A Model for Developing and Implementing Computer Integrated Manufacturing Systems

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INTRODUCTION

As the end of the century approaches, the manufacturing workplace is evolving into a sophisticated enterprise, characterized by increasing automation and emerging technologies designed to make American manufacturing more competitive in the global market. Perhaps nowhere in modern business is technology-induced change more difficult to implement and manage than in manufacturing. In fact, much of modern manufacturing management is experimental because of managements unfamiliarity with the technologies available in the contemporary industrial workplace. One of these technologies is computer integrated manufacturing, or CIM.

WHAT IS CIM

Computer integrated manufacturing (CIM) - factory automation involving computers in the many tasks associated with manufacturing.¹

The textbook definition given above is CIM in its most narrow and shortsighted configuration. Computer integrated manufacturing is the effective integration of computer technologies and systems to aid the manufacturing business in providing customers with high
value, high quality products in a timely manner. CIM generally refers to a network of computers and machines run by people to achieve optimal manufacturing productivity. CIM is the integration of islands of automation. CIM's complexity tends to increase the closer you get to a traditional, complex factory. Conversely, it becomes more simplistic as you move to a continuous factory or just-in-time operation.\textsuperscript{iv}

CIM is one of several contemporary manufacturing concepts that comprise modern manufacturing technologies. As with other modern manufacturing tools (Decision Support Systems, just in time, total quality assurance), CIM's capabilities are based on the power of modern technologies. But it is greater than just a new technology. It is more than using computers to combine a decision support system with automated manufacturing operations. It is an organizational strategy.

"The word integrated is the most important of the entire lexicon of CIM. It means coming together, the antithesis of standing alone. It is the cornerstone of the CIM philosophy. It implies that all functions, activities, decisions, and questions be acted on not solely for the immediate task at hand but for what it means for the entire entity."\textsuperscript{iv}

The modern view of integrated manufacturing includes all of the necessary activities for transformation of raw materials and labor (human or mechanical) into the finished product, delivery of these products to the end users, and supporting the product's performance in the field. Conceptually, this begins in development, which can be part of the marketing function. It includes customer survey, product design, and specification activities. These design and specification activities are usually the responsibility of the engineering function. The traditional manufacturing concept, the actual production of the product is at the core of the modern view. Finally, delivery and after-sales activities (customer support, warranty repair) that are usually part of the sales function. This definition of manufacturing is much more encompassing than the traditional responsibilities associated with the manufacturing component of a corporation.

HISTORY OF CIM

Since the 1950s, the major functions of manufacturing businesses followed separate paths towards automation. Most successful automation efforts were found in production operations. Parts manufacturing used highly mechanized machinery driven and controlled by cams and complex mechanical equipment like screw machines. Process manufacturing used cam driven controllers and limit switches for operations like heat treating, bottling, and the like. Design, engineering, planning and production control functions were manual assisted by slide rules and later calculators. Communications between functions and between organizations was paper based.

When the concept of computer integrated manufacturing was coined by Dr. Joseph Harrington in 1944\textsuperscript{v}, it was expected to solve manufacturing's competitive problems. These early concepts of computer-integrated manufacturing (CIM) was that of an automated factory, an environment where interconnected computers controlled the machinery of production. Human labor was eliminated. CIM and factory automation became synonymous. Manufacturers invested heavily in technologies, only to find that all of those computer-driven mechanisms were not making factories significantly more productive, more cost efficient, or more competitive. Systems people had automated individual operations without regard for the business reasons for doing so, with little thought for the varying information needs of the end users, and without actual integration of the technology into the manufacturing processes. "CIM resulted in individual cases of automation in a desert of confusion, not in integration."\textsuperscript{vi} Because of this, CIM became a dirty acronym.\textsuperscript{vi} In fact, many industry consultants said "The term CIM is dead. They say that it has failed to live up to expectations."\textsuperscript{vii} However, these early failures were primarily the result of improper application of CIM, and they don't alter the premise of CIM as a valuable tool for greater productivity, quality, and competitiveness. According to Sandy Kurtzig, CEO of ASK Computer Systems, there are three principle causes of the initial failures of CIM: "We didn't have the basic tools needed to make affordable, reliable connections between various pieces of automation. The
automated systems we were trying to link were not fundamentally designed to be integrated, and third, it's extremely difficult to coordinate a number of different solutions on an ongoing basis. As systems change and develop, it's very difficult to keep the integration replacement up to date. "\textsuperscript{ix}

The truth is that CIM is more alive than ever, but it has taken on a new set of dimensions. CIM today bears only slight resemblance to the CIM vision of ten years ago. CIM still involves computers controlling robots, but that is only part of the total concept.

BENEFITS OF CIM -

There are four basic techniques to determine what the tangible benefits from any capital investment, including CIM, are to a business:\textsuperscript{x}

1. Payback period
2. Return on investment
3. Net present value
4. Internal rate of return.

These are traditional financial formulas which management can use to determine the value of CIM to the company. However, the justification process for advanced manufacturing technologies in CIM must be viewed differently from the traditional process for three reasons:\textsuperscript{xi}

1. Project Size. CIM investments are projects without ends. Investments made today eventually will be replaced by new technology. Most benefits from CIM accrue with time as advances in both hardware and software take hold.

2. Project components. Since CIM requires various successful installations of advanced manufacturing technology, benefits will accrue due to the synergism of various pieces on the shop floor. The integration of advanced manufacturing technology long term is what makes CIM a self-liquidating expense.

3. Identification of CIM soft benefits. The installation of advanced manufacturing technology in a manufacturing environment can provide significant intangible benefits that traditional financial justification methods don't recognize. The benefits most often cited by business executives are reduced manufacturing costs, improved flexibility on the shop floor, responsiveness to the market, improved product quality, improved product design, small lot manufacturing, reduced inventories, and optimal customer service.\textsuperscript{xii}

While these benefits are hard to quantify, they can reduce operating costs, improve customer relations, and stimulate sales. The key to evaluating these soft benefits is to understand that a CIM environment allows for fewer levels of management and therefore provides for better use of the business's assets, both human and mechanical. The result for the company is improved decision making and significantly improved profitability.

Computer integrated manufacturing, by joining all the functional areas in the business, can provide a variety of automated services in the factory. For businesses to remain competitive, advanced manufacturing technologies must characterize the factory of the future. In this regard, computer integrated manufacturing has many applications:

Order management. CIM allows for faster delivery and responsiveness to customers and to customer orders through electronic data interchange. In essence, customers will electronically secure and lock in supplier capacity for the product. Additionally, a business will be able to respond to inquiries from its customers instantaneously through electronic data interchange. Being able to respond to customers with rapid information will result in extra business, retaining customers, and getting closer to the customer.

Computer-aided design (CAD). Through CAD, CIM allows the computer to assist in minute details and specifications of a customer order or to simulate variations of the order.

Manufacturing resource planning (MRP II). This allows the production schedule to be simulated and integrated using one information base to direct the operations on the plant floor to balance supply and demand.

Computer technology. CIM allows different hardware to be integrated to communicate with one another (open system). It provides a database foundation for both artificial
intelligence and expert systems.

Computer-aided manufacturing (CAM). CAM allows for factory machinery to be programmed through numeral controls (NC) tape preparation and computer numerical control (CNC).

Robotics. Robotics allow for the minimization of human activity in the areas of pick/pack, excessive lifting, transportation, and repetitive manufacturing operations.

Automated guided vehicle systems (AGV's). AGV's allow for driverless forklifts and automated storage and retrieval systems. As JIT becomes more imbedded in future manufacturing disciplines, the role of computerized material-bundling equipment will become more vital.

Group technology. Allows for the coding and classification system to group various families of parts or activities, and to aid in both inventory use and part standardization.

Vendor scheduling. CIM provides for improved scheduling of customer orders to improve delivery and internal processing. In the future, orders will be booked directly via electronic data interchange into a vendors upcoming production schedule.

Although this is just a partial list of the uses for computer integrated manufacturing in the factory, it shows that CIM is much more than a means of computers controlling machines.

PRINCIPLES OF CIM

For CIM to be successful businesses must consider the following five fundamental issues involved:

> PEOPLE AND THEIR CRUCIAL CONTRIBUTION TO MANUFACTURING
> TOP MANAGEMENT'S COMMITMENT TO THE PHILOSOPHY
> CIM SHOULD BE PUT IN THE CONTEXT OF A WELL-DEFINED BUSINESS STRATEGY OR VISION
> THE TECHNOLOGY PLAN, THE SYSTEM ARCHITECTURE FOR CIM, MUST INCLUDE ALL ELEMENTS OF THE COMPANY
> IT IS EXTREMELY IMPORTANT WHEN CHOOSING SUPPLIERS TO ACCESS BOTH THE BREADTH AND DEPTH OF THEIR SUPPORT CAPABILITIES

PEOPLE AND THEIR CRUCIAL CONTRIBUTION TO MANUFACTURING - "Manufacturing, in general, has not done a very good job of understanding how you link the people and the process into this CIM thing." In the past, CIM projects became automated disasters because management became enamored with the technology and computer side of the program. They completely forgot about the people side and neglected to incorporate people into the development process. Information technology will reshape every company that survives through the 90s. However, businesses will not be able to incorporate technology advances if they do not find a way to make workers comfortable with computers. Additionally, workers will not have the requisite skills and abilities to succeed and advance if they are not able to work with computers.

Almost every white-collar job in america requires some level of familiarity with computers. Additionally, it is estimated that 75% of industrial workers also need at least elementary computer skills. Management must understand what enables workers at any skill level to be able to master their computers.

Companies that have transformed their work forces with technology have distilled a set of principles that apply equally to workers on an assembly line or in the front office. These principles include the following:

THINK OF HOW TO EMPOWER YOUR WORKERS, INSTEAD OF DUMPING TECHNOLOGY ON THEM- The most advanced enterprises have realized that they have got to deal with the people side at the same time they deal with the technology.

LISTEN TO YOUR EMPLOYEES WHEN DESIGNING A SYSTEM (BOTTOM UP) - Managers of highly automated operations are unanimous, if you don't involve the users, you will develop the wrong system. Nobody understands the job like the people who do it. They can tell you how to design the tools that will let them work more efficiently. They will trust new technology more if they had a say in it and knew it was coming. The company wins more commitment from its workers when they feel their contributions were valuable in the design of the system.
UNDERSTAND AND COMMUNICATE YOUR BUSINESS OBJECTIVES- Employees will accept and learn new technologies if they understand their importance. Fancy computers seldom make much difference in productivity if workers do not understand how the technology helps achieve business goals. It is important to see new technology as only part of a total vision of a changed organizations. Therefore, management must look at the information employees need, the materials they need, the incentives they need, and all other aspects of the business, not just automating.

TEACH YOUR EMPLOYEES BY HELPING THEM IMPROVE THEIR PERFORMANCE- The most important aspect of incorporating new technology is learning to do the job better, not learning how to operate the computer. Traditional classroom instruction is seldom the best way to go. The most useful training comes only when workers need it. Three common approaches are:

1. Mentors, other employees in the organization who know a little more than most, who can help others when questions arise.
2. On-line help programs within the software.
3. Simultaneous interactive video training for workers.

DON'T IGNORE THE GENERATION GAP - People who grew up in the Nintendo generation have an advantage over their elders. These younger workers adapt more readily to technological incorporation into the workplace. Conversely, big-time computer klutzes may slip in the pecking order if they can't handle the new technology deftly. Some companies introduce workers to computers by using computer games to make them comfortable interacting with a screen.

To implement CIM you have to design technology that is usable by people. If people do not use the systems, you might as well throw them away.

According to Lee Sage, national director of automotive services at Ernst & Young, "it became apparent that the manufacturing companies that were doing the best job were those that didn't necessarily have the best technology. What they had was a heavy orientation towards people."

TOP MANAGEMENT'S COMMITMENT TO THE PHILOSOPHY -

"The biggest obstacle to CIM implementation...is getting the necessary cross-functional and senior-management support for the fundamental change required to implement CIM across the business." The most important part of successful technological integration is top management commitment and participation. It is estimated that technological illiteracy at the top plagues 90% of American companies. Yet there is no better way to get middle management and supervisors to use computerized tools than to let them see the boss using it first.

Therefore, the first worker who has to be brought up to techno-speed is the person on top. In many cases, the major stumbling block to implementation of CIM is a lack of familiarity with the technologies at the upper levels of management. Of the company presidents, chairmen, and CEOs who responded to a Industry Week survey, 58.3% said they are only 'vaguely familiar' with CIM technologies.

CIM SHOULD BE PUT IN THE CONTEXT OF A WELL-DEFINED BUSINESS STRATEGY OR VISION -

The most important elements of CIM are the business processes and strategies that are developed to support it. They are what drives the whole process. Secondary to all of that is the computer hardware and software. In order for CIM to function properly, it must significantly advance the company's ability to improve quality, increase productivity, provide flexibility in lot sizes and schedules, reduce costs, and help shorten the time it takes to get products designed and to the market.

"CIM should never be viewed as being the objective or ultimate goal. The purpose of undertaking the CIM journey is not to have a CIM system. Rather, the purpose of implementing CIM is to help the firm survive by developing a distinctive corporate advantage through its manufacturing capabilities. To this end, CIM requires, as a prerequisite, a well-developed, well-understood, and widely known corporate strategy."

The entire company needs to be represented in CIM planning. Walls and boundaries between departments and functions must come down. Making CIM an integral part of the overall
business strategy and involving people from all parts of the company in planning for CIM will greatly enhance its chances for success. "The thing that most people missed in implementing CIM is the fact that, by itself, CIM isn't enough. The critical missing piece is the concept of an enterprise strategy, which repositions your company to do that which it does best."

Many executives are still sorting out their definitions of CIM and its functional role in the overall operation of the business. There has been a gradual shift in thinking in recent years away from a strict technology focus and towards an overall business strategy focus. Managers are asking themselves what are their business objectives and how does CIM fit into these objectives. However, according to an Industry Week Magazine poll, only 32.9% of managers report that their companies have a long-term strategy for implementing CIM. The lack of long-term strategies may have an explanation in the fact that information technologies have been mushrooming at a rapid pace, and manufacturing planners are faced with an unmanageable array of new hardware and software applications. Additionally, the trend toward open-system computing and its implications for selection of computer systems is not fully understood by the top-level executives who will eventually make the go/no-go decisions regarding technology purchases.

THE TECHNOLOGY PLAN, THE SYSTEM ARCHITECTURE FOR CIM, MUST INCLUDE ALL ELEMENTS OF THE COMPANY

The ideal system architecture for CIM will ensure that information can flow where it is needed when it is needed. It must also be flexible enough to be adaptable to the changing needs business and rapidly advancing technologies, while protecting the value of existing investments in the system and technology. Overall, many manufacturing businesses have not been extremely successful at integrating people, processes and functions into an overall CIM concept.

"What we are really talking about is going beyond CIM to computer-integrated business management, and hitting on all the key things you need to do to succeed as a business."

IT IS EXTREMELY IMPORTANT WHEN CHOOSING (HARDWARE AND SOFTWARE SYSTEM) SUPPLIERS TO ACCESS BOTH THE BREADTH AND DEPTH OF THEIR SUPPORT CAPABILITIES

In today's marketplace, a business must look beyond products and pricing when selecting suppliers. Slow start-up, downtime, and other production-related problems cut the very heart out of profitability, and can greatly reduce any competitive advantage attained with CIM.

Manufacturing companies must look for supplier-support capabilities that include: application engineering, training, installation and start-up, coordination with the equipment manufacturer, proper documentation, maintenance, repair-return depots, phone support, on-line system support, and emergency service. Support should be available 24 hours a day, seven days a week, year around. If the company is global, the supplier's ability to support world-wide operations must be taken into consideration prior to the purchase decision.

OBJECTIVES AND IMPLEMENTATION OF A CIM SYSTEM

The overall job of computer integrated manufacturing strategic planning requires a comprehensive look at the process equipment, facilities, personnel structure and roles, plus the scheduling and control requirements. Implementation of CIM requires the development of a CIM master plan, which encompasses a critical look at the current plant scheduling and control hierarchy (if in an existing facility), a detailed description of the desired plant scheduling and control system hierarchy, and a plan to manage the transition from the current state to the desired future state. This plan must incorporate all functions of the operation (marketing, personnel, engineering, etc.) in their relationships to manufacturing and production control.

In order to provide for the overall objectives must be defined of the organization, objectives for the various technology systems expected to be required to meet the business's long range needs. These systems include database management systems, communications networks, process controls, process optimization, process improvement and decision support systems.

Database management systems should be open in nature and must interconnect,
interrelate, and integrate all department and area databases of the business, including corporate, division, research, and marketing strategies, as well as plant operations and production control.

Communication networks must provide plant-wide information exchanges with appropriate interactive work stations and permit ready access to plant information by all users of the data. Additionally, they must provide for intra-plant, intra-division, and intra-organization communication as needed.

Process control must make computer automated control available in all areas of the manufacturing process. In addition, the technology must expand the scope of conventional control to include the following supporting goals:

1. Minimize the manual entry and recording of all measurements and operational decisions to minimize errors and expedite data acquisition.
2. Simplify the conducting of economic and operational studies to permit quick analysis of unusual operating conditions.
3. Increase the process and system engineer's productivity through readily accessible, efficient and comprehensive analysis and design tools.
4. Increase the scope and interactive access to history data to permit thorough analysis of process and operational problems.
5. Expedite the process of system expansion and growth.

Process optimization must permit the expansion of efforts in simulation, optimization, and scheduling of process operations.

Process improvement must make use of the available plant-wide information to modify the overall process so as to reduce the number of rejects which are produced.

After completion of the objectives analysis the major steps in the implementation of a CIM system are:

1. Analysis of the existing manufacturing system (if existing plant) or new facility design for compatibility with CIM technology.
2. Analysis of the existing and proposed management and personnel structure for the plant in view of its compatibility with the proposed CIM system.
3. Development of the system master plan for designing and implementing the CIM scheduling and control hierarchy.
4. Develop expected systems costs and project timing in conjunction with systems benefits and projections, thereby establishing justification concerning systems costs and anticipated payout.
5. Iterate the steps outlined above until acceptance is obtained from all personnel concerned and company justification criteria is satisfied.
6. Implement and execute system master plan
7. Follow up and adjust as necessary.

CONCLUSION

CIM has evolved into a concept of a totally integrated facility through the use of computer technology. The use of CIM is a powerful business tool to enable manufacturers to better compete in a global marketplace. Implementation of a CIM system must be carefully planned. Managers must realize that CIM implementation is a major strategic decision. As with any other major strategic decision in an organization, the implementation of CIM has two major requirements to insure its success. Top management must be completely and totally behind the efforts to establish a computer integrated manufacturing system. Without complete top management backing, the difficulties that will arise during installation will cause a waning of support and may eventually result in discontinuance of the effort.

Additionally, the people who will be using the system must "buy into" the concept. There will be a natural reluctance to accept the new technologies by those unfamiliar with them and by those who fear they are being replaced by computers. Management must teach these people about the benefits of CIM and must involve them in the design and implementation of the system. When this bottom-up approach is imp

lemented, the people using the system are involved with it and will be committed to its
success.

However, it must be remembered that CIM is not a cure-all or an answer in itself. “Most experts agree that getting operations in order should be the first approach to becoming competitive....The technical components are only tools in a necessary common-sense solution....Competition will not wait five years for us to begin implementing CIM. We must rely on the use of technology not for the sake of technology, but for the practical and economical benefits that can be realized now.”

DEFINITIONS -

CAD - Computer aided design - the use of computers in the design of manufactured products. Computers allow for more rapid calculations, what if analysis, comparison of alternatives and provide computer generated drawings and diagrams.

CAM - Computer aided manufacturing - the array of manufacturing procedures which are aided or augmented by computers including numerically controlled machines, robotics, automated batch manufacturing systems and automatic assembly systems.

CIM - Computer integrated manufacturing - factory automation involving computers in the many tasks associated with manufacturing. Computer integrated manufacturing is the effective integration of computer technologies and systems to aid the employee in providing customers with high value, high quality products in a timely manner.

CNC - Computerized numerically controlled - a numerically controlled manufacturing machine that has its own dedicated microcomputer.

DSS - Decision Support System - “A general term for a management information system component that helps managers extract essential data from other systems and then apply analysis and decision procedures to the retrieved data to make unstructured decisions.”

EDI - Electronic data interchange - exchanging business transaction data between organizations or between functional departments within an organization using electronic communications. Data are in specified formats understood by both organizations.
IRR - Internal rate of return - the interest rate at which the cash flow stream equals all the costs of the proposed investment in advanced manufacturing technology.

JIT - Just in time - The philosophy that idle inventories (raw material, work in process, finished goods) are wasteful, and these inventories should be reduced as much as possible. This is accomplished by managing the timing of the movement of manufactured parts within the factory and the receipt of purchased parts so they arrive in very small lots very frequently, sometimes every few minutes or hours, regardless of whether the vendor is located near to or far from the factory. xxvi

MRP II - Manufacturing resource planning - the integration of all functional areas (marketing, engineering, production, accounting, hrm, finance, etc.) of a manufacturing business to provide for the smooth, continuous production of products.

NC - Numerically controlled - a manufacturing machine's instruction program is based on mathematical relationships which tell the machine how far to advance its tools, how many cuts to take, to what depth, and the like. xxvii

NPV - Net present value - a discounted cash flow method that relates the flow of monies and the timing of such investments over the life of the project.

Payback approach - calculating the recovery time for the initial capital outlay through cash flows generated. It is best used as a device to determine when an investment will be satisfied rather than as an indicator of the potential value of an investment.

ROI - Return on investment - a ratio that attempts to determine the financial gain from the project compared with the initial capital costs incurred. While the ROI approach can place capital expenditures with varying lives on a comparable basis, it doesn't consider cash flows.

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