Revitalising the Manufacturing Industries through CIM

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Abstract

Today mangers in many enterprises are confused with varying technologies and new terminologies that prevail in the Public domain. To make adoption and implementation issues complicated, there are many researchers pursuing similar concepts but in different names to solve part of the issues that are or can be addressed by a CIM system. Therefore, this paper summarizes the evolution of manufacturing technologies that are associated with developments towards a CIM system, and reviewed some of the new terminologies and technologies, which were proposed during the last four decades. This review is aimed at overcoming the confusion with the new terminologies that have been generated in the past four decades. Further, this paper articulates that all these new proposals are in deed the sub-system or sub-solutions of CIM. Finally, this article focuses on latest research developments in CIM and provides a stepwise justification methodology towards a CIM system for a small or a medium enterprise.

Keywords
Manufacturing concepts, Virtual enterprises; Virtual CIM; CIM; Step-by-step integration.

1. Introduction
An enterprise that relies on traditional manufacturing systems cannot satisfy the needs of globally distributed customers and match the capability of the competitors, since these traditional systems are only deployed within an enterprise and this enterprise does not have the capability to maximise the potential and strength that are available in different parts of the world. Therefore, a more flexible and comprehensive methodology is necessary to overcome the distance barriers, facility sharing problems and communication obstacles. This need has lead to the concept of Virtual Computer Integrated Manufacturing (VCIM), which is a network of interconnected and globally distributed Computer Integrated Manufacturing (CIM) systems across geographical boundaries, whereas CIM is an integration of localized manufacturing facilities. Although, with available technologies and systems in Computer Integrated Manufacturing (CIM) and its related technologies, the application of CIM in manufacturing enterprises is a reality and can meet the need of the enterprises.

Hence, proactive enterprises seek the application of intelligent and integrated manufacturing systems in order to meet the customer's demands and be the winners in the competitive market. In addition, in today's market non-price factors such as quality, product design, innovation and delivery services are the primary determinants of product success in the global arena. In 1998, National Science Foundation of United States of America (USA) commissioned a study to create a vision of the competitive environment for manufacturing and the nature of the manufacturing enterprise in time to come and published the ''Visionary Manufacturing Challenges For 2020'' [Committee on Visionary Manufacturing Challenges Board et. al.]. The committee of experts identified the most important technical, political, and economic forces for manufacturing as follows [Committee on Visionary Manufacturing Challenges Board et. al.]:

- Global distribution of highly competitive production resources will be a critical factor in the organization of manufacturing enterprises to be successful in this changing technical, political, and economic climate.
- Developments in innovative process technologies will change both the scope and scale of manufacturing,
- Environmental issues will be predominant as the global ecosystem get strained by growing populations and the emergence of new high-technology economies,
- Rapid responses to market forces are required to survive in the competitive climate, enhanced by communication and knowledge sharing,
- Information and knowledge will be shared by manufacturing enterprises and the marketplace for effective decision making,

While the concept of CIM is broadening its application in manufacturing and other industries, it is interesting to note that new manufacturing and management strategies have also begun to surface during this last five decades. Lean Manufacturing (LM), Just-In-Time (JIT), Concurrent Engineering (CE), Cellular Manufacturing (CM),

agile manufacturing, responsive manufacturing, holonic manufacturing, distributed manufacturing, and collaborative manufacturing are some of the new terms evolved over the last four decades to reflect the dynamic nature of improvements in manufacturing applications. Although, these new terms are being generated every few years, the concept of CIM is far broader than these new terms.

2. Need for Integration

The need for a holistic and systematic integration has evolved due to the problems in individual automation solutions adopted by the manufacturers. Individual automation in functional units produced many islands of automation in an enterprise and these automation units could not facilitate communication between functional units. These issues and the complexity of emerging technologies, economics, increasing human limitations, and competition from abroad has forced the initiation of integrated computer aided manufacturing (ICAM) Programme by the United States (US) Air force [Foston AL et. al]. The ICAM Programme conducted in 1983 found that the industrial automation was infested with critical problems [Appleton DS], such as information could not be controlled by users, changes were too costly and time consuming, systems were not integrated, and data quality was not suitable for integration. These problems were the product of having job shop mindset when deriving automation solutions in an enterprise. This mindset produced individual automation units with lack of proper planning for enterprise-wide issues. Therefore, these individual units became standalone, which could not be connected together for information sharing and streamlined manufacturing. With this unplanned implementation of integration, the full benefits of automation in an enterprise were not obtained. Although, these individual automation units improved local productivity, they were insufficient in providing necessary logistical support to improve the productivity, efficiency and quality throughout an enterprise [Gunasekaran A et.al].

3. Developments in Integration Technologies and Systems

Integration provides a competitive advantage by linking new and existing hardware, software and middleware of the functional units, together with database management systems, data communications systems and other ICT systems into a coordinated and efficiently managed process. In order to appreciate the historical developments that had taken place during the last four centuries, the evolutions in manufacturing technology towards integrated systems are summarised in Fig. 1. However, the precise time span for the evolutionary stages cannot be determined and not given in this figure. The stages of shop floor automation from the level of manually controlled machines towards integrated cells, respectively, automation for manufacturing management improved from paper-based control to flexible or agile systems. In the mean time, integration of manufacturing systems has evolved from physical systems integration to application integration, and then to business process integration [Vernadat F]. Physical systems integration involves interconnection of manufacturing facilities and data exchange among various units through computer networks that rely on standard communication protocols. This integration considers low levels manufacturing resources. Application integration considers integration and interoperability of systems on heterogeneous platforms. This stage involves sharing data and information among all facilities, distributed processing environments, and common services for execution environments. Today, this information sharing aspect includes both wired and wireless connections across various systems. Finally, the business integration concerns integration of all functions, business processes and systems at an enterprise level (within an enterprise and beyond to business partners and customers) which include e-commerce, customer relationship management, global logistics, supply-chain related applications and many others.

2006	Resource Scheduling for Virtual CIM Systems
2005	Collaborative CIM systems concept development
2000	Frame work and Architecture of Virtual CIM
1997	Virtual CIM concept Introduction
1986	Distributed CIM Concept Introduced
1980 1981	Advanced Systems in CAM, CAPP, CAQC, AS/RS Application of CIM Systems
1970	Developments in CAD, Applications of CAM based system and Introduction of Concept of CIM
1955	Beginning of CAM and Developments in NC; such as CNC,DNC
1950	Early Developments in NC for Automation
1930	Very Large Mass Production Systems
1900	Mass Production Systems
1750	Mechanization and early factory Systems

Figure 1. Evolution in Manufacturing Technology [Sev V et. al]

4. Revitalizing Terminologies

The realisation of CIM requires effective integration of a number of available AMTs. At the same time, many variations in manufacturing methodologies were developed and proposed by researchers to revitalise the manufacturing industries. These new terminologies are summarised according to the historical perspective.

4.1 Revitalizing terminologies for organisations

The developments in concept created new terms such as Smart organisations, Dynamic enterprises, Extended enterprises, Virtual enterprises, Virtual enterprise networks, Intelligent enterprises, Integrated enterprise, Agile enterprise, Lean enterprise, Centers of excellence, Process-driven organisations, e-enterprise, Borderless enterprise, Complicated or complex manufacturing systems, Flat structures and others. These terms have been used by researchers to describe various aspects of an enterprise and its operational aspects.

However, the analysis of these explanations for the new organizational aspects as of manufacturing strategies and terms, which are evolving simultaneously to CIM, shows that CIM could still provide all the features of lean, agile and concurrent manufacturing in an integrated manner. The concept of dynamic enterprises, intelligent enterprises, integrated enterprise, agile enterprise, lean enterprises, process-driven organisations and others can be fulfilled by a true CIM system in an enterprise. Similarly, the concept of extended enterprises, virtual enterprises, virtual enterprise networks, centers of excellence, e-enterprises, borderless enterprise and others can be matched by a VCIM system in an enterprise. The potential for CIM in manufacturing industries is considerably large. Nevertheless, there is often a mismatch between the hypothesis of CIM, which is a management and manufacturing strategy towards a fully integrated factory, and the application in a real world for a realistic factory, due to technical expertise of the employees, rigid organizational structures, unplanned initiatives without a strategic intent and other related issues. These are the barriers for adopting a CIM system or any hybrid system in an organization.

4.2 Revitalizing terminologies on software applications

Various software systems that help manufacturing enterprises to comprehensive plan and control operations are being provided to date by many software vendors with various complexity and operational features. While the concepts are being developed, tested and applied, various ICT vendors produced software applications with plethora of acronyms such as Materials Requirement Planning (MRP), Manufacturing Resource Planning (MRP II), Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), Advanced Planning & Scheduling System (APS), Supply Chain Execution (SCE), Customer Relationship Management (CRM), Advanced Order Management (AOM), Warehouse Management Systems (WMS), Transport Management System (TMS) and others.

MRP software was developed in late 1960s early 1970s and was well known through a book published with a title 'Material requirements planning: the new way of life in production and inventory management' written by Dr. Joseph Orlicky [Orlicky J.]. MRP software helped automate the planning and controlling of production and related inventory functions of an enterprise from raw materials to finished goods. MRP later evolved to Manufacturing resource planning (MRP II)—a term which was coined by Oliver Wight in 1974 [Crabtree D]. MRP II expanded the capability and scope of the MRP systems by linking related support functions such as marketing, finance, engineering, purchasing and human resources.

ERP describes a suite of multi-modular software applications that are integrated to serve and support multiple business functions and the suite of applications in ERP package are expanded to include modules such as finance, administration, manufacturing, project management, transportation, human resources and other modules which help automate the business administration functions of an enterprise. The ERP systems, a term originally coined by the Gartner Group in early 1990s to describe the extension of the concept the next generation MRP II software [Barton P.], linked the databases of an enterprise to execute the business operations seamlessly and helped in avoiding multiple and redundant entry of the same information and processes.

However, many of the issues such as inherent complexity, high cost, large timelines to implement, inadequate in-house expertise and training, overly customised software, unrealistic expectations on the capability and overly relying on ICT to solve the problems, corporate culture and management's adaptability to the issues are some of the known issues, which made these software applications to fail. Although, the concept of MES represents a new and practical approach to link information with action on the shop floor to help the managers in improving quality, response, and profitability in the operation, An MES is considered as a collection of systems that are integrated through a common database to manage, monitor and control all production and related activities at the facility level. In this trend, the newcomers on this trend would be CRM, SCM, and e-commerce related applications such as e-business, web-enabled, e-procurement, e-fulfillment and others. These systems are being evolved with the technological developments and implementation issues in par with the development of manufacturing concepts.

4.3. Terminologies on management and manufacturing strategies

Agility requires: reduction in product development time; allowance for considerable customisation of product features; and incorporation of highly adaptive, flexible and efficient manufacturing practices in the product development and manufacturing cycle. The concept of agile manufacturing is similar to the concept of LM by emphasising on small batch sizes. The initial coining of the term agile manufacturing was the result of a 1991 study initiated by inter-agency task force appointed by the US department of defence [Kidd PT.]. As Kaizen involves all employees in an organization for continuous refinement and improvement of existing activities, and CIM relates to integration of manufacturing activities, both concepts are complimentary to each other. Kaizen, which is a Japanese term for achieving continual improvement by cooperatively involving everyone concerned, is still part of the Japanese manufacturing system to date. Kaizen, which became a way of life in Japan when industries start to revive after the World War II, has been helped by the support government and management on adopting quality related tools introduced by Deming and Juran [Imai M.].

In late 1950s, Japanese automobile manufacturers realized that the mass production did not fit into the production and management strategy required to satisfy the product differentiation which was evolving as a fundamental market feature [Lamming R.]. This realisation resulted in the formation of the Lean Manufacturing (LM) concept. LM involves addressing the product strategy, product development, supply chain, manufacturing and product distributions for the production of diverse products in small batches.

Just-In-Time is a management philosophy aimed for producing only the right amount and right combination of parts at the right place at the right time. JIT has been a part of the Toyota production system as production and inventory control approach for eliminating manufacturing wastes. Taiichi Ohno at Toyota developed and perfected JIT concept during early 1970s in Japan, and he is now referred to as the father of JIT [Institute for Manufacturing.]. Implementing CIM in an organization will help achieve JIT principles easily and effectively.

CE could be considered as a management strategy rather than the manufacturing strategy. The concept of Concurrent Engineering (CE) has been around the manufacturing circles from early 1960s in various forms requesting the use of multi-disciplinary teams to accelerate product introduction. CE involves a systematic and simultaneous approach to the integrated design of products and their related processes including marketing, manufacturing, sales and purchasing [Syan CS]. Further, it involves formation of multi-disciplinary teams for the rapid product development and introduction of the product into the market.

BPR achieves these objectives through business modeling and analysing techniques. BPR method eliminates unproductive and unnecessary business activities and operations in an enterprise and actuates process simplification and if necessary out-sourcing.

Cellular Manufacturing (CM) system, which combines the advantages of process and product layout to optimise the job shop arrangement, is an alternative production system to the conventional conveyor line and

batch production systems. CM systems, which are derived from the application of Group Technology (GT), is a major building block of LM system that helps companies manufacture variety of products with less waste compared to conventional ways [Lean Sigma Institute.]. Applying CM in an enterprise will result in lower unit cost of production, shorter lead-time to market, higher inventory turnover, and work-in-process control without sacrificing the flexibility.

The concept of Holonic Manufacturing System tried to solve the issues that arose out of hierarchical structures and rigid implementation architectures wrongly perceived as a result of CIM implementation [Babiceanu RF et. al]; the CIM concept itself did not enforce the rigidity and master–slave relationships among the manufacturing systems.

5. Status of CIM in Organisations

In today's competitive market, across the globe many companies have adopted the concept of CIM and implemented a partial or a full CIM solution to meet the required effectiveness and efficiency in all operations. Attaran [Attaran M.] reviewed the adoption of CIM among manufactures in USA and has given a few case applications including Motorola, Allen Bradley Texas Instruments and Tandem computers. He [Attaran M.] stated that although CIM technology was evolving rapidly and many CIM successes were reported as many companies could afford implementation of CIM within their financial reach, still there were a few failures when it was implemented without a proper strategic plan. Similarly, in China, during 1996–1997 there were more than 100 CIM applications were reported among state owned enterprises [Zhou Y et. al]. These enterprises invested in CIM systems using government financial subsidies and government- directed technical support from universities and research institutes; therefore, they have had success and progress in CIM implementation. However, most of the CIM enterprises in China did not realize the higher expectations the companies have had with respect to CIM systems, as in early stages of CIM implementation, most managers and researchers regarded CIM as an all purpose solution rather than an integrated manufacturing strategy. The failures on CIM implementations were mainly due to the reluctance to change management practices and organizational structures in state-owned organisations to match the requirements for an effective use of CIM philosophy and methodology [Zhou Y et. al].

7. CIM Implementation

The step-by-step integration towards CIM is a methodology developed at CAMR for assisting SMMEs achieves the goal of a fully integrated enterprise despite limited resources and expertise [Chirachavala C.]. Although, a justification and optimization methodology for an integrated system such as CIM, had been developed at CAMR with the capability to quantify intangibles, that methodology was not applicable fully to a small or medium enterprise, as a company in this category often do not anticipate a holistic system approach at the beginning of the automation process. Therefore, a need for a step-by-step integration approach was introduced to enable the SMMEs systematically accumulate sufficient capability and cohesiveness towards a fully integrated system. An organization, which prefers to adopt this methodology, is provided with a list of subsystems, which has individual AMT components as a subset. The components and the subsets are to be selected according to the four critical attributes: nature of the company, opportunities, existing resources and capabilities and special needs [Chirachavala C.].

Nature of the company: By identifying the nature of its operation and the business they are in, the company would be able to select the best initial subsystem that will be more applicable to them. For instance, if the business were dealing with import/export, selection of inventory or shipping subsystem prior to selecting a system that enables either marketing or project scheduling would be more appropriate.

Opportunities: The opportunities the organization has in the marketplace and the SWOT analysis will help identify the strategies the company needs to implement. In addition, this will enable the company to identify some particular strength they may need during different seasons and in a different market.

Existing resources: By identifying existing resources that are in the company's disposal and by selecting a subsystem (or the subset components) that can be easily implemented; the organization can reap the benefits of integration (or the use of AMT) quickly and reliably. In addition, this attribute will require the company to identify the AMTs that already exist in the company and that can be used as CIM modules towards an integrated system. For instance, if the accounting department has a computer with the basic office related software, by complimenting the computer with the necessary accounting software, many of the accounting related tasks can be automated.

Special needs: In some special circumstances, a company may need to have extra capabilities and functionalities to fulfill customer satisfaction. If this need is identified, the company can choose a subsystem that is relevant in satisfying this special need. Based on the above methodology, a systematic integration flow chart for a typical small or medium manufacturing company has been identified as shown in Figure 2.

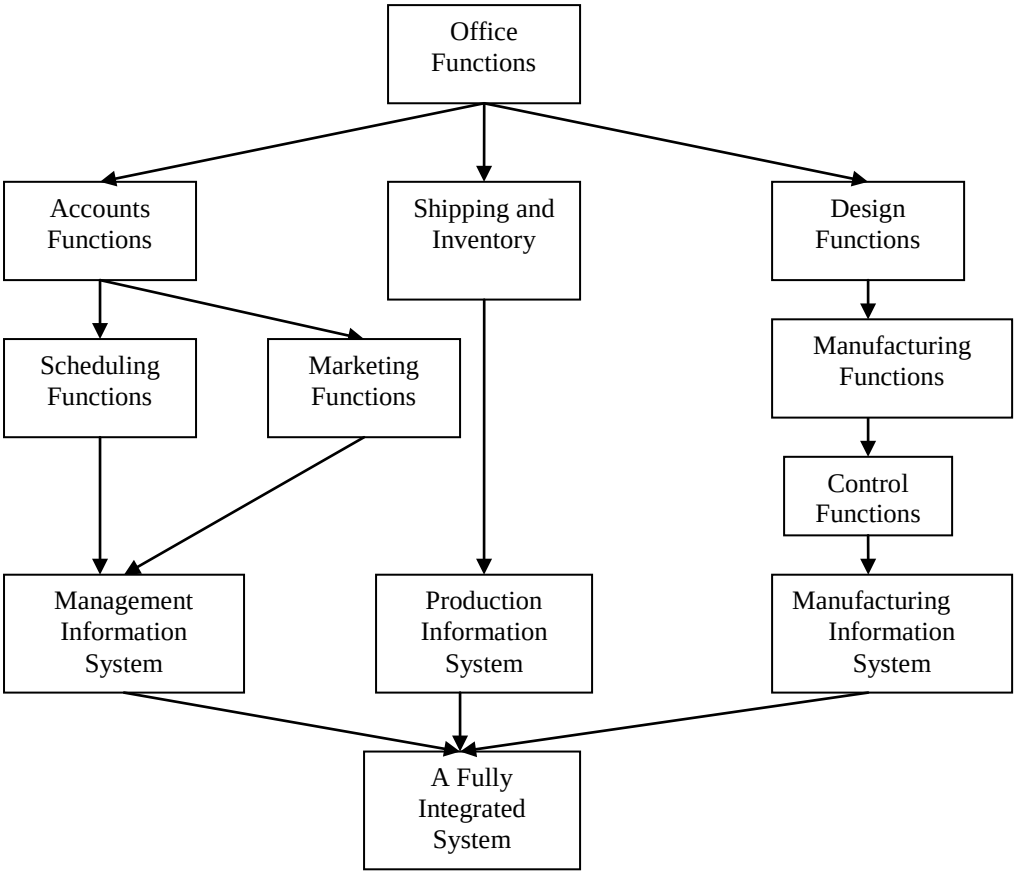

Figure 2: Integration flow chart for a small or medium manufacturing company.

8. Conclusion

The successful future of manufacturing industry is inextricably involved in the efficient and effective utilization of CIM and its components. Although a plethora of terminologies for manufacturing technologies has been proposed by various researchers during last four decades to overcome many of the industry issues that were the result of the new global market conditions, still a CIM system or appropriate CIM modules can provide the features suggested by those new methodologies. CIM is an overarching methodology and philosophy compared to the new terminologies such as LM, JIT, CM, agile manufacturing, responsive manufacturing, holonic manufacturing, distributed manufacturing, collaborative manufacturing and others. Similarly, CIM is a complimentary methodology for the concept of CE, Kaizen and others. Therefore, research on CIM and applicability of CIM modules with available ICT tools to manufacturing industry to overcome the current economic climate should be pursued with vigor.

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