ELSEVIER

Int. J. Production Economics 34 (1994) 313–327

international journal of
production economics

The design of computer-integrated manufacturing systems

A. Gunasekaran*, I. Virtanen, T. Martikainen, P. Yli-Olli

School of Business Studies, University of Vaasa, P.O. Box 297, SF-65101 Vaasa, Finland

Abstract

Computer-integrated manufacturing (CIM) offers a number of useful and potential opportunities for improving the system performance of the manufacturing firm. However, it has been reported that there is always difficulty while implementing CIM due to lack of integration between various functional areas of manufacturing such as sales, research and development, design and engineering, production planning and control, distribution in terms of both material and information flows. This may be due to the design problems of CIM. Realizing the importance of CIM both from the investment and operational efficiency points of view, an attempt has been made in this paper to investigate and design and implementation issues of CIM. The purpose of this paper is to: (i) review the design and implementation approaches from a strategic point of view, (ii) identify the gap between theory and practice in the design and implementation approaches of CIM, (iii) suggest a suitable framework for the design and implementation of CIM with a view to improve productivity and quality and (iv) suggest future research directions in the development of CIM.

1. Introduction

During the last decade, computer technology has had tremendous impact on the performance of manufacturing systems. The role of computer in computer numerically controlled (CNC) machine tools, robotics, and flexible manufacturing in automated production systems have been discussed by many researchers. However, in addition to the computer process control, there are many other applications of computers in the operations of a manufacturing firm. These applications range from product design to production planning and control, and include the other business functions such as order entry, cost accounting, and customer billing. One of the most important roles of the computer in manufacturing is in the information processing for the purpose of integrating different functional areas such as design, manufacturing and business operations into a well integrated and smooth operating system. The role of computer has given rise to the term computer-integrated manufacturing (CIM). The motivation for CIM has been based on the perceived need for manufacturing industry to respond to changes more rapidly than in the past. CIM promises many benefits including increased machine utilization, reduced work-in-process inventory, increased productivity of working capital, reduced number of machine tools, reduced labour costs, reduced lead times, more

* Corresponding author. Tel.: + 358 61 3248 476. Fax: + 358 61 3248 467. E-mail: agu@chyde.uwasa.fi.

0925-5273/94/$07.00
SSDI 0925-5273(93)E00015-3

consistent product quality, less floor space and reduced set-up costs.

CIM co-ordinates all relevant activities associated with both the product and its manufacturing automatically. The concept is that all of firm's operations on the production function are incorporated in an integrated computer system to facilitate the automation of the operations. The computer system is embedded in all activities of the firm. During the course of designing/developing CIM systems, one should consider different strategies of manufacturing which again depend upon the business strategy including new production concepts and technologies such as Just-in-time (JIT), optimized production technology (OPT), flexible manufacturing, and quality function deployment (QFD). The CIM technology may enhance competitive advantage, but it must be recognized that the integration of various computerized systems produced by different companies may often lead to some technological difficulties. In addition, the capital investments needed for the development and implementation of CIM are substantial. Hence, it is very important to provide a system after necessary changes in order to facilitate the system for computer integration. Even the level of complexity of developing CIM could be reduced or even simplified by making necessary improvements within the system. It should also be noted that computer-aided design (CAD)/computer-aided manufacturing (CAM) is part of CIM and it possesses wide scope than CAD/CAM. That is, CIM includes all of the engineering and design functions of CAD/CAM, together with all the business functions such as sales, order entry, accounting, distribution, etc. [1].

A general layout of the CIM system is shown in Fig. 1 which includes all the functional areas of

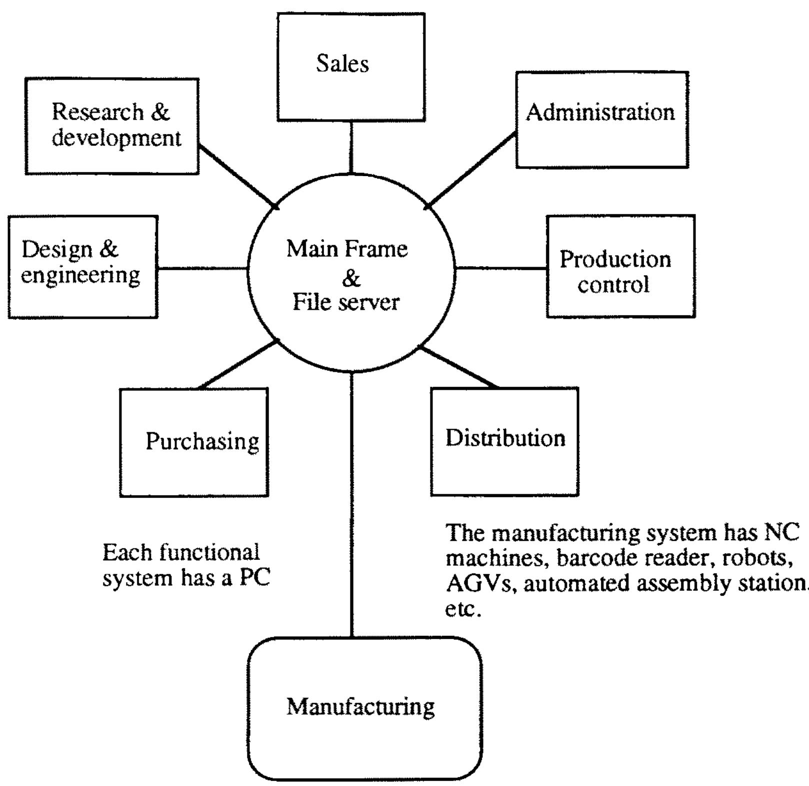

Fig 1. A general layout of the CIM system.

manufacturing systems [1]. Each functional area is connected to a PC and all these PCs are connected to main frame and file server. The manufacturing system has numerically controlled machine tools, barcode readers, robots, AGVs, automated assembly station, etc. In short, CIM is an automation of the information-processing activities in manufacturing. It provides data and knowledge required to the automated production system. Automation is an important and integral part of CIM, which is the application of mechanical, electronic and computer-based systems to achieve the processing, assembly, material handling and inspections that are performed on the product. A number of research reports has appeared in the literature to deal with design and implementation strategies of CIM. However, there is no systematic framework for integrating productivity improvement strategy with CIM strategy and the groundwork required for an easy implementation of CIM such as JIT for simplifying the material flow, to simplify the logistics and decision making and information processing factors. Nevertheless, the development of CIM can be made easy provided that proper production climatic conditions are established with the help of JIT, FMS and OPT. Therefore, considering the potential applications of CIM in manufacturing industries, an attempt has been made in this paper to provide a framework for the design and implementation strategies of CIM by giving due consideration for integrating the business and CIM strategies and using the available new manufacturing concepts and technologies for preparing the platform for easy processes of CIM implementation. Having reviewed some of the available literature on CIM, a set of future research directions are indicated in order to enhance the effectiveness of the design and implementation processes of CIM. The design and implementation issues are generally affected by the factors such as complexity of the material flow, business strategy, manufacturing strategy, availability of knowledge workers, software professionals, information flow pattern and decision-making processes, product and process complexities and supplier/purchasing activities.

A general logic of the CIM system is shown in Fig. 2. The major components of CIM are CAD and CAM technologies, computer numerically control (CNC) equipment, robots and FMS technology. CAD can be defined as any design activity that involves the effective use of the computer to create, modify, or document an engineering design [1]. CAM is defined as the effective use of computer technology in planning, management and control of the manufacturing function. In addition, the computer system is used to integrate design and manufacturing processes and then manufacturing process and other production planning and control systems (such as inventories, materials and schedules) and to integrate of manufacturing activities with both vendors and suppliers [2]. For example, the design of packaging materials for transporting fragile parts will require geometric data from the CAD system, this implies the relationship between CAD and distribution systems. In CAM, using simulated production runs, for example, the milling process is displayed on the screen once the contours of a part to be processed have been established. Then estimate the production time for the part and this process explains the relationship to work scheduling and cost estimation of the process which again implies the association between CAM, cost accounting, CAD and computer-aided engineering (CAE). However, it should also be noted that production requires not only information about the part to be processed, but also manufacturing instructions in the form of NC programs and this explains the link between production control and CAM.

There is also a close link between technical and organizational aspects like the company's data acquisition, information about orders, production facilities, inventories and personnel which will be recorded and they form the input to the production control. This illustrates the relationship between CAM, data acquisition, production control, computer-aided quality control (CAQC) and pay-roll accounting [3].

The organization of this paper is as follows: Section 2 presents an analysis of the design and implementation problems of CIM. A review of the previous design and implementation approaches of CIM is presented in Section 3. Section 4 comments on the design and implementation strategies of CIM. A framework for the development of CIM is presented in Section 5. Section 6 offers a set of

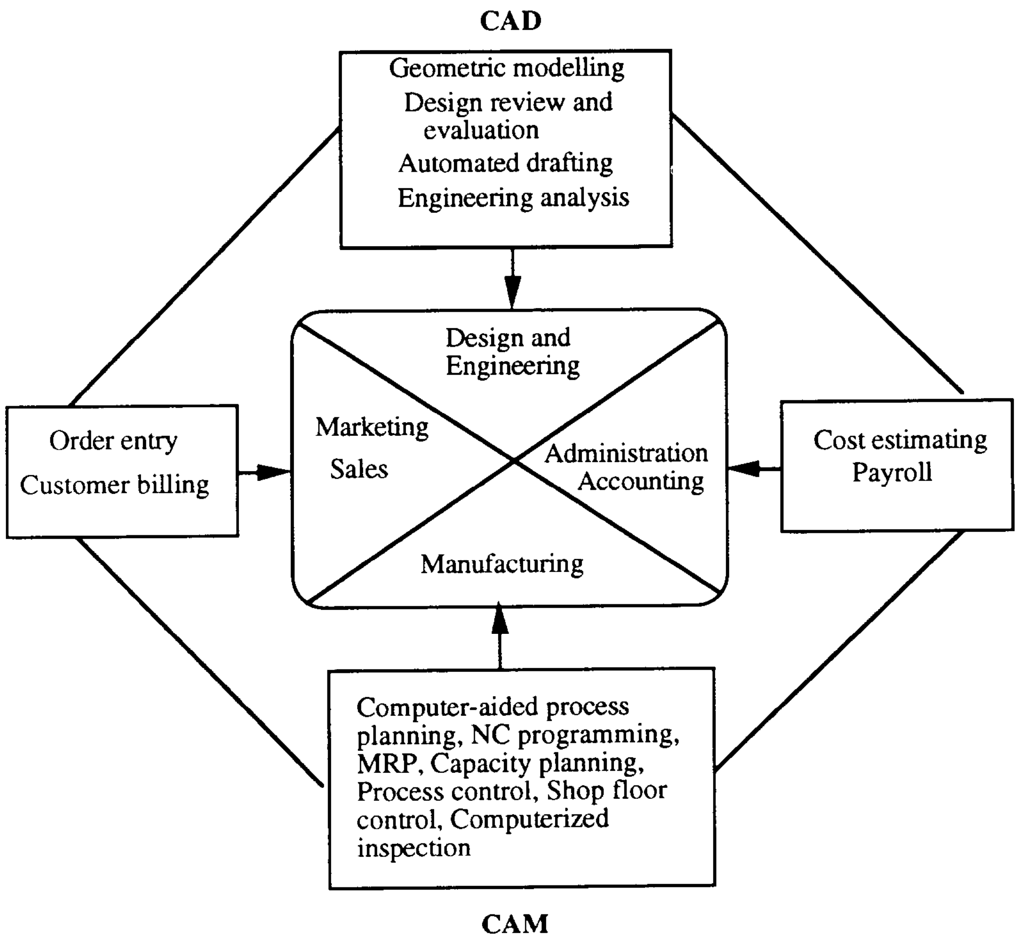

Fig 2. A general logic of the CIM system.

future research directions in the areas of CIM. Conclusions of this research are presented in Section 7.

2. Analysis of the design and implementation problems of CIM

Because of the higher investment and design complexity of the CIM, it becomes very essential to improve the development aspects of the CIM system at early stage of the design, because the performance of the system depends upon the design stage as well as the operational stage of the system. In order to gain a better understanding of the design and implementation issues of CIM, the basic ingredients of the design and implementation problems are analysed in this section. CIM integrates design, manufacturing and management using computer systems with an objective to reduce the lead time of the product.

Many companies in the past have automated various operations independently within their organizations. This has led the companies to develop islands of automation. These islands of automation have only improved the local productivity, but they are not sufficient to provide necessary logistic support to improve productivity and quality of the whole organization. For the purpose of achieving the total system integration using computers, attempts have been made to develop a suitable strategy/concept and hence the CIM has been evolved [3]. Tie and Lin [3] proposed an approach which consists of three major steps for CIM development: (i) identify the functions and information flows within a total business context of the manufacturing enterprise, (ii) build mathematical models for each of the functional areas within a manufacturing system with an objective of optimizing the data required in these functional areas, and (iii) carry out CIM optimization based on the results of simultaneous strategic and economic analysis.

Fig. 3 illustrates the design and implementation process of CIM. The computer-integrated system design involves basic design, detailed design and design of production planning and control. Based

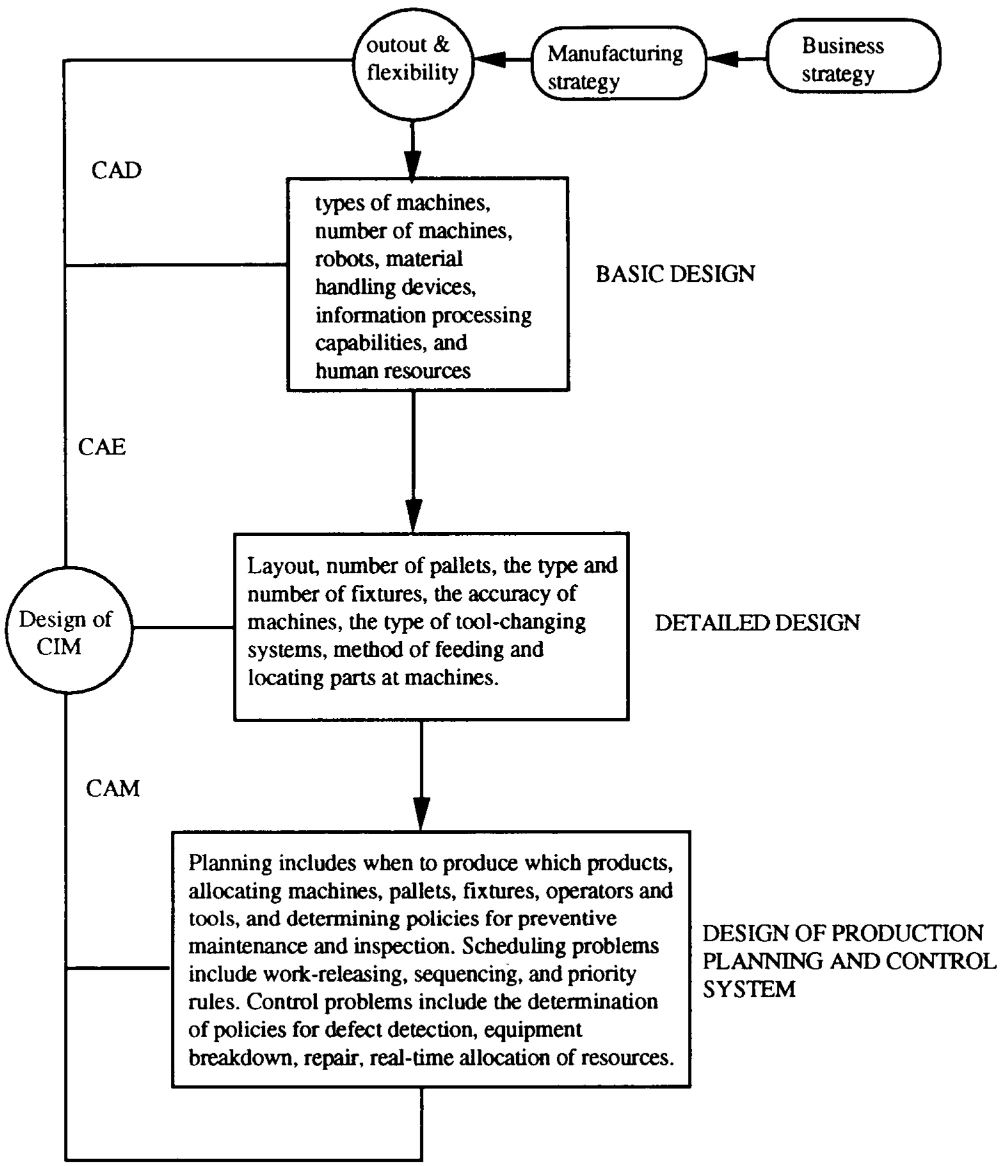

Fig 3. Design of CIM—a strategic thinking.

on the business strategy, the company decides the manufacturing strategy. In the past, CIM as a manufacturing strategy has been very successful for improving the output rate and flexibility as well as quality. Once the CIM has been selected as a manufacturing strategy, then the manufacturing strategy is translated into specific strategies and subsequently activities depending on the hierarchical structure of the company in terms of expected material and information flows. As depicted in Fig. 3, these activities include the selection of machines, capacity required, information processing, and human resources at the basic design. The detailed design level, for example, includes layout, pallets, tools, co-ordinated measuring machine, etc. Finally, the design of production planning and control system includes resource allocation problems, scheduling and control of various production activities. The application of CAD/CAE is found both at the basic and detailed design levels. The application of CAM is found at the production planning and control level. Further details about the integration of various hierarchical activities are to be achieved by CIM as depicted in the figure by combining the CAD/CAE and CAM activities [4].

A general logical framework is necessary to understand the complex interactions in order to integrate CIM elements of an organization successfully. This particular framework necessitates suitable tools/methods for analysing the interaction as well as integration processes. The tools should take into consideration all the relevant aspects of manufacturing, such as manufacturing process, decision-making systems and information systems. Nevertheless, one should take into consideration all areas of the company in order to assure continuous and uniform evolutionary system development of CAM and CIM.

A general guide-lines is provided in Fig. 4 for gradual implementation processes of CIM. A three-stage plan can be adopted for the implementation process. Stage 1 should plan to meet the existing demands for capacity and integrate new production processing capability using CAD data. Stage 2 should deal with mechanical integration issues, such as increasing throughput and quality while reducing the level of inventory. This may also include increasing quality through total process control. Final stage should deal with the computer integration of facility and continuous improvements. The gradual implementation of CIM will help to reduce the risk involved in implementing CIM because of the higher investment involved in CIM developments [5].

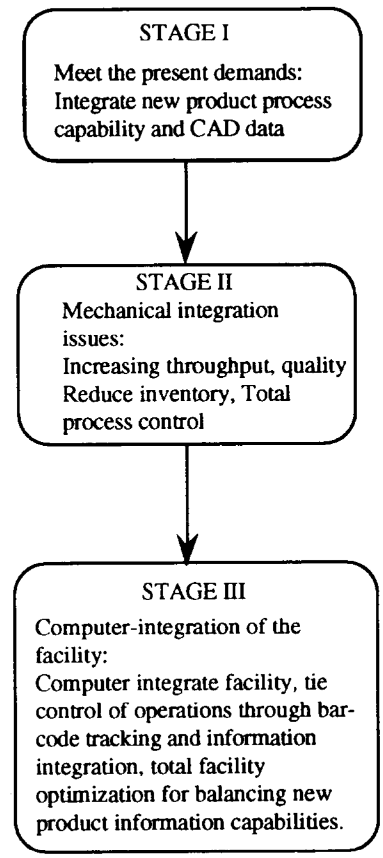

Fig 4. Gradual implementation processes of CIM.

The application of GT concept in CAD/CAM plays an important role in the design of CIM. In GT cell, the parts to be processed are grouped into families and the machines into groups so that each family is associated with one machine group and vice versa. In addition to the design of GT cell, the availability of a coding system for parts, production sequences, are grouped together with a database to provide necessary information for the design of CAD/CAM [6]. In the following section, an overview of the available literature on the design and implementation problems is presented.

3. Review of previous design and implementation strategies and approaches to CIM

During the past few years, a number of reports has appeared to deal with the design and implementation issues of CIM. Czernik and Quint [7] introduced a concept for planning CIM systems, which allows an interdisciplinary team of system developers such as engineers, industrial economists, personnel economists and a suitable method for system development. As examples, they described three methods for the planning of CIM: (i) GRAI (method of describing manufacturing system), (ii) PN (Petrinet method) and (iii) SADT (structured analysis and design technique). Further, they suggested a method which is a combination of GRAI and PN and appears to be a feasible solution for developing a CIM system for industrial manufacturing. Pan et al. [8] argue that during the last decade many companies have accomplished significant improvements in material handling through the implementation of new technologies. However, based on the review of literature, the material handling systems (MHSs) have not been coupled well with manufacturing operations when merged into a CIM environment. One view of the relationship between MHSs and CIM is that if the automated production system is associated with the CIM system, then MHS is also associated with CIM. They offered a model using artificial intelligence (AI) methods for the integration of materials handling, manufacturing operations and decision making within a CIM environment.

Blass [5] presented a gradual implementation procedure of a CIM in Allen-Bradly, a world-wide manufacturer of industrial automation controls and systems. A three-phase plan, one for each year of the process, was begun. Phase 1 (1989–1990) planned for meeting the existing demands for capacity, integrating new production processing capability using CAD data. Phase 2 (1990–1991) dealt with mechanical integration issues, such as increasing throughput and quality while reducing the level of inventory. This also includes increasing quality through immediate total process control. The third phase, which was started in 1992, deals primarily with the computer integration of facility and continuous improvements. While many large companies including General Motors and IBM have implemented CIM, small firms have rarely achieved company-wise integration of all computer systems (CIM). This is because small firms often feel that they lack the in-house expertise to implement new computer technologies and the cost of hiring a consulting firm to assist will also be too expensive. Considering the role of CIM in small-scale firms, Ohsen [9] provides guide-lines to plan a CIM such that it maximizes the use of in-house staff. The general requirements of CIM design such as software module integration, future system growth, system security, training, system maintenance and custom programming are also discussed.

Bertrand and Wortmann [10] explain the developments of an information system based on the complexity of the problem, differences between production system control and goods flow control and nature of the interface concepts and definitions. At the same time, they emphasized that the information system should be able to co-ordinate the goods flow through these production units system. These interface concepts and definitions will facilitate the use of the newly emerging information technologies such as real-time on-line data collection and other communication networks in CIM. Bosch [11] stressed the role of co-ordinated measuring machine (CMM). This is a tool which can be used to improve quality on the shop floor which again depends upon the alignment with other subsystems in a CIM system. In addition, the task of measuring should be integrated with the process planning. The implementation of computer aided production management system (CAPM) depends upon the complexity of the overall manufacturing systems. Maull and Childe [12] claim that the implementation of CAPM can be made easy if the overall manufacturing is first simplified. Second, any methodology must include a software specification as most companies will require a computerized solution. Third, the overall performance of the system may be enhanced by suitable changes in the infrastructure that supports the software and integration.

The experience with the design and implementation of CIM in Novatel has been presented by Groves [13]. The management of Novatel has approached the problem first by identifying the limits of CIM with an objective to achieve a fully computerized and networked organization. The strategy starting with identifying the limits is called as the computer-integrated enterprise (CIE). Novatel started with implementing a computer network based on workstations from Hewlett–Packard's Apollo division for an organization-wide system. The network has no central workstation, allows anyone at any workstation to communicate with any other workstation. This idea of CIE reaches well beyond manufacturing into every aspect of the company's operation from business system to product development and prototyping. For example, in the design area, Novatel identified the limitations of conventional sequential approaches to engineering and therefore, adopted the alternative of concurrent engineering. This particular approach permits the company to carry out the development activities in parallel with a view to get market sooner with a better product.

The use of software packages such as SIMAN and CINEMA is very important to model the behaviour of the CIM system and to build a simulation-driven animation of the manual manufacturing system and the proposed CIM system. Using this methodology, Sommerville [14] developed a model for CIM design which differs considerably from the current state of today's technology. Their model views the development process as a sequence of activities that follow the traditional sequential waterfall model of software engineering. Because of the price and performance of today's computer technology and its highly interactive interface, their development process is based on successfully developing more sophisticated prototypes at all stages of the life cycle. This is an interactive approach to system design which identifies the problems at early stages of the life cycle and minimizes the risk of major system design flaws. This prototyping approach in conjunction with appropriate models has the following features: (i) users can criticize and influence the development of CIM, (ii) helps them to evaluate potential problems early in the development life cycle, and (iii) companies gain insight into the potential of CIM as a business strategy. The success of CIM system depends upon the effective scheduling and control. Harmonosky and Robohn [15] discussed the real-time scheduling in CIM. Considering the dynamic nature of manufacturing processes, intelligent real-time scheduling using computer technology is more appropriate.

Kaltwasser [16] claims that justifying a CIM system is one of the foremost important steps in implementing the CIM. The more obvious factors that enable a manufacturer to justify CIM system are: reduced costs of material, direct and indirect labour, and reduced scrap, rework and inventory. Factors such as reduced cycle time, increased capacity, improved quality of products and customer service, greater production facility and improved market position are less obvious items but are very important. More people started implementing CIM as a system integrator. A system integrator is the co-ordinator of manufacturing processes, information and people. The following are the main responsibility of integrators: (i) must physically link parts of the facility (shipping and receiving areas, storage, work-in-process, production), (ii) must analyse production capacity and ensure that all processes both automated and manual are capable of meeting the prescribed production pace, and (iii) must handle the flow of information, especially in the context of material flow.

Kellso [17] provides the building blocks of those key CIM elements in any CIM application as: (i) information management and communication systems, (ii) material management and control systems, (iii) process management and control and (iv) integration. The information management and communication systems are the computers which link the various development and decision making activities to each other; included are the MRP system, the shop floor control system, the management scheduling system and the communications from the floor. The second area of control involves management of the material movement. This system is a combination of mechanical movement equipment and the material control systems which track and schedule product through manufacturing. The third area of control in his CIM model is process control and this includes down loading of the appropriate recipes or process instructions and monitoring the process itself. Prabhu et al. [18] presented a classification of temporal errors in CIM systems for the development of a framework for deriving human-centred information requirements.

Waldoch [19] justifies the expanded scope of Integrated Manufacturing systems (IMS), particularly in the areas of waste reduction, increased machine utilization, inventory reduction, clarification of manufacturing process, improved cost accounting, better lot tracking and faster installation of new manufacturing systems. The author presents a case study of Brookings plant. In the early 1980s, the Brookings plant, already automated at the operational level, started investigating approaches to CIM. At this stage, the project was still concentrated on the engineering aspect of plant information processing, particularly a high level of process control. Around 1986, management increased the scope of the project for the total integration of all the information technology in the Brookings plant. That is how the CIM has been transformed into IMS.

According to Sakakibara and Matsumoto [20], one of the solutions to improve productivity and quality is to implement CIM. This has been realized by various approaches, developing database management systems for strategy and support, making both domestic and overseas information on sales and distribution on-line, building a new laboratory, expanding R & D facilities, implementing CAE/CAD/CAM and technical data-base information systems throughout the company, developing FMS for factory-wide automation. The corporate product engineering group has set the final target as an unattended factory, and is now extensively implementing CIM in co-operation with sales and engineering departments in several plants. The authors focus on the NIPPONDENSO CIM in Kota plant specializing in car-electronics and describe how to integrate entire systems. The company has built CIM plant called "UTOPIA KOTA" according to the concepts as indicated in Table 1.

Kaeli [21] presents the following steps in launching a CIM initiative: (i) select the team leader, (ii) mobilize the CIM team, and develop a mission statement, (iii) identify the model job, (iv) identify the major functional areas, i.e., participative matrix, (v) analyse each functional area, entity diagrams, strengths and weakness, (vi) select relevant CIM criteria, (vii) evaluate the CIM opportunity matrix. This process draws upon all major organizational units. It also fosters a "team" environment to nurture the CIM effort. Realistically, the entire analysis can be completed within several months, provided full-time team leader is available. The above review of literature has provided with the numerous insights into the development of CIM which would help to further set the attention to come out with new ideas and directions for improving the development process of CIM.

Table 1
Issues in the development of CIM [18]

Basic concepts
Pursue an ideal just-in-time system
Make the most of the information network: co-operation with sales, engineering and production departments and speedy information flow
Build up know-how: develop and make an active use of in-house products (barcode products, etc.)
Make an easy-to-use system with sufficient reflection and feedback from the shop floor
Establish a production system of higher productivity and better quality
Develop an integrated automation line for products, etc.
Implementation and design process
The organization from top management including all other related employees
Smoother communication with related departments and all-out efforts
Intensive operation training for managers, staffs and workers of the manufacturing department
Design for counter measures against system interference
Adjustment of system operation and maintenance systems.
Problems and requirements on production control
Catch the real-time production information synchronized with the material flow in each process (integration of material and information flow)
Connect organically with the systems for quality control, in-plant logistics, line control, production planning in head office, etc.
Provide field action and production scheduling functions against changes (new product introduction, design change, order change, production change, etc.).

4. Comments on the design and implementation approaches to CIM

After reviewing the literature on the design and implementation procedures of CIM in the previous section, the following observations are noteworthy:

(i) The starting point of the development process of CIM is very important as it will decide the future prospects of CIM both in terms of productivity and quality. Therefore, the scope of CIM should be evaluated in the light of the typical lack of sufficient knowledge about CIM's potential, the effect of a longer planning horizon, effect of delaying CIM implementation on company competitiveness and the operations integration effects [22, 23].

(ii) The following requirements of the CIM should be considered while implementing CIM systems: required hardware platform, integration requirements, compatibility, accounting conventions, numbering systems, security requirements, data-processing skills, level and type, size, and cost.

(iii) In most CIM systems, direct labour and direct material cost are no longer significant. The direct labour cost should be made part of the overhead. Overhead cost are significant compared to direct labour and direct material costs. For instance, machine hours would be an appropriate allocation basis instead of direct labour hours, especially when the overhead costs are pooled by the machine centres [24].

(iv) The implications of CIM for human workers are many and should be considered at the earliest stages of CIM planning and implementation to assure peak performance from a totally integrated system [25]. The companies which are in the process of implementing CIM should provide a comprehensive training programs in order to provide well-trained workers familiar with the principles of automation, computer technologies and manufacturing process.

(v) The results from implemented CIM show considerable improvements in key performance measures. However, the success stories indicate that the CIM installation has usually gone through a difficult implementation period. It may be that the implementation difficulties have been taken to heart since the growth in the use of FMS has been much slower than might have been expected. A key element in the successful implementation is the quality of the design of the CIM.

(vi) The integration task extends beyond co-ordination with the process engineer. To be fully effective, the shop floor CMM should be integrated with the CAD system and the factory host computer. By integration with the CAD system, the inspection procedure can be prepared at the time the part is designed. Similarly, integration with the factory computer is important because it offers the opportunity to generate an overall quality information system.

5. A strategic framework for the development of CIM

The strategy behind the success of implementing CIM should have the following three features: (1) use of barcode extensively for integrating materials and information, (2) advanced mixed and small batch production system (FMS) with line control system, (3) configured inplant information network using Local Area Network (LAN). Most of the reports on design and implementation issues of CIM either present their own experience from a particular case study or focus on a narrow subject of CIM systems. Therefore, there is a need to develop a general framework for the design and implementation of CIM. The important elements of such a framework are as follows:

(i) The analysis presented in the previous sections suggests that there is a need to study carefully the development of CIM apart from simply automating the information systems and process control. The impact of CIM in each and every area of manufacturing should be considered in the light of implementation conditions for CIM. This, of course, leads to the integration of various functional areas using suitable computer technologies. In addition, the benefit of CIM not only lies within the production, but also outside production such as support activities, maintenance, power supply, design and engineering and marketing. A general guide-lines for the development of CIM is presented in Table 2.

(ii) Nevertheless, the manufacturing strategy should fully support the objective of the business strategy. Moreover, there has to be alignment between manufacturing strategy such as CIM implementation and business strategy with a view to achieve full potential and benefits of implementing

Table 2
Guide-lines for the development of CIM system

Action
Define CIM
Strategic goal of the firm and the corresponding long-term CIM strategic plan
Commitment from top management
Prepare a comprehensive CIM plan
Implement from the bottom focusing on CIM business strategy
Develop for the long-term plan
Simplify, plan for integration, automate, and then integrate
Emphasize the basics
Place emphasis on indirect labour, engineering and management functions
Design for manufacturability
Clear cut information flow
Investment analysis
Education of management and work-force
Assign the most capable people to the programme
Open communications.

CIM. The company's limitations in terms of capital, knowledge workers, complexity of the material flow, layout types, etc. should be considered while designing and implementing CIM.

(iii) Since the nature of information and material flows influence the decision making of the whole organization and hence the design parameters of CIM systems, the new production concepts such as JIT, TQM and ZI and technologies such as FMS and OPT should be considered while formulating the development process of CIM.

(iv) There is a need to understand to CIM strategy and business plan by appropriate people in the company who are responsible for the development of CIM with an objective of improving productivity and quality. For this purpose, educating all level of employees, especially engineers, managers, software professionals, information scientists, and supervisors who are directly responsible is very important for the development of CIM. Documentation of the objectives and the responsibility of different people in CIM development projects is essential for eliminating any lack of co-ordination between different parties involved in the implementation process of CIM.

(v) While deciding the CIM development strategy, factors classified internal (capital, knowledge workers, number of products, number of components for each project, complexity of the processes, inventory level, etc.) and external factors (competitors, demand, government support and regulations, etc.) tremendously influence the CIM development process. For instance, if the system has already implemented JIT system, then the process of integration using CIM concepts becomes somewhat easier. The government support either in the form of financial or technical will certainly help the implementation process by minimizing the risk of losses in investment and production while implementing CIM. Moreover, while deciding the level of integration, priority should be given to critical areas which influence the major manufacturing activities under the circumstances of limited capital available.

(vi) Top management develops the CIM strategy based on the business strategy considering the internal and external factors as discussed earlier. The middle management should work-out the CIM development programme. The workers along with middle-management staffs are responsible for the implementation of CIM. The co-operation among different level of employees can be achieved in developing CIM by smoother communication systems.

(vii) One should aim for an intelligent factory. Based on the concept of the JIT system, the company-wide information flow, material flow system should be established using information networks. This kind of computer-integrated system should accommodate changes in any of the areas such as plant management control, production control, quality control, physical distribution equipments, production line, technical information management, human resource management, cost management and so on.

(viii) The design factors for a new design approach should include both economy and part functionality. Concurrent engineering (CE) has as its purpose to detail the design while simultaneously developing production capability, field-support capability and quality. It consists of a methodology using multidisciplinary teams to carry out this concurrency: CE tools in the form of algorithms, techniques and software, and the expertise and judgement of people who make up the complete design and production sequence. The essence of CE is the integration of product design and process planning into one common activity, i.e. CAD/CAE. Concurrent design helps to improve the quality of early design decisions and has a tremendous impact on life cycle cost of the product.

(ix) Workers operating CIM should be highly skilled. The design of the organization should permit interaction among many departments – manufacturing, engineering, purchasing, marketing and accounting. In a changeover from conventional manufacturing, the organization plan should include the details of redeployment of the work force and a strategy for restructuring the organization. For such organizational changes, all parties, including top management, all departments, professional staff, union leaders and workers, must be brought into the adoption process.

(x) Following feasible CIM strategies for improving productivity through a better design of CIM are presented in Table 3. Naturally, in order to achieve effective system performance in terms of meeting the company's objective as a whole, the CIM strategy must be aligned with productivity improvement strategy which is again based on the business strategy.

(xi) A key component of CIM implementation methodology is to reduce the overall complexity of the manufacturing system. This may call for process simplification, e.g. through the use of flow lines or cells. One should recognize that because of data volumes, most companies will still need a computer-based production management system, so that the approach must lead to a software specification. We should also recognize that the overall performance of the system can be considerably enhanced through the infrastructural policies, procedures and practices that govern the operation of the system, so any solution must be a balance between software and infrastructure.

(xii) To maximize the effectiveness of CIM technology, communication with both vendors and suppliers should be automated and integrated with the manufacturing activities. This might also include service and field support after the sale.

6. Future research directions on the design and implementation issues of CIM

Most of the literature deals with a specific situation offering their own experiences in a particular situation for the design of CIM. Nevertheless, they can also be used for other situations provided that the conditions are identical. However, one can easily observe that most of the literature do not seem to have considered the strategic issues linking the business strategy and CIM strategy in the light of the characteristics and compatibility of the systems for implementing CIM. Considering the limitations of the available literature and great demand for the tools on the design and implementation of CIM, the following future research directions may provide some fruitful results in the development of CIM for an improved productivity and quality.

(i) The future research area of CIM is to develop a system like computer-aided tools (e.g., artificial

Table 3
Productivity strategy vs. CIM strategy

Productivity strategy	CIM strategy
Business planning improvement	Flexible manufacturing/automation/design for differentiation
Process improvements	CAD-equipment and process design, flexible machining systems
Better product design	CAD-design, CAE, design for manufacturability, GT, engineering analysis
Improved production planning and control	Production smoothing, MRP, MRP II, OPT, JIT
Improve purchasing activities	Automated purchasing/electronic vendors/follow-up
Marketing	Demand management, forecasting, integrated-data bases, on-line, real-time order tracking
Quality control improvement	Computer-aided inspection, statistical process control, adaptive controls, continuous inspection

intelligence, expert systems) for evaluating different alternative processes of developing CIM by offering various methods. Depending on the stage and the problem, one or more methods can be established by such a system.

(ii) Continuous organizational change appears to be a major driving force for changing information systems. One should first study why flexibility is needed in CIM systems and the level of flexibility required in softwares. Usually, two types of flexibility requirements are identified, namely, changes in operational procedures and changes in decision making. Operational procedures are generally supported by transaction processing software, and information systems' contribution to decision making is by decision support systems (DSS) and by structured decisions systems (SDS) [26].

(iii) A functional approach should be developed for integrating the concept of operational safety during the specification phase of CIM systems. This approach should take into account various factors such as human operators, production tools, and production flow. The purpose of such a research is to help the designer in elaborating functional specifications using operational safety data [27].

(iv) Guide-lines should be established for designing CIM and build CIM systems with little or no prior computer experience for manufacturing people [28]. Artificial Intelligence and Expert Systems should be developed for studying the alternative designs of CIM.

(v) A two-stage manufacturing integration should be proposed. During the first stage, the manufacturing operations integration should be done and during the second stage one should focus on what type of integration has to be build. This scheme will provide system designers with the ability to document and thus efficiently transfer and implement solution technologies or "know-how" for each class of integration; the ability to identify which integration classes are most desirable or beneficial to a specific company; and the basis for setting up a CIM implementation plan or programme [29].

(vi) Suitable configuration for CIM should be decided before the implementation process which generally centres around the identification of tasks to computerize, the selection of feasible software packages, and improving software compatibility. In order to include flexibility in CIM, manual policies, procedures, and practices should be established.

(vii) The two most important areas that should be given due consideration in the design of CIM are (a) when system has time-critical tasks and (b) the need for computer expertise in establishing a local-area network in the proposed CIM system.

(viii) Suitable mathematical models should be developed for each of the functional areas of manufacturing system for optimizing the information required for the development of CIM and to carry out CIM optimization based on the results of simultaneous strategic and economic analysis. Besides, economic justification models for CIM implementation are also to be developed to study the pros and cons of CIM in a particular manufacturing company.

(ix) A framework should be established to study the impact of GT application on the information required and process control operations while designing the CIM. Also, the role of concurrent engineering and quality function deployment (QFD) on the development of CAD/CAE systems should be established for different practical environments in terms of various characteristics of the company under consideration for the implementation of CIM.

(x) The role of new manufacturing concepts such as JIT, ZI and TQM on the development process of CIM should be studied further in order to reduce the complexity of the implementation process of CIM and the subsequent optimization of investments involved. In addition, suitable models should be developed to study the implications of QFD and GT applications in the design of CIM.

(xi) The software and hardware compatibility in implementing the CIM and their respective costs should be considered while optimizing the investments in the light of the performances of the selection of both software and hardware.

(xii) The human factors should be given due consideration while designing CIM and there is a need to establish the level of skill and training required in order to develop and maintain the CIM system.

(xiii) Suitable models should be developed for the investment decision making on CIM systems

[30]. Moreover, Activity Based Costing (ABC) should be developed for CIM environment [31].

7. Summary and conclusions

In this paper the concept of CIM from different angles has been discussed and analysed for better understanding of the concept. Then the literature available on the design and implementation of CIM has been reviewed with an objective of bringing the pertinent issues to the fore concerning the development of CIM in the real-world applications. Based on the review and analysis of the approaches available on CIM, a framework has been proposed for the design and implementation of CIM. Moreover, future research directions are suggested considering the gap between theory and practice with a view to increase the application of the theoretical approaches in the design and implementation of CIM in practice. The tools available for the design and implementation of CIM should be tailored to the production process and information flows and in their total integrated form. A CIM system should be designed by examining various approaches and methodologies of integration from each area that affect the efficiency of the other areas in manufacturing systems.

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