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Abstract: Here we focus on the benefits associated with a CIM system, the importance of a corporate strategy, including CIM as a priority, the financial accounting issues surrounding justifying a CIMS, the associated data management issues, and the resulting human factors. Methods of implementing a CIM system, and integrating total quality management with the CIM philosophy are suggested

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There are many different views on what Computer Integrated Manufacturing (CIM) actually is. Is it Flexible Manufacturing Systems (FMS), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) or Numerically Controlled (NC) machines? All of the previously mentioned technologies are elements or subsets of CIM but are not in and of themselves "CIM". As Jean Noble writes, CIM "is the integration of all functions towards common goals. With CIM, engineering, manufacturing, marketing, and information systems can no longer operate in isolation." [17, p. 44] Although the technologies mentioned previously may have common goals they are usually not goals which cross over and integrate all the functional groups of an organization. With this definition it is clear that CIM is not just a technology but rather a **philosophy**. Through CIM there is a shift from "the focus of manufacturing from physical and mechanical operations on materials to knowledge work utilizing a variety of computer and communications technologies." [10, p. 226] CIM can aid corporations through "its reduction of leadtime, its predictability of operation, its consistency of results" and will be most effective when it is "derive(d) from its integration and automation of multiple elements into a complete system." [16, p. 21]

Since CIM is a philosophy with an emphasis on creating a complete and integrated system it is imperative that the factors of a CIM system (CIMS) are defined and understood. This paper will focus on the benefits associated with a CIM system, the importance of a corporate strategy which includes CIM as a priority, the financial and accounting issues surrounding justifying a CIMS, the associated data management issues, and the resulting human factors. In addition there will be a section on suggested methods for implementing a CIMS and also how to integrate a "total quality management" philosophy with the philosophies of CIM.

Why CIM?

Any manufacturing philosophy has certain advantages associated with it. Some of the positive trends currently being identified by U.S. Manufacturers include as a result of manufacturing automation include:

" - Higher quality
- Lower inventory
- Flexible flow lines
- Automation
- Product line organization
- Effective use of information " [19, p. 207]

In addition to these trends, the benefits of a CIMS would also include:

" - The supply of immediately required inventory at the line eliminates central storage and physical barriers on the factory floor.

- The decrease of direct labor and the increase of knowledgeable workers on the plant floor creates a need for training and new incentives.

- Vendors and suppliers are no longer viewed as adversaries but now become a manufacturer's partners in profit and cost can be driven out of raw materials and purchase parts.

- Paperwork is radically reduced" [12, p. 31]

The biggest advantage that CIM offers is **integration** which "lowers the effective size of a company by making communications faster and more accurate...". [8, p. 40] This is especially important if leadtime is a variable in market share. Jean Noble states that CIM operations increase "their (the corporation's) ability to respond quickly to new opportunities and allows them to gain market share at the expense of less flexible competitors." [17, p. 45] Another benefit of an integrated system is that "CIM based flexible manufacturing permits multiple niche/high variety business strategies..." [10, p. 226] This is one of the primary reasons why it is necessary to have upper management support and understanding of a corporation's decision to implement CIM -- especially in the high technology market place where product life cycles are shrinking.

Figure One illustrates the competitive advantage an organization can yield through CIM through process flexibility and integration throughout the organization. This figure depicts the "underlying relationship between product innovations and process technologies over the product's life cycle". [14, p.195]

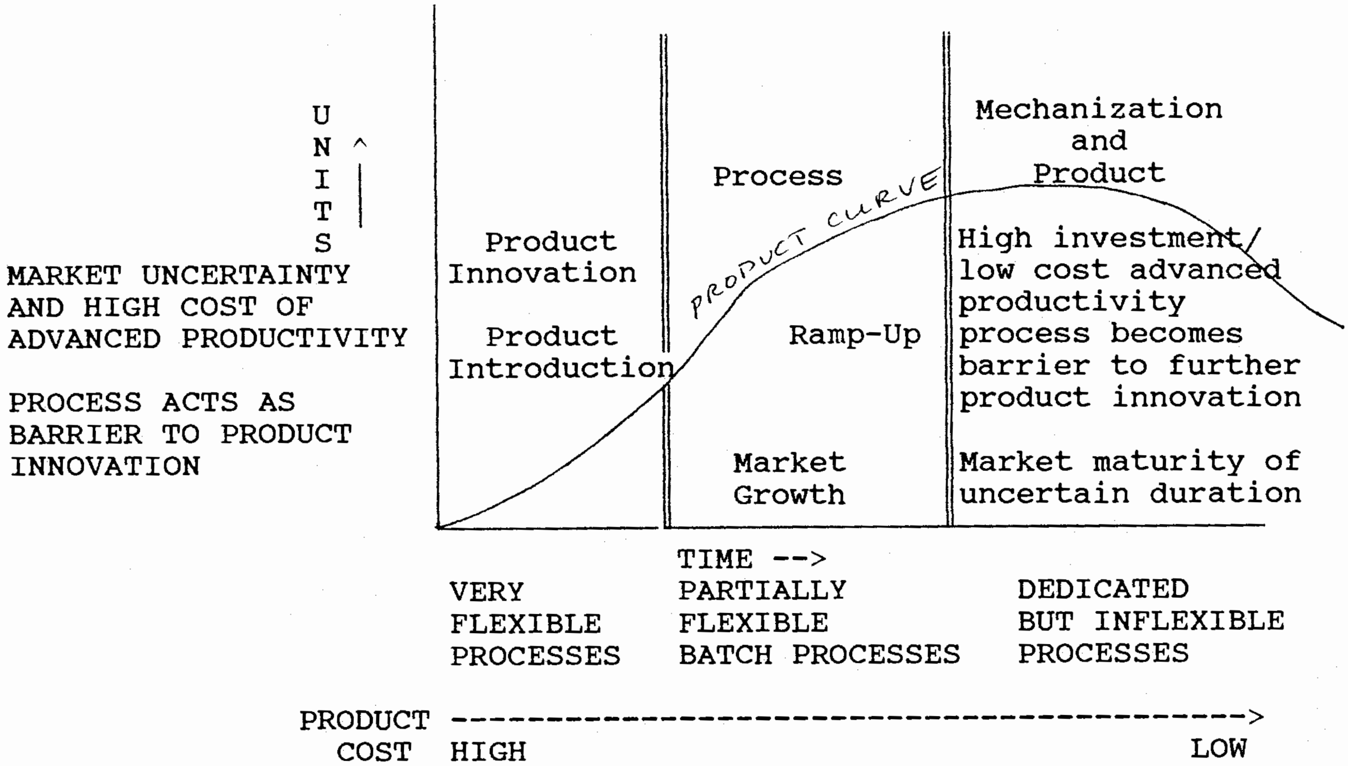

Figure 1 [14, p. 195]

According to Joel Goldjar and Mariann Jellneck, a generally accepted manufacturing strategy rule is that "As a product matures, design becomes standardized and innovations shifts from product features to production process development." [10,p. 229] From this statement the opportunities exist to "develop a process capable of producing high volumes of a fixed design at the lowest possible cost" [10, p. 229]. The benefits from utilizing a CIM strategy are many but, in order for it or any capital intensive program, to work there must be support and commitment from upper management.

Strategy

Logically "CIM will (or should) affect all areas of a company" [15, p. 24]. Any implementation which theoretically could have this large of an impact upon an organization will have management's approval -- usually upper management levels. With this in mind, it is obvious why one of "the most important issues to consider during the justification process is whether CIM is compatible with the organization's long term strategy." [17, p. 44] If CIM does not fit into the long term strategy then the upper management may or may not be willing support it. Along with long term strategy, "Capital investment policies and 'the levels of risk implied' by ventures into new technologies will have an effect on the rate of adoption of the new technology." [19, pp. 88-89] Advanced Manufacturing Technologies such as CAD, CAM, and FMS have "forced American companies to reexamine the role of manufacturing in their overall strategy." [8, p. 207] It is through this reexamination that realistic expectations of manufacturing technologies and philosophies will begin to take form. For instance, "As production automation matures from workstation and cell automation through integration with plant systems, different economic benefits accrue at different rates. Direct labor reduction benefits often accrue quickly and may reach a maximum with little or no integration. But they are partially offset by a relative deterioration in indirect labor benefits which are not overcome until integration is complete." [1, p. 52] Depending upon management's short and long term strategy the "islands of automation" mentioned above may be an effective means of applying advanced manufacturing technology without utilizing total system integration. The long term pay back, however, will most likely require total integration via a CIM system.

Questions that need to be asked before implementing CIM, on both an application level and a management level are:

" - Is there sufficient product range to take advantage of CIMS flexibility

- Do customer needs change sufficiently to make rapid response a competitive advantage

- Are competitors gaining market share through their own automation efforts" [17, p. 44]

The answers to these questions will not only determine if a CIM system may yield a competitive and strategic advantage but also it may indicate some of the intangibles that need to be addressed in justifying such a system.

Financial and Accounting Considerations

The financial and accounting functions are under a great deal of scrutiny when it comes to justifying and associating standard costs with any type of advanced manufacturing technology or CIM application. This is partially due to the absence of a "a generally acceptable method (which) is available to measure the long-run effects of investments in technology." [7, p. V-2] The financial considerations for justifying "the benefits of CAD/CAM cross multiple functions and come to light mainly in the long run. Standard accounting procedures, on the other hand, were designed for highly focused investments and ignore long term factors like market fluctuations and technological innovation." [7, p. V-1]

The standard method for calculating the cost of manufacturing a product is to sum the components of direct labor, direct material, and all other costs, or manufacturing overhead. A method such as this causes discrepancies as "the overhead measured as a percentage of total manufacturing costs is relatively small, anywhere form 10 to 40%. However, the overhead becomes the largest of the three components in CIMS because of the higher depreciation cost of numerical control (NC) machines, computers, microprocessors, automated transportation systems etc." [3, p. 42] By these standards manufacturing products with higher quality and less operator interaction end up costing the organization more due to overhead factors like indirect labor which could be from engineering support and/or training, depreciation of the automated equipment, building utilities, and allocated costs. This in turn can lead to "the inherent potential of such technologies may be lost, however, if a company's accounting system does not properly reflect the costs and benefits of operating in such an environment" [8, p. 206]

Many authors have suggested solutions to mend the ways of traditional accounting methods, included below are some options:

> " - Stop using plant-wide overhead pools; instead, accumulate overhead cost in smaller pools. Ideally, overhead should be pooled for each machine center.
>
> - Instead of direct labor hours, machine hours would be an appropriate allocation basis, especially when the overhead costs are pooled by the machine centers.
>
> - Direct labor hours and their cost are no longer significant in most CIMS. The direct labor cost should be made part of the overhead. Then the manufacturing cost would have only two components, direct material cost and transformation cost." [3, p. 43]

Through the utilization of methods such as these there is the opportunity to better understand what the true components of a product's cost are. Once understanding and methodologies are developed for standard cost accounting they can be used to help influence the ways that financial decisions are made. If in fact the **basic financial objective** is "to discover if cash flow equals benefits less costs. Benefits are the projected annual savings; costs are the recurring operating costs; and the cash flow is the net income after taxes plus noncash charges." [18, p. 25] then why are so many advanced manufacturing and CIM purchases not funded?

Some industry analysts feel that, "traditional financial justification procedures based on internal rate of return or short payback periods are said to be the greatest barriers to adopting a new manufacturing technology." [1, p. 50] These methods are not completely adequate for justifying CIM purchases because this "methodology assumes stability in the economy, technology, labor and most important the marketplace behavior of competitors". [7, p. V-2] Regardless of the methodology, the "basic questions to ask with every justification method are

1) benefits
2) costs
3) opportunity costs
4) time value of money." [polakoff,p.25]

These questions neatly outline if the CIM system will meet the **basic financial objective** spoken of earlier. Once aspect that the financial objective equation did not touch on was "opportunity costs".

If CIM is not implemented what will it cost the organization? "A drawback of these traditional techniques in justifying CIM projects is that they ignore subjective criteria. For example, CIM investments are often measured against a status quo alternative. Status quo assumes that there will be no change in market shares or revenues if CIM is not implemented" [17, p. 45] John Canada of North Carolina

State University suggests that financing for CIM ventures should be "based on the common procedure of categorizing investment projects as either opportunities (which are independent of each other) or alternatives (which are mutually exclusive)." [7, p. V-3] This allows the justification process to be viewed differently than the measurement against a "status quo". The opportunity costs could take the form of the following intangible or "soft" benefits:

" - Improved flexibility on the shop floor
- Reduced manufacturing lead time
- Faster delivery of new products to market
- Improved product quality
- A more skilled and better trained work force
- Improved product design
- Optimal customer service " [18, p.29]

Benefits such as these allow a "... shift from treating financial figures as the foundation for performance measurement to treating them as one among a broader set of measures." [6, p.131] This is not to say that the financial figures are no longer important but rather that there are other criteria which should also be accounted for.

The traditional financing criteria used in industry today "are four basic techniques to determine what the "hard" benefits are from advanced manufacturing technology:

1) Payback period
2) Return on investment
3) Net Present Value
4) Internal Rate of Return" [18, p. 25]

The payback period determines how long it would take to repay the purchase price for a capital purchase based on the expected benefits. The payback time is expected to be within 1/2 to 1/3 of the purchase's life time in order to be funded. Return on investment deals with the difference between the expected benefits and depreciation costs of the purchase over its lifetime divided by the initial purchase cost.

Equation 1. $$R.O.I = \frac{\text{BENEFITS - DEPRECIATION}}{\text{INITIAL COSTS}}$$

A percentage is obtained from equation 1. This percentage must be greater or equal to the corporate discount rate - the minimum return rate that the corporation will allow. The third and fourth methods both relate to the future value of money. Given the minimum return rate that the corporation will allow the future value of all benefits is calculated. When all of these cash flows are brought back to "time zero" and if the cash flows are greater than the initial costs then the purchase would be funded. The internal rate of return utilizes the same technique except that it requires an iteration about the discount rate (what the future value of money will be worth) until the sum of the cash flows (benefits) brought back to time zero is equal to the initial costs. By this definition if a proposal has been approved by Return on Investment then it will be approved by the Internal Rate of Return.

These financial measures insure that the investment is realistic. If the CIM can not be justified on financial measures alone then intangible or "soft" factors may need to be introduced. Since "CIM permits (and requires) close integration across business functions, so that engineering designs what manufacturing can make, carefully matched to what marketing has 'accurately' determined the market wants" it is extremely important that all groups understand what their motivating factors for implementing CIM are -- even if these factors are not measurable in a straight dollar sense. [10, p.228]

Human Factors

There are several expected outcomes of moving to a CIM system. "Human considerations in design and implementation of a CIM system may be divided into three areas in which impact will be felt -- installation and implementation, operation and maintenance, and safety." [21, p. 36] The installation and implementation area contains one critical phenomena which is employee resistance to change. One author wrote that the resistance to change "seemed to be more a result of introducing radical procedural change into a company culture where each employee had been encouraged and expected to challenge anything he or she perceived as being detrimental to the common good." [16, p. 28] This affects the organization and its cultural structure in what some refer to as a flexible "post-Fordist" factory. "The integrated factory of the future will be characterized by fewer employees, greater technical skills, increased teamwork, more communication between the top and bottom levels of the factory hierarchy, and greater perception by management and employees that they are part of an integrated community." [Badham, p. 217]

Because of these implications such items "must be considered at the earliest stages of CIM planning and implementation to assure peak performance from a totally integrated system." [21, p. 36] Employee involvement and acceptance is a key issue in having an integrated system which works. In order to facilitate a smooth transition into the CIM system there are "three basic stages where the operational employees can be brought into the FMS picture: at the design/planning stage, at the installation stage or at the implementation/operation stage." [16, p. 22]

In addition, "the transition from direct to indirect labor occurs not only because additional support is required but also because jobs are reclassified." [1, p. 52] For this very reason, "Education, in all forms, was considered to constitute 90% of the total FMS 'effort'" at one CIM installation site.[16, p. 22] Many companies have already instituted comprehensive training programs. One example is the 1000 hour training course which workers from General Motors Corp. Saginaw Vanguard factory go through in order to be adept at problem solving skills, computer programming, etc.

Another critical area of the human factors associated with CIM is operation maintenance. Issues such as "databases, work stations, multiple-system interfaces, appropriate grouping of equipment/personnel, competent task assignment, robots, programming and maintenance" [21, p 39] would be linked to operating and maintaining a CIM system. With complex tasks such as these the need for extended training arises again.

Due to the nature of advanced manufacturing technologies employed with a CIM system there is a also a need for safety concerns such as: "proper training, human/machine interaction, sensors/shutdown systems, automated mobile equipment, robotic/ automated workcell entry". [21, p. 39]

Data Management

Through the addition of CIM manufacturing has become an 'information intensive' activity"[10, p.226] Many people are wondering how to effectively utilize the information which is spewing out from their computer based or automated systems. Engineering Data Management or EDM is one label associated with this scenario. Rod Hodgman, a manager for Digital Equipment Corporation's Engineering Systems group states that "unless managements seek computer-automated methods for EDM problems, they are risking the strategic benefits of their computer-aided-engineering investments." [22, p. 56] This is very clear if one considers that "the design process will control as much as 80% of the manufacturing cost structure and is a controlling factor in time-to-market competition." [22, p. 56] There are several important features of an EDM system such as compatibility of CAD/CAM hardware and software, system security and access to data, flexibility to grow and expand, a comprehensive solution, the financials such as return on investment, and user friendliness and adaptability. [22, p. 57]

<u>How to implement CIM</u>

There is no "cook book" scheme to the implementation of CIM. As mentioned at the beginning of this paper, CIM is more than an advanced technology -- it is a philosophy which will require commitment and support at all levels of the organization. Some recommendations for those who are interested in implementing CIM in their facility include:

"1. Investigate CIM alternatives today
2. Develop a CIM project team
3. Realize CIM requires a long-term focus
4. Develop tomorrow's skills today" [18, p. 29]

With any new technology or manufacturing philosophy there will be detours and "roadblocks". Examples include "lack of corporate CIM strategy, the MIS department, and end-user apathy, ignorance, and fear." [15, p. 25] Political or territorial issues (with respect to MIS) need to be dealt with as any other human factor would be. This includes knowing when the best time to solicit help from others is or when the introduction to the CIM system should be.

The final list of suggested actions is from the book <u>How to Integrate CAD/CAM Systems</u>. Although the CAD/CAM technology is actually a subset of CIM the implementation plan should be quite similar.

> "1) Management must be committed.
> 2) Create a technical team to implement the project
> 3) Take inventory (of operations managements's goals for the system)
> 4) Form a management policy/steering committee
> 5) Do a careful and comprehensive study of the CAD/CAM industry
> 6) Model the information flow and engineering process at your company
> 7) Plan a comprehensive benchmark test
> 8) Make a decision support matrix
> 9) Select and order the system
> 10) Plan the startup
> 11) Plan for a shakedown test
> 12) Get as many functions into a production mode as quickly as possible". [8, pp. 44 -57]

<u>Similarities with Total Quality Management</u>

In my opinion, there are a number of similarities between the implementation of CIM and that of Total Quality Management. To begin with, "the big push for quality programs and the development of quality standards and procedures put CIM into a better position for success than it has ever been." [15, p. 24] Part of the reason for this is that American manufacturers are realizing that in order to be competitive we need to eliminate "rework, scrap, excesive inspections, lost business, and other shortcomings." [20, p. 25] In an attempt to eliminate these "undesirables" methods such as Statistical Quality

Control (SQC) which is based upon "statistical theory formulated 70 years ago by Sir Ronald Fisher" began to be utilized in industry. [5, p. 95]

SQC is different things to different people; by some "it is considered a production tool. Actually, its greatest impact is on the factory's social organization." [5, p. 95] This is similar to CIM being visualized by some as an "automation" tool for production but it achieves the most when it is treated as a **philosophy** which is integrated throughout the entire organization. For the Malcom Baldridge Award winner, Xerox, there was a need to "change individual and corporate behaviour so that quality was the paramount consideration in each decision, every day, at all levels." [20, p.25] Whether CIM, SQC, or TQM the philosophies all require an unprecidented commitment by all level of individuals in the organization. As Xerox put it "This commitment to quality, as we now define it, was an enormous undertaking". [20, p.26]

Aside from philosophy there are also similarities in the interaction of roles between CIM and TQM. SQC, unlike most CIM applications, will "almost always increases the number of machine operators". However, like CIM it will produce a "sharp drop in the number of nonoperators: inspectors". [5, p. 95] This focus of not inspecting quality into the product and "building it right the first time" emphasize the waste of non-value added operations.

With respect to human factors both TQM and CIM strive to treat the worker as more than an a live peice of equipment. "SQC makes it possible to attain both traditional aspirations: high quality and productivity on the one hand, work worthy of human beings on the other." [5, p. 96] At Xerox, for instance, with the TQM effort there was a "joint union-management quality process, and an experimental concept that included Quality of Work Life (QWL) training and teams." [20, p. 25]

Another similarity between SQC and CIM is the manufacturing accounting and the shortcomings associated with it. In both CIM and SQC there is a need to deviate from traditional cost accounting methods. SQC's "aim is to integrate manufacturing with business strategy." [5, p. 96] "Traditional cost accounting can hardly justify a product improvement, let alone a product or process innovation. Automation, for instance shows up as a cost but almost never as a benefit." [5, p.97]

Conclusions

CIM is an opportunity for industry to totally integrate their operations from design, procurement, manufacturing, information systems, marketing ... In order to succeed at this undertaking, however, all levels of management must be committed to pursuing CIM as a philosophy -- a way of doing conducting business on a day to day basis rather than as a tool which is utilized when needed. When coupled with a manufacturing strategy/philosophy like Total Quality Management, CIM will be able to obtain "the new performance goal (which) is continuous improvement, measure continuously against world-class competitive targets." [12, p. 32]

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