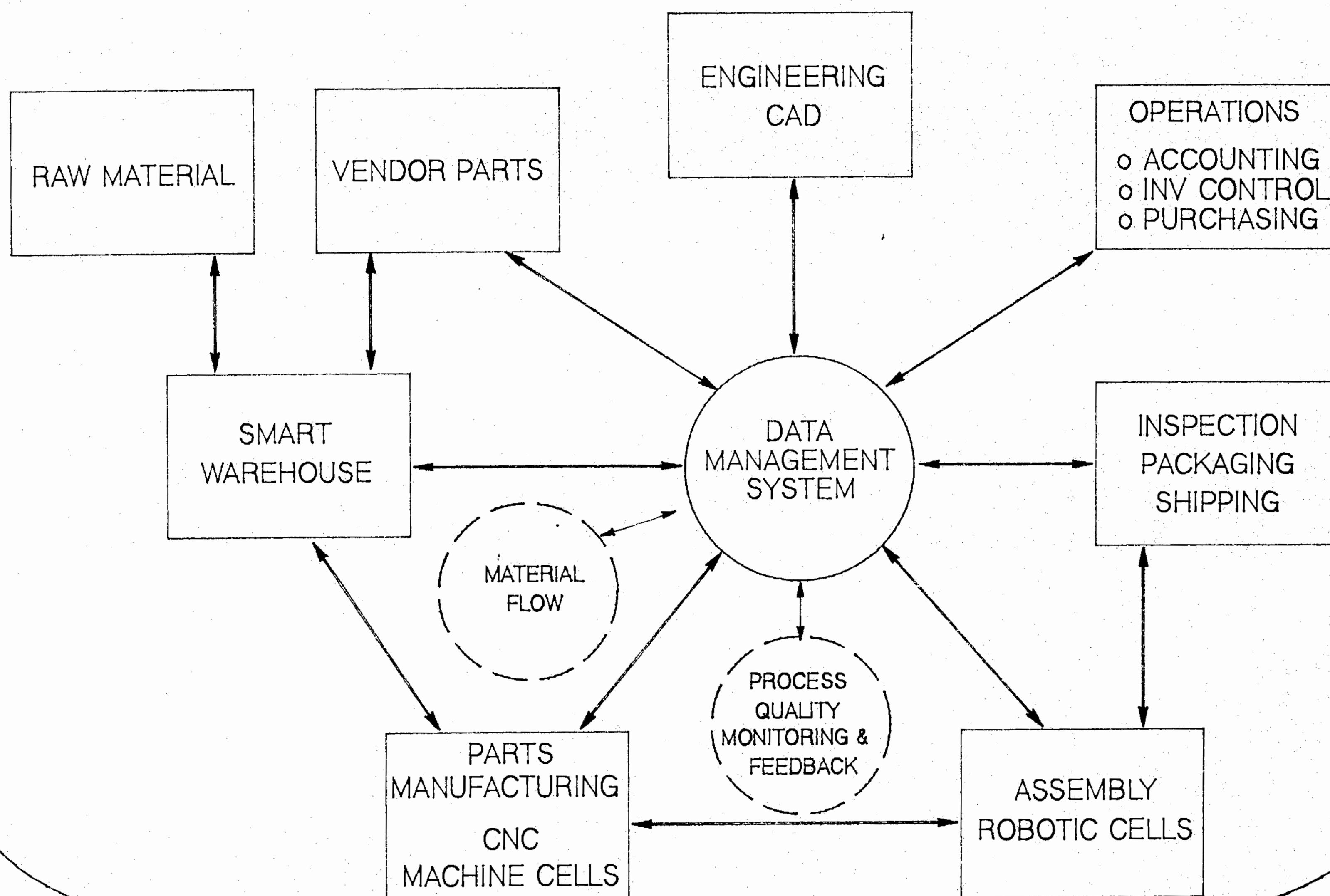
Ultimately, CIM represents the goal of many firms which desire to link their technology investments with integrated information flow to assist in improving production and planning throughout the organization. This paper attempts to raise the awareness of several critical considerations that should be made prior to planning for implementation on a wide scale. Although risks are present, proper planning can assist in creating a successful mechanism for gaining competitive advantage in the market through exploitation of CIM technology.

C. Definition of Computer Integrated Manufacturing

The interpretations and definitions of Computer Integrated Manufacturing (CIM) are widespread and varying, usually dependant upon the linkage made when thinking of a specific application. Often, the terms "computer aided design" (CAD), "computer aided engineering" (CAE), or "computer aided manufacturing" (CAM) are used interchangeably with the term "CIM". However, based on the available literature, I have concluded that CIM is a more broad arena than these other terms connote. Peter Vail's model[1] depicted below is one of the better mechanisms for understanding the true context of computer integrated manufacturing. While I feel that some additional linkages should be shown in the model, (like "material flow control", and "overall process quality monitoring and feedback"), I contend that his picture captures the essence of the true definition.

MODEL OF COMPUTER INTEGRATED MANUFACTURING

(VAIL, PETER S., COMPUTER INTEGRATED MANUFACTURING, BOSTON, PWS-KENT, 1988 PG.4)



The concept of CIM implies a management philosophy rather than a specific set of computer hardware or software controlling a piece of machinery on the manufacturing floor. According to Kochan, "the term ... (CIM) refers to the integrated use of computers in all sections of enterprise, from the planning of production, through the design and manufacture of a product, up to the ensuring of good quality."[2] Thus, the use of computer assisted techniques in all areas of the company become a major force in market competitiveness when they are linked together to achieve the maximum leverage from the available technology. It is the integration of these departmental functions into a whole that provides the strength to maintain critical mass in product development and manufacturing. Merchant holds that "full CIM [total integration of design to finished product] has not yet been accomplished anywhere in the world. ... the greatest degree of integration has been accomplished in the shop-floor portion of the system, in the form of flexible manufacturing systems (FMS)."[3] While the ultimate goal of CIM is to provide a start-to-finish intelligent factory, the initial step is in automating the production process for a minimal amount of manual intervention.

D. Strategic Implications of CIM to the Firm

"With an increase in global competition, concerns about declining productivity and quality of U.S. manufactured goods has spurred interest in advanced manufacturing technology" report Nazemetz and Udoka. They contend that a specific reason for successful advanced manufacturing technology is difficult to pinpoint, but offer that alignment of the organizational system with corporate strategy, employee education, and pace and method of implementation are key differentiators.[4] Most manufacturing environments are characterized by a high degree of information intensity. CIM provides a method for improving productivity and reducing waste by allowing critical communications to be coordinated through a centralized function. However, in many instances, the roles of the engineering and production organizations must be changed to facilitate a greater degree of teamwork between the groups. Generally, this means a change in the company culture must occur across the entire manufacturing infrastructure. Additionally, the focus on manufacturing as a strategic competitive advantage in the global economy requires support from the top levels of company management. In their description of the "factory of the future" Ainsworth and Freund state that successful implementation of CIM requires 4 steps: 1. Analyze the firm's strategic environment and identify where the technology can be used, 2. Identify improvement opportunities, 3. Develop supporting manufacturing strategies, 4. Develop implementation plans. They further maintain that key success factors in the adoption of CIM include carefully controlled evolution, solid planning and communication, and top management commitment.[5] Consequently, successful firms will heed the call to a renewed look at their cultures and missions as they begin to approach the selection and use of key technologies (like CIM) for manufacturing competitiveness.

1. Justification and Financial Considerations

When deciding to commit to a new technology that requires both software and hardware purchases, the first question usually asked is "what's the ROI for this project?" or "what is the payback period?". Though traditional techniques of measuring the investment have centered around quantifiable numbers called "ROI" or "payback period", these measurement methods may not be applicable to changes in manufacturing technology. In fact, a quick review of the available measurement methodologies shows that there is not a current model for justifying these kind of purchases based on numbers alone.

A brief summary of the popular financial comparisons include: payback period, return on investment, net present value, internal rate of return, and so forth. (Refer to a text on finance, such as Financial Management by Brigham and Gapenski, 1988.) Without delving into the specific limitations of each of these, I will summarize by stating that treatment of tax considerations, value of the cash flows after reaching the payback period, and the time value of money are key differentiating factors. Based on completeness of the numerical measures themselves, I recommend that a modified IRR (IRR*) and/or NPV methods be utilized where possible, since they capture a more suitable picture of profitability.

However, even these techniques fail to include the many intangible factors that are hard to quantify. For example, how do you quantify equipment safety by making a trade-off between profit dollars and the value of a human life? What about improvements in product quality, changes in the makeup of the workforce, reduction in inventories, redefinition of the business, or changes in market share? Francis and Helzerman concur by stating that "...all the payback and rate of return theories really apply only to situations where the nature of the (manufacturing) operation is unchanged. ...They 'measure the wrong things' when it comes to justifying modern factory automation to replace the hard automation of yesteryear."[6] Consequently, justification of CIM using capital equipment, cost-based analysis may not be an adequate measure that reflects the total advantage to the firm. Thus, management judgement plays an important role in the decision to implement projects like CIM. (I am reminded of an old slogan that reads, "good judgement comes from experience; experience comes from bad judgement.")

Ultimately, it is critical to weigh the quantifiable trade-offs, the intangible concerns of the business, and the risks of the project in making the final decision to accept or reject a specific proposal. However, recognition that the very nature of the company's business may be changed by the adoption of CIM technologies should be a critical consideration during the decision-making process when attempting to justify increases in factory automation. Randhawa and West summarize by commenting, "thus, a long term strategic view of investment as (opposed) to the more prevalent short term, cost-justified view is necessary if the full potential of computer integrated technology is to be attained, and US industry is to be revitalized."[7]

2. Implementation Methods

Although the interpretations, classifications, and definitions of CIM vary, based on my readings there appears to be a general consensus on the requirements for successfully implementing a CIM strategy. The tactics generally involve a two-fold attack on the problem: gaining support and strategic planning from upper management levels, and performing the actual implementation from the grass roots upward. Perhaps it is best recounted by Bierbaum, who states that "the top down approach focuses on the automation task as a downward extension of traditional management information systems and data processing technologies. The bottom up approach views CIM as an upward extension of factory floor process and machine control systems."[8] In the majority of readings on CIM and Flexible Manufacturing Systems, obtaining upper management support is recommended as a vital step in ensuring project success. One of the primary reasons for needing this high level of support is that the CIM solutions usually cross many functional boundaries of an organization. Consequently, a "champion" for the project helps to link the various needs of these departments and focus on a more broad solution for the company. However, this "champion" must be supported by engineers, designers, and top managers, who are willing to cooperate with him and effect a satisfactory solution.

"A support network that spans functions and departments will get more cooperation than the presence of a single champion. ... Probably the greatest danger in the selection process is the temptation to make the EDM system a point solution that can't grow as needs expand," states Donald H. Brown of D.H. Brown Associates.[9] He further recommends that implementation of a new (CIM) solution should be isolated from simultaneous changes in the company when he asserts, "Don't overlay a new EDM system on top of changes to the organization, process, or design tools. It won't work. Make changes before or after."[10] The ability to correctly identify and attribute changes in the workplace to the CIM solution plays an important part in the long term adoption of the new system. Therefore, introducing a new system may be more effective if made independently of other organizational changes.

Other issues in the commencement of a CIM endeavor are the compatibility of the hardware and software being considered. The ability to integrate various workstations and controllers provides the flexible manufacturing system with a decisive advantage over the firm that does not have this capability. Furthermore, ease of use, ease of adaptation or modification, and data security considerations should be evaluated before undertaking an integrated network installation. It is important to point out that while the interactions of each player in the implementation process is critical (user, integrator, management, etc.), their roles must be clearly defined. A Role Interaction Model developed by Padmanabhan and Souder supports this separation of duties, as they state, "...

implementation failures are likely to occur when the players step out of their roles, assume roles that are most appropriately played by others or fail to carry out their individual roles."[11] Thus the successful adoption of the technology also requires attention to guiding the role behaviors of the participants, which can be managed to provide maximum effectiveness for the firm.

E. Flexible Manufacturing Systems as Partners to CIM

1. Workcell Automation and Robotics

Generally used in medium volume production applications, robots offer the ability to perform specialized tasks at relatively high throughput rates and with highly repeatable quality levels. Francis and Helzerman propose one definition for industrial robots when they state, "robots are flexible tools ... normally used as a fixed piece of automation"[12] A key component in robot control is the use of automated vision systems to work in conjunction with the robot cell, assisting with checking presence or alignment of parts prior to being placed. In my experience at HP, robotics are generally used throughout a factory where the degrees of accuracy for part placement cannot be met by a human, where tasks create high worker fatigue, where the ergonomics of the operation are not conducive to safety, or when the job is repetitive and tedious for people.

a. Key Differences Between CIM and Robotics

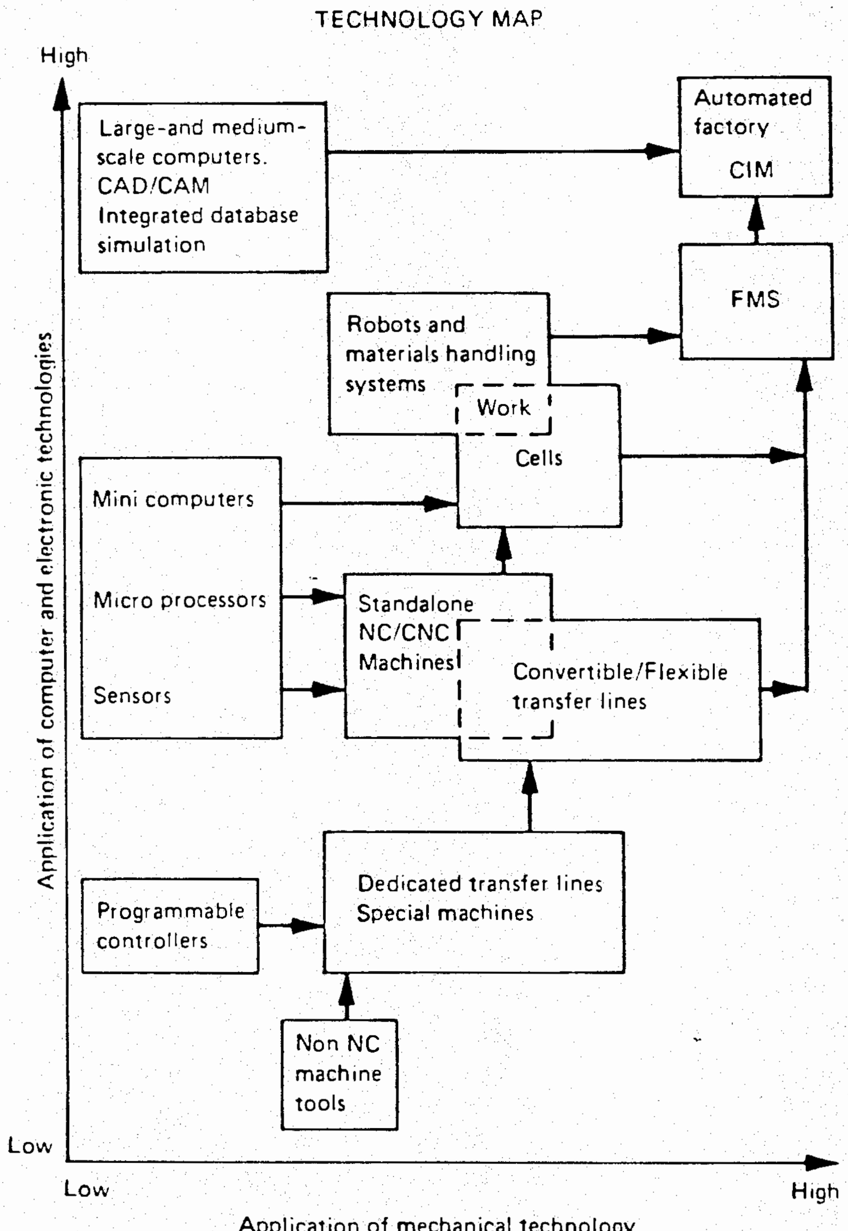
Given that robot operation is computer controlled, why isn't "robotics" equal to "CIM"? First, robotic controlled cells, computer controlled machines, and even automated test equipment represent a much smaller scope of automation in the factory than does a CIM solution. These individualized pieces of smart technology provide what is termed by many authors as "islands of automation". One author, Thacker, further clarifies the difference by maintaining that automation is not the same as integration when he states, "the benefits of new computerized technologies are severely diluted if the integration is still manual. ... CIM is the integration of the islands of automation."[13] The ultimate leverage for the firm comes not from computerizing many small segments, but in the synergy that is created from linking these segments together under one common set of criteria. A continuing discussion from Thacker is worth reporting here:

> The challenge of CIM is both technical and cultural. The technical challenge is the breadth of technologies involved. Though they are all computer based, they are all intended for widely varying applications. The challenge is further complicated by the number of different vendors, the incompatibility among systems (from the same vendor as well as different vendors), and the lack of standards for data storage, formatting, and communications. Specification of CIM technologies requires an understanding of the applications, the technology, and the communications and integration requirements that will be required of that technology by other systems, functions, and people, as well as data communications and integration technologies. ... CIM requires organizations to view their operations as a whole and not as fragmented functions.[14]

Seifert concurs and adds further emphasis on the definition of CIM by stressing the integrated nature of the technology. He states, "CIM can become the vehicle for embedding procedural discipline in operations by reducing the need for manual intervention. Since mechanization equals automation plus integration, the major benefits of information mechanization come from the integration component of that relation."[15]

Although robots offer flexible automation which can be utilized in various production environments, CIM is the "umbrella" strategy under which integrated networks in the factory can flourish and be made maximally productive. "Since CIM is a grouping of technologies and since the goal is constrained by economic realities, we can think of CIM as a management philosophy that allows us to optimize our productive resources."[16] Further, robotics are considered as elements of a flexible manufacturing system, while FMS is considered an element of CIM. The relationship becomes more evident with the aid of a technology map showing computer, electronic, and mechanical technology linkages on the factory floor. This overview demonstrates relationships between the flexibility of an automated solution, and the requirements for applying specific features of the available technology.

Exhibit 7. Technology map.



YOUNG, FLEXIBLE MANUFACTURING SYSTEMS, AMA, 1986, PP. 37

"Flexible manufacturing represents the first major breakthrough in CIM by bringing together parallel developments in process control, material handling, and computer technology."[17] Leimkuhler asserts that intelligent manufacturing systems (IMS) is a further step beyond FMS in the movement toward true CIM technology. (See the table below.) Thus, FMS is generally perceived as the first stepping stone and IMS as the second, in the trend toward true CIM implementation throughout the various functions of the organization.

IMS Attributes, Functions, and Goals
(Leimkuhler, pg. 250)

IMS Attributes	IMS Goals by Function		
	Planning	Design	Control
Flexibility	Strategic Policies	FMS cells, & Tooling	Robotics and AGVs
Integration	Quick Turn-Around	CAD/CAM & CAPP	Compatible Architect.
Intelligence	Computational Modelling	Knowledge Based Design	Sensing & Expert Systems

b. Similarities Between CIM and Robotics

While the primary difference between CIM and robotics is one of scope, this breadth versus depth distinction also contains many characteristic features which require deliberation using a similar approach. First, the investment decisions for a CIM application and a robot installation both involve considerations for large capital outlays. This need for financial commitment generally dictates that a justification of the expense is made consistent with the methods previously discussed in this paper. Additionally, once the expenditure is sanctioned, the selection processes used to choose robots and/or CIM equipment to fit the application needs are similar in nature. First, an overall assessment of the business strategies must be made since an understanding of organizational goals is critical to the success of the firm. Next, an assessment of the available technology must be made to determine how the needs of the organization can best be met. Finally, the implementation of the projects must be carefully planned and coordinated to allow for mapping the needs of the company with the deliverables of the technology.

Furthermore, the recommended implementation techniques for integrating the new technology into the organization follow similar paths for both CIM and robotic systems. Both require top management commitment and a project "champion" to maintain momentum during the undertaking. Ultimately, with either topic, management must be careful to prevent major dislocations of the work force, or changes in corporate culture that are not intended. This is usually accomplished by employee training, a gradual introduction of the new technology, and full management support for the projects. The ultimate outcome of both CIM and factory robotics is that people can now make products with machines, not with their hands. With information technology and flexible automation integrated into the corporate structure, the responsiveness of the company to the competitive environment is optimal.

2. Material Assembly

The use of CIM technology in leveraging high efficiencies from material assembly operations is another example of an advanced manufacturing technique. There are two aspects of managing the material assembly with electronically controlled means. The first is in generating the translation of CAD developed data into the file formats needed by the various assembly equipment. This part recipe translation is generally required for robotic equipment, axial and radial part placement, and even automated test equipment. The second aspect of automated assembly control is in providing a "real time" change-over of the parts on the machine to accommodate a sequential mixed-mode production operation. Automating the programmatic download of part recipes to assist in machine set-up for the next assembly operation is a common application of CIM technology. A continuous assembly line does not slow down to allow for the next machine set-up period, and the machine utilization is kept high at individual cells because they are always kept busy. It is an even greater contribution to the manufacturing operation if that machine happens to be a critical constraint to the process.

Although cellular manufacturing tools are highly beneficial, their use may bring many other process problems to light. In an assembly operation, for example, humans generally "make" parts fit even when slight deviations in part tolerances exist. Automation is not that "smart" and consequently the vendor's parts must be closely monitored for accuracy throughout the production process. Ultimately, however, the use of these automated assembly tools will force consistency and repeatability into the manufacturing process.

3. Material Flow Control

"It is now recognized that improvements in material handling must occur if manufacturing capability is to improve. Improvements will be critical in reducing inventories, improving quality, reducing cycle times, increasing productivity, and lowering costs."[18] Even though traditional focus on the movement, storage, and control of material has been to force-fit a linkage between automated islands, this lax view is changing as companies recognize the importance of the material handling function. "Because a material handling system cuts across cost centers and departmental boundaries, it functions as an integrating agent for manufacturing. For this reason, many consider the material handling system to be *the* systems integrator."[19] Material storage, transport, and control plays an important role in the company's ability to be responsive to the marketplace and maintain competitive advantage.

A good automated storage and retrieval system (AS/RS) can help cut WIP and reduce the amount of handling that the material undergoes. By reducing the amount of non-value-added handling that the parts and subassemblies undergo, the exposure to damage (ESD or drops, etc.) can also be minimized. The individual part packaging design also contributes to the amount of storage space needed in the facility, and to the amount of "pre-use" intervention required by an operator. The controlled use of Automatic Guided Vehicles (AGVs), transport conveyors, and robots throughout the factory can substantially reduce the need for high levels of direct labor involvement in material handling. These design schemes can be automated for the establishment of specific delivery times, locations, and part quantities.

On the assembly line itself, material flow can be controlled by computer monitors that continually receive inputs from optical or mechanical position sensors along the line, and send out directional information to conveyor sections, buffers, or other machines. Using CIM technology for line control and monitoring can enhance the efficiency of the operation and can also provide automatic signalling to operators when a problem occurs. This helps to focus fast attention on the down process and acts as an aid in marshalling the appropriate resources to solve the problem.

Another application of CIM to the material flow aspects of the factory are the ability to monitor cycle times throughout the process. For example, "time stamps" can be made prior to entering an assembly operation, a buffer cell, or when idle, and this can be electronically compared with the finish time to provide a profile of the process flow. Techniques such as this are helpful in identifying critical resources and bottlenecks in a synchronous manufacturing process. (The simulation of material flow patterns and impacts on buffer sizes and inventory levels can be facilitated with computer-based software simulation packages. However, this paper will not treat the subject of simulation in any detail except to mention it as an alternative to better understanding the process flow and identifying potential bottlenecks and/or critical resources on the factory floor.)

4. Information Flow/Software Considerations

Information flow throughout the assembly operation is becoming more closely tied to the actual material flow process as computer control develops in the factory environment. Data communications is one of the most important aspects in the design and implementation of a computer integrated manufacturing system. From my experience, one of the biggest problems that manufacturers face is in linking the myriad of computer controlled hardware together to form an integrated system. Because the selection of vendor hardware is so enormous, the variety of communications protocols is widespread. "Arguably, the greatest impediment to computer integrated manufacturing (CIM) in the discrete parts manufacturing industry is robust, flexible shop floor level [software] control."[20] Several authors suggest modeling the software communications around a "layered" approach to provide flexibility in establishing software connections. Many variations are suggested in the literature, but the most generally accepted standard is the International Standards Organization's Open Systems Interface (ISO-OSI) model for computer networks. As discussed in detail by Tanenbaum, this model consists of dividing the communications protocols into seven layers: the physical layer, the data link layer, the network layer, the transport layer, the session layer, the presentation layer, and the application layer.[21] Using this framework allows for interconnecting multiple distributed computer systems so that they appear individually transparent to the user and cross-system connections are perceived as one machine. Utilizing a flexible software format will allow for future leverage in connectability and integration of hardware platforms as they continue to develop at a rapid pace.

F. Impact of CIM on Product/Process Quality

1. Automated Data Collection

Many CIM applications are aimed at supporting the gathering, analysis, and/or presentation of data generated on the factory floor. These types of applications typically involve the use of barcode scanners to help in the automatic routing of material from one location to another. Placing barcodes on products is helpful in generating and tracking defect data for the specific parts being manufactured. Using CIM software, the barcode label can be scanned and the individual defects can be recorded for analysis and repair, and for future process improvement opportunities. The data can be entered either manually by humans, with touchscreen terminals, or with barcode wands.

One advantage of using barcodes is emphasized by the following statistics from a seminar on industrial bar coding: the rate of mistakes in human data entry is one in every 300, while the rate of mistakes in bar code entries is one in a million.[22] Consequently, the more automated the data entry function becomes, the higher the quality and accuracy of the recorded data.

CIM toolsets can be utilized in providing the electronic transfer of the collected data to concerned parties in the process such as personnel performing repairs. With the electronic storage and presentation of defect data, the handling of material tracking, paper trailers, material lists, and/or failure data can be automated. There are several specific characteristics of an automated data management system which provide benefits to the firm. From personal industry experience, some of these include:

- Timely data and data distribution
- Useful and effective display formats
- A singular source of information about factory performance
- Documented data definitions for consistent recording
- "Institutionalized" set of process area metrics

While the benefits of such automated data collection are evident, there are down-sides as well. Once the process is in place to allow automated data collection and manipulation, the problem shifts to information management. Because more volume and variety of data are available, there may be a tendency to either ignore the data or to spend too much time getting lost in the details. Either scenario is costly and at the expense of the process quality. "Long lists of current operational data are almost useless as CIM systems operate at a speed that renders detailed manual analysis of masses of data difficult or impossible. The manager's time should be devoted to optimizing the system and dealing with problems, not analyzing a mass of production and status reports."[23] Thus, the key to this aspect of data automation is providing the most "useful" information to the decision-makers in a timely manner. Based on industry applications and personal experience, some examples of the types and categories of data that can be generated may include:

- o Paretos of defects by causes
- o Paretos of defects by assembly type
- o First pass yields at various process steps
- o Amount of scrap generated
- o Total number of assemblies built by shift/station/etc.
- o People count numbers throughout the process
- o Number of total repairs made by assembly/component/etc.
- o Number of returns from downstream processes

"With conventional data-handling systems, ... fully half a manager's time was spent getting data on which to operate. [But with CIM] all the data the manager needs, correct and current, are at his fingertips."[24] Additionally, alarms can be programmed to sound when defect levels accelerate, when multiple failures occur, or when the process control specifications are no longer met.

Often, it is difficult to determine the "high wants" from the "musts" when establishing data collection categories, and the relationship between the user community and the CIM implementation experts becomes even more important to the success of the program. The dynamic nature of the CIM controlled environment dictates that understanding the needs of the user community (after identifying who the true users are), and providing flexible solutions which can be easily changed or adapted to meet evolving requirements as the process matures, is key to coordinating successful operational activities.

2. Relationship to Total Quality Management (TQM)

The increase in Just-In-Time (JIT) manufacturing philosophies has assisted the firm in focusing on quality improvements to their products and manufacturing processes. Total Quality Control (TQC) and Statistical Process Control (SPC) are techniques that have been emerging over the last decade to help the company isolate defects to their root causes so that they can be eliminated from future production activities. TQC is a philosophy that recommends viewing all job activities as processes, and managing those processes through a structured approach for continuous improvements. Statistical process control (SPC) is a TQC tool used to analyze data and monitor process variables "real time" rather than as an end result. With SPC, the process variation can be measured statistically and control charts can be developed to monitor the activities and allow for appropriate adjustment to the manufacturing process.

Computer integrated manufacturing tools can incorporate the use of SPC information to either identify the current state of the process through automated monitoring, or by taking the next step and providing a method of automatic adjustment to the process parameters based on real time parametric information. This automated control offers a powerful step in the integration of defect information and factory automation to result in production at a continually high quality level. The primary deliverable from incorporating a TQC approach is increased quality and customer satisfaction.

G. Future Trends

High costs and a weak economy have been prohibitive factors to the introduction of more CIM technology, but the costs of both hardware and software continue to decline, which should improve their acceptance. Further, the emergence of systems integrators who offer turnkey solutions is increasing, which should result in better visibility of the CIM solution for manufacturers. "Where flexible manufacturing systems have been installed, results have been dramatic and, as these experiences become more widely known, the usage of FMS will grow."[25] Along with sophistication in hardware and software dedicated to manufacturing applications is the technology of computer communications. At my company, this area has shown increases in customer demand for workstations, local area networks (LANs), and peripheral computer devices. Also, the advent of simulation software packages allows better designs with engineering CAD systems, modelling of material flow, and optimizing of the factory communications networks, as well as the factory performance. As technology continues to develop, and applications become more widely available, the movement of firms toward more advanced manufacturing methods will be vital for their survival in the open market environment.

1. Changing Roles for Employees

In the drive toward more factory automation, there are many sociological consequences that need consideration by company management. The impact of technology on the shop floor workers can be perceived by them as a positive contribution to their working environment, or as a personal threat to their own job security. "Many industrial tasks are unpleasant or dangerous and well worth eliminating. In the case of jobs which are boring rather than dangerous the benefit of eliminating this work has to be weighed against the effect on the displaced worker: he or she may transfer to more interesting work, or equally boring work or be made redundant."[26] The manufacturing management team must strive to actively shape the factory floor, both in terms of technology and people skills to create the right balance for a competitive edge. "Manufacturing firms will have to learn how to recruit, train, manage, evaluate and reward 'knowledge workers', as machines and electronic controls take over the traditional 'touch labor' and even most of the plant floor 'skilled' labor of the past."[27]

In my opinion, this reality requires a return to the basic considerations of management such as understanding people's motivations, finding a match between their needs and those of the organization, and communicating the decisions in a method that facilitates a positive work environment. Older employees for example, may find it difficult to return to school to acquire additional training or upgrade their skills, while younger employees may be more willing to do so. However, the degree to which the employee skills correlate with the new technology should be of utmost concern. Gupta suggests five activities to pursue when trying to assess the integration of new technology into the work environment:

- o Analysis of current tasks and skills
- o Analysis of the new activities that will be created by FMS
- o Analysis of the fit between the tasks and the ability of operators
- o Developing a strategy for worker involvement
- o Developing training programs[28]

Furthermore, as the technology enters the factory and the job content of the workers changes, more technical skills will be required to operate and maintain the equipment used in the automated cells. Additionally, this effect will likely transfer to the engineering organizations, and a shift away from traditional "electrical" and "mechanical" skills may give way to a fundamental knowledge of both disciplines in order to meet the design and service level needs. "The education and training levels required to operate the CIM factory will be higher for all organization members....higher levels of creativity and innovation will also be required."[29] The ability to hire people with the requisite skills will become more difficult as the specialization and educational aspects of the overall factory environment continue to change, and the available pool of qualified labor becomes increasingly scarce. Teamwork among the employees will become even more important, and the expected levels of dedication to the job will increase. Klein warns that in this role shift "... managers in high-commitment work systems particularly have to modify their workers' expectations without appearing to be reversing philosophy. ... They ought not to promise workers autonomy when they mean them to deliver an unprecedented degree of cooperation."[30] Consequently, both the initial impact and the longer term repercussions of using CIM technology present themselves as demanding challenges to an organization's management.

H. Conclusions

The keys to future success of the manufacturing firm are in its ability to be responsive to the marketplace while maintaining a high quality and low cost product. CIM technology offers toolsets which are currently being adopted, although the total vision of CIM has yet to emerge in any sizable scale. "The 'Factory of the Future' is best defined as a factory with a high level of flexibility plus a very short response time in all aspects of its operations. This in not a 'CIM factory' *per se*, but rather a factory made possible by the use of CIM technology. This factory will have many of the characteristics of a computer-based information system."[31] Because of recent developments in high technology fields, the installation of computer controlled equipment has increased drastically. However, in my experience at HP, technology always seems to lead our ability to manage it, and along with these impressive gains comes the reality of attempting to integrate it into a workplace which may not be ready to accept it. Traditional financial justification techniques, poor implementation, and human resistance to change, all factor into the equation that will make CIM a success or failure for the firm. "... the solution to fading competitive ability, sluggish productivity growth, and poor quality cannot be found exclusively in the mythical black box of a miraculous technology. To realize the full potential of technology, close attention to the way products are designed, streamlining flow of parts and materials through the factory, and better relations with customers and employees are essential."[32] Thus, CIM is not a panacea for all of the factory's problems in attempting to stay competitive. The impacts on people, applicability of the technology to advanced manufacturing techniques, as well as the successful adoption of changes in the company's basic manufacturing philosophy must be considered in great depth before the company can successfully deploy CIM as a strategic weapon for continued leverage of its market presence.

I. Endnotes

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[20]Joshi, S.B., Mettala, E.G., and Wysk, R.A., "CIMGEN - A Case Tool for CIM Development", in Proceedings of the Third ORSA/TIMS Conference on Flexible Manufacturing Systems (Manufacturing Research and Technology Series, ed. by Stecke, Kathryn E., and Suri, Rajan), Amsterdam, Elsevier Science Publishers, 1989, p. 239.

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[28]Gupta, Yash P., "Human Aspects of Flexible Manufacturing Systems", Production and Inventory Management Journal, Second Quarter, 1989, p. 34.

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[30]Klein, Janice A., "The Human Costs of Manufacturing Reform," Harvard Business Review, March-April, 1989, p. 66.

[31]Goldhar and Jelinek, p. 232.

[32]Gupta, p. 30

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Ainsworth, WIlliam J., and Freund, York P., "The Factory of the Future: Just in Time for What?," Information Strategy, Vol. 4, Iss. 3, Spring, 1988. States that JIT is the first major step toward CIM, and CIM's major benefit is reduction of labor costs in mid-management. Successful implementation requires a four step process and top management support.

Bierbaum, Kris, "Are You Making the Right Connections?", Plant Engineering & Maintenance, Vol. 12, Iss. 5, May, 1989. CIM helps in achieving product conformance to specifications. Purports two approaches to CIM implementation: Top down and bottoms up. Also discusses the human interfaces to the manufacturing systems.

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COMPUTER INTEGRATED MANUFACTURING

AGENDA

- DEFINITION AND MODELS OF "CIM"
- IMPLEMENTATION CONSIDERATIONS
- AUTOMATED MATERIAL HANDLING
- AUTOMATED DATA GATHERING AND METRICS
- FINANCIAL JUSTIFICATION ISSUES
- ORGANIZATIONAL AND HUMAN CONSIDERATIONS
- IMPLICATIONS FOR DESIGN ENGINEERING
- TIME--TO-MARKET BENEFITS
- MATERIAL AND VENDOR RELATIONSHIPS
- ELECTRONIC DATA MANAGEMENT
- SOURCES OF HELP
- CONCLUSIONS

WHAT

IS

"CIM"

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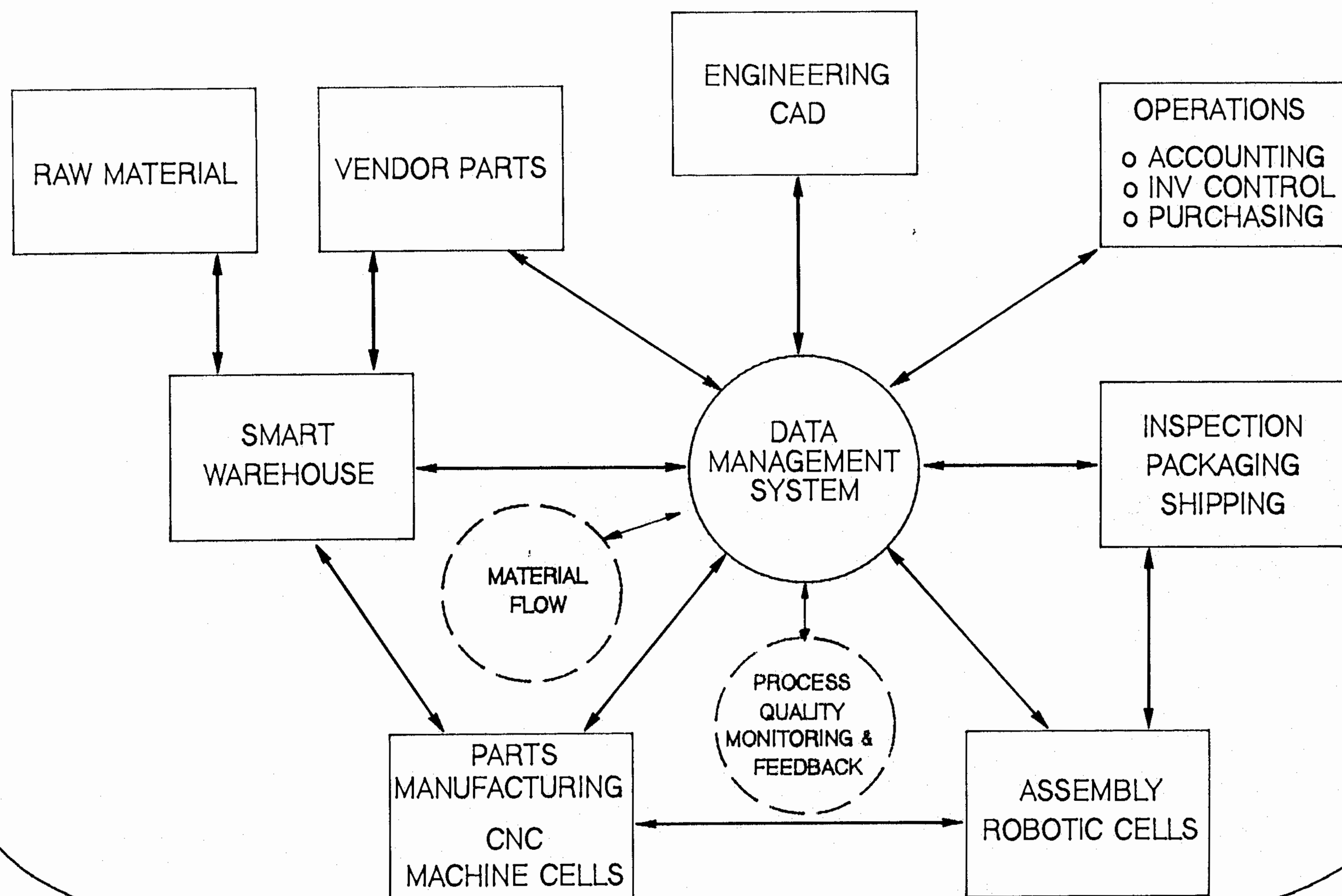
MODEL OF COMPUTER INTEGRATED MANUFACTURING

(VAIL, PETER S., COMPUTER INTEGRATED MANUFACTURING, BOSTON, PWS-KENT, 1988 PG.4)



"CIM" DEFINED:

"THE TERM "COMPUTER-INTEGRATED-MANUFACTURING (CIM) REFERS TO THE INTEGRATED USE OF COMPUTERS IN ALL SECTIONS OF ENTERPRISE, FROM THE PLANNING OF PRODUCTION, THROUGH THE DESIGN AND MANUFACTURE OF A PRODUCT, UP TO ENSURING OF GOOD QUALITY."

(KOCHAN, D., ED. CAM DEVELOPMENTS IN COMPUTER-INTEGRATED MANUFACTURING, BERLIN, SPRINGER-VERLAG, 1986, PG. 254)

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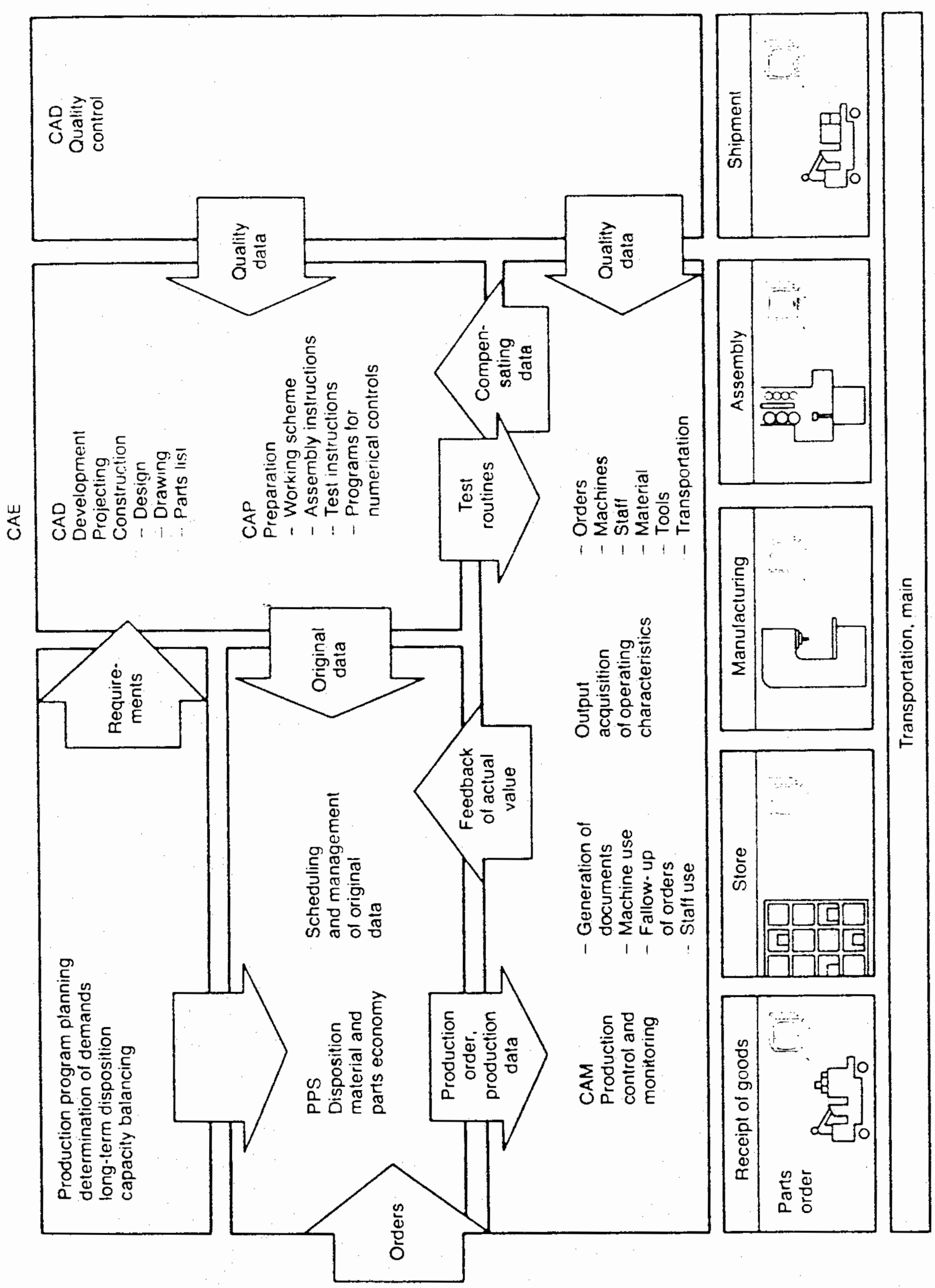
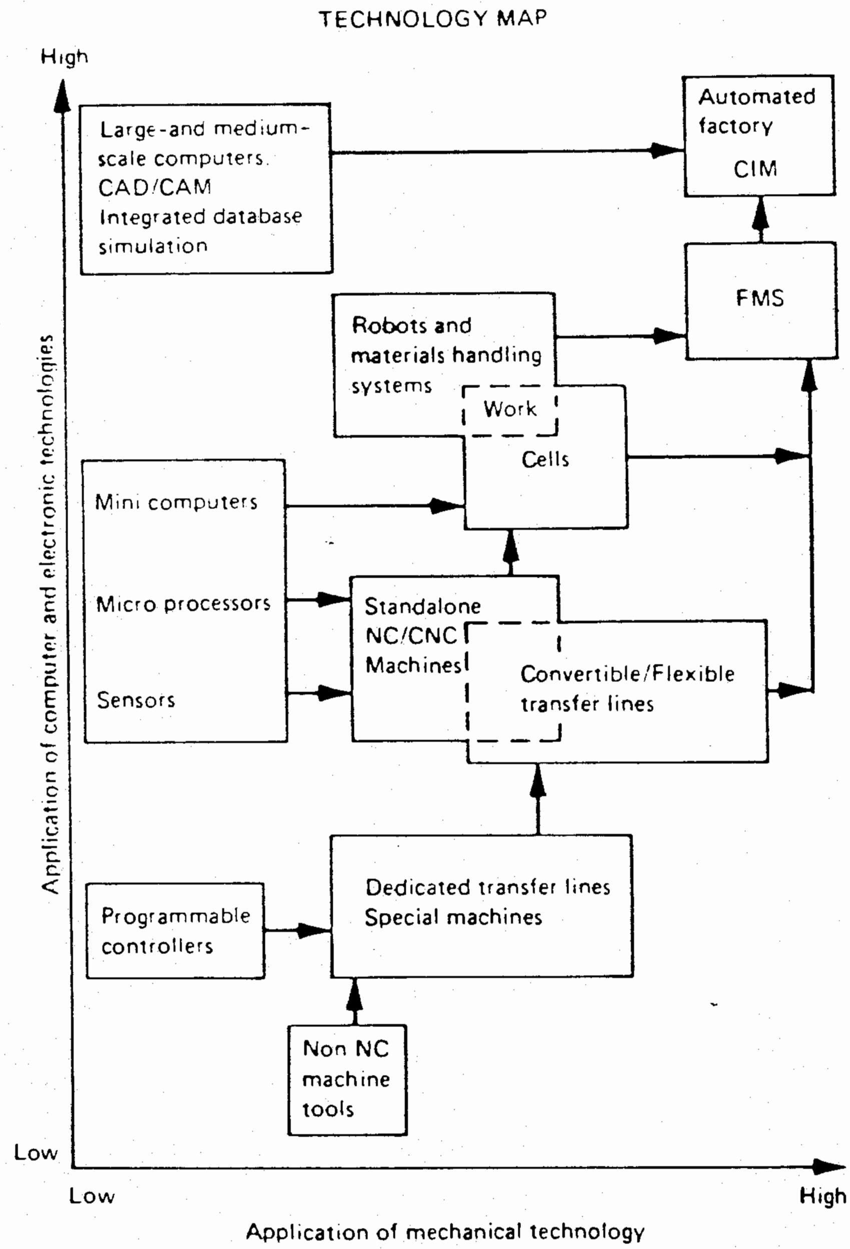


Fig. 138. Main functions of computer-integrated manufacturing (from Waller [241])

Exhibit 7. Technology map



YOUNG, FLEXIBLE MANUFACTURING SYSTEMS, AMA, 1986, PP. 37

PRE-IMPLEMENTATION CONSIDERATIONS

- DEFINE MANUFACTURING OBJECTIVES
- ESTABLISH AN "FMS" PROJECT TEAM
- UNDERSTAND THE TECHNOLOGY
- CONDUCT A PRELIMINARY EVALUATION
- PREPARE A REQUEST FOR PROPOSAL
- EVALUATE THE VENDOR PROPOSALS

YOUNG, FLEXIBLE MANUFACTURING SYSTEMS, AMA, 1986, PP. 46–50

IMPLEMENTATION OF SPECIFIC APPLICATIONS

- COMPATIBILITY OF HARDWARE/EQUIPMENT
- SOFTWARE COMPATIBILITY/NETWORKABILITY
- DATA SECURITY/ACCESS LEVELS
- EASE OF USE (OPERATION and MAINTENANCE)
- FLEXIBILITY TO MEET CHANGING USER NEEDS
- FINANCIAL ASPECTS (NPV, IRR, IRR*)
- HUMAN ASPECTS (TEAMWORK IS ESSENTIAL)

KEYS TO SUCCESSFUL IMPLEMENTATION

- COMMITMENT TO THE PROJECT
  - IDENTIFY A "CHAMPION"
  - TOP MANAGEMENT SUPPORT IS VITAL!
  - NEED LOWER LEVEL COOPERATION
  - ALLOW BOTTOMS-UP IMPLEMENTATION
- DEVELOP A LONG TERM STRATEGY
  - LINK TACTICAL PROJECTS TO THE LONG TERM PLANNING
- INTRODUCE THE SYSTEM INDEPENDENT OF OTHER ORGANIZATIONAL CHANGES
- MAKE THE FIRST ONE A SUCCESS
  - START SMALL

BENEFITS OF AUTOMATED DATA GATHERING

- TIMELY DATA and DATA DISTRIBUTION
- USEFUL AND EFFECTIVE DISPLAY FORMATS
- A SINGLE SOURCE OF INFORMATION ABOUT FACTORY PERFORMANCE
- DOCUMENTED DATA DEFINITIONS for CONSISTENT RECORDING
- "INSTITUTIONALIZED" SET OF PROCESS AREA METRICS

DATA GATHERING/METRICS

- PARETOS OF DEFECTS BY CAUSE
- PARETOS OF DEFECTS BY ASSEMBLY TYPE
- FIRST PASS YIELDS AT VARIOUS PROCESS STEPS
- AMOUNT OF SCRAP GENERATED
- NO. ASSY's BUILT BY SHIFT/STATION
- PEOPLE COUNT NUMBERS
- NO. OF RETURNS FROM DOWNSTREAM PROCESS
- NO. REPAIRS BY ASS'Y/COMP/SHIFT/STATION

ASPECTS OF MATERIAL FLOW

THE BASICS:

PRODUCTS

VOLUMES
MIX

PARTS

SIZES
PACKAGING
QUANTITIES
SPECIAL REQ'S (eg. ESD)

ASPECTS OF MATERIAL FLOW

"ADVANCED" ISSUES"

FACTORY LAYOUT

AISLEWAYS
DISTANCES
TRAFFIC
SAFETY

TRANSPORT

PEOPLE
AGVs
CONVEYORS
SPECIAL STORAGE (DUST FREE, NITROGEN)

AUTOMATED STORAGE AND RETRIEVAL SYSTEMS (AS/RS)

ADVANTAGES OF AUTOMATED MATERIAL FLOW

- MINIMIZE LEAD TIMES
- IMPROVE TRACKING
- ELIMINATE BACK-UP PROCESSING
- REDUCE MATERIAL HANDLING AND WASTE
- INCREASE INVENTORY ACCURACY
- HELP TO EFFICIENTLY UTILIZE CCRs
- MINIMIZE NON-VALUE-ADDED ACTIVITY OF THE WORKFORCE

A REMINDER ON CIM:

AUTOMATION

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INTEGRATION