



A Reference Model and a vision for manufacturing system for 2030

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ABSTRACT

The manufacturing enterprises are now experiencing high pressure of competition. In addition, the advancement in computer software, hardware, networks, information technologies and integration has been gradually reshaping the manufacturing companies by shifting from the industrial age to the information and knowledge era. Due to these elevated competitiveness and advanced computer technology, a number of new manufacturing and management strategies (e.g., Lean production, Just in time, Kaizen, Concurrent Engineering (CE), Cellular Manufacturing (CM), Agile manufacturing, Business process re-engineering (BPR), Agent-based systems (ABS), Computer Integrated Manufacturing (CIM), virtual manufacturing system have emerged for the innovation of manufacturing industries. The developments in organizational concepts created new concepts such as Smart organizations, Centers of excellence, Intelligent enterprises, Integrated enterprises, Virtual enterprises, Virtual enterprises networks, Dynamic enterprises, Extended enterprises, Agile enterprises, Lean enterprises, Process-driven organizations, e-enterprises, Borderless enterprises, Complicated or complex manufacturing systems, Flat structures and others. These terms have been used by researchers to describe various aspects of enterprises and its operational aspects. Although they have different definitions and scopes, there are several common issues: integration of enterprise functions; integration of enterprise resources; and collaboration. In addition Various vendors produced software applications such as Materials Requirement Planning (MRP), Manufacturing Resource Planning (MRP II), Enterprise Resource Planning (ERP), CAD/CAM systems, 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. This paper proposes a Reference Model and vision for Manufacturing System for 2030 and discussed various aspects of future manufacturing enterprise..It supports the inter-enterprise functions/resources integration and collaboration over the networked environment.

Keywords

Concurrent engineering; Computer integrated, manufacturing, Virtual enterprise; Multi-agent system

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INTRODUCTION

Global competition has brought about changes that are characterized by product proliferation with shorter and uncertain life cycles, innovative process technologies, and customers who simultaneously demand quick response, lower costs, and greater customization. Companies must cope effectively with continuous and unexpected changes in order to become competitive. The ability to respond quickly and effectively (time-based competition) and to satisfy customer needs has become a defining characteristic of competitiveness for many manufacturing enterprises. In addition the trend towards a global market and the increasing customer orientation impel the manufacturing discipline to seek new paradigms, such as concurrent engineering, lean production, Just in time, agile manufacturing, computer integrated manufacturing and virtual enterprises (VEs). In addition, the advancement in computer hardware, software and networks and information technologies has been gradually reshaping the manufacturing companies by shifting from the industrial age to the information era. These characteristics of elevated competitiveness and advanced computer technology have created many management and manufacturing strategies to improve the everyday business process of a company, including Business Process Reengineering (BPR) [1], Concurrent Engineering (CE) [2], Supply Chain Management (SCM) Lean Manufacturing (LM), Computer Integrated Manufacturing (CIM)[1] etc. Although the above strategies have slightly different definitions and scopes, there are several common issues. In today's information age, the customers and markets are sophisticated and demand high-quality products at reduced cost and with shorter delivery times. In addition, in today's market non-price factors such as quality, product design, process planning, innovation and delivery services are the primary determinants of product success in the global markets [3]. In 1998, National Science Foundation of United States of America (USA) commissioned a study to create a vision of the competitive environment for manufacturing enterprise and the nature of the manufacturing system in 2020. The committee of experts identified the most important technical, political, and economic forces for manufacturing as follows [4]:

1. sophisticated customers will demand products that are customized to meet their needs,
2. rapid responses to market forces are required to survive in the competitive climate,
3. creativity and innovation are required in all aspects of the manufacturing enterprise to be competitive,
4. developments in innovative process technologies will change both the scope and scale of manufacturing,
5. environmental issues will be predominant as the global ecosystem get strained by growing populations and the emergence of new high-technology economies,
6. information and knowledge will be shared by enterprises and the marketplace for effective decision making,
7. 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.

Today, in order to satisfy customers and be the market leaders, manufacturing systems should have the capability to integrate enterprise functions and improve organizational culture and structure, using international standards in design process planning and manufacturing. Manufacturing systems should also be flexible, adaptable, proactive, responsive to changes, and be able to produce variety of high-quality and innovative products quickly at a lower cost. In addition, they should be able to address new environmental requirements, complex social issues and capable of operating within dynamic geo-political boundaries. Hence, manufacturing companies were compelled to seek advanced technologies as a solution for the last five decades or more. Today, In 2015, manufacturing enterprise need to study and create a vision of the competitive environment for manufacturing system in 2030. This paper identified the most important technical, organizational and economic forces for manufacturing system.

THE VISION FOR MANUFACTURING SYSTEM FOR 2030

The vision for manufacturing enterprise for 2030 should consider all changes in the nature and operations of manufacturing system due to many challenges that will be generated by the social, technological, economical, organizational and political environment, the needs of the marketplace, and opportunities created by technological breakthroughs. In addition it should consider all changes in management and manufacturing strategies and organizational environment and climate. The vision for 2030 identified many challenges for manufacturing such as:

Lean Manufacturing (LM)

Lean starts from the refusal to accept waste [5]. Lean is a management philosophy focused on identifying and eliminating waste throughout a product's entire value stream, extending not only within the organization but also along the company's supply chain network. Lean is achieved through a set of mutually reinforcing practices, including Just in time (JIT), Kaizen or continuous improvement, total quality management (TQM), total productive maintenance (TPM), design for manufacturing and assembly (DFMA), supplier management, effective human resource management [6]. 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, 1993). Although there is agreement on the positive impacts of lean production on quality and productivity [7].

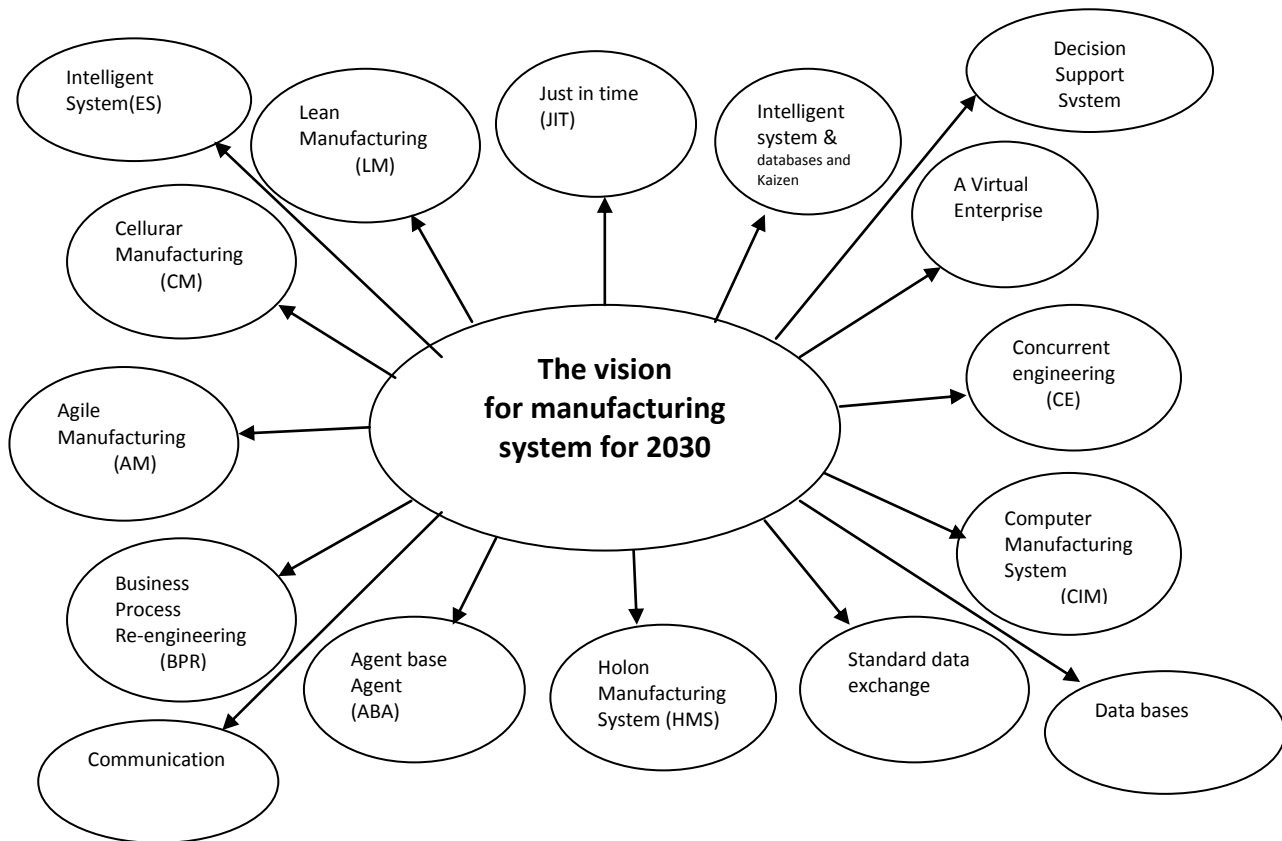


Fig. 1. Various dimension of manufacturing system model in 2030

Just-In-Time (JIT)

The JIT philosophy is known by different names such as stockless production; short cycle manufacturing and etc.[8]. Increasing numbers of manufacturers are taking a serious look at the just in time strategy of production to become more competitive in global markets. An important element of the JIT strategy is the purchasing function [9]. A successful purchasing program cannot be carried out unless cooperative buyer/supplier relationships are maintained. A successful relationship first rests on choosing good suppliers. Many experts agree that supplier selection is the most important activity of purchasing [10]. JIT suppliers should be selected on the basis of how they meet a multitude of specific requirements-requirements that do not depend solely on price, but the total "cost of ownership" of materials. JIT 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 [11]. In mid 1970s, this concept was widely accepted and used in many companies in Japan. Later, in 1980s, JIT was adopted in USA, one of the early adopters being the General Electric [12].

Kaizen

Kaizen 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 [13]. Implementation of the Kaizen concept has been enormously contributed to the success of manufacturing in Japan to date [14]. However, the authors of this paper believe that by having an effective CIIME system in a manufacturing enterprise, Kaizen can be easily achieved and the associated issues resolved. Because CIIME will help to achieve continual improvement.

Computer based Concurrent Engineering (CE)

The concept of 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 [2]. In concurrent engineering the full range of policies, techniques, practices are used for integration of manufacturing functions and increasing productivity and quality of products, that are developed in shorter times and lower cost. In design of product, early consideration of its function and manufacturability need to be made, Two approaches- team and computer-based are



used. The former involves team from design, process planning, production planning, manufacturing, marketing and so on. Chosen for their knowledge and abilities to contribute to product development. Although this approach has been widely implemented and significant benefits realized [15][16] [17]. [18]. Management of the CE team has been reported to be occasionally ineffective and costly. In consequence an alternative automated internal logic operation is now being explored. It offers design justification, manufacturability evaluation and optimization for the entire product life-cycle[19] [20]. CE could be considered as a management and manufacturing strategy. A computer based CE approach to IIMES is the subject of this paper. Nevertheless, implementing CIIME in an organization will help to achieve CE principles easily and effectively. CIIME involves a systematic and concurrent approach to the intelligent integrated design of products and their related processes including marketing, manufacturing, sales and purchasing and after sales.

Cellular Manufacturing (CM)

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[21] and [22]. CM combines the advantages of product and process layout to optimize the job shop arrangement, is an alternative production system to the conventional conveyor line and batch production systems. Applying CM in a manufacturing 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. Although, some researchers considered that CM, which was promoted to west by Professor J.L Burbidge in 1960s, was based on the concept of GT developed by the Russian engineer S.P. Mitronofanow[23] [24]. CM had many parallel and independent developments in Germany, UK, USA, Italy and other countries. Furthermore, the history of CM is long and complex than the linear developments prompted by others [25]. However, the author of this paper believe that by implementing CIIME system in a manufacturing, enterprise will provide the flexibilities and benefits of CM in an efficient and cost effective manner.

Agile manufacturing

Agile Manufacturing (AM) is a manufacturing paradigm that focuses on smaller scale, modular production facilities, and agile operations capable of dealing with turbulent and changing environments. The concept of agile manufacturing emphasizes on small batch sizes. However, agility requires: reduction in product development time; allowance for considerable customization of product features; and incorporation of highly adaptive, flexible and efficient manufacturing practices in the product development and manufacturing cycle [26]. 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 defense [27]. This department was asked by the US congress to take some appropriate actions in relation to concern of declining US manufacturing industry and reduced manufacturing competitiveness, and was asked to investigate what would be the actions required for the US industry to regain global manufacturing competitiveness by the early 21st century [28].

Business process re-engineering (BPR)

BPR is the term coined by Hammer and Champy in early 1990s [29]. BPR involves identifying each business activity, evaluating the importance and relevance of the activities towards achieving the business goal and redesigning all the activities in an efficient and economical manner to achieve the business objectives. BPR achieves these objectives through business modeling and analyzing techniques. BPR method eliminates unproductive and unnecessary business activities and operations in an enterprise and actuate process simplification and if necessary out-sourcing. The concept of BPR was popular in the 1990s, but when organizations tried to implement BPR they found that to accomplish the goals of the BPR vast resources in terms of ICT, training, materials and facilities were required. In addition, due to the huge complexity involved in this BPR method, an integrated and holistic approach was required. Therefore, the adoption of BPR failed in many organizations, although there were a few notable successes [30].

Agent-based systems (ABS)

Agent-based systems are being developed by researchers from late 1980s. These systems utilise intelligent agents, which are derived from Artificial Intelligence (AI). Developments in distributed AI and distributed computing technology has propelled this research on agent-based systems and enabled these systems to be applied in manufacturing enterprises. Many researchers tried to define the agents and their capabilities in various ways. One of the comparisons of definition of agents and the classification of agents has been found in Ref.[31]. however, Wooldridge and Jennings' definition of intelligent agents has received wider acceptance among agent-based researchers [32]. In the meantime, Shen and Norriin 1999 in their extensive review of agent-based systems for manufacturing and related applications stated that the intelligent agent technology has been applied in many areas including manufacturing enterprise integration, supply chain management, manufacturing planning, scheduling and control, materials handling, and holonic manufacturing systems. Because of the applicability and efficacy of an agent-based system, Wang et al have applied this concept to their developed VCIM framework [33][34].

Holon Manufacturing System (HMS)

The concept of HMS, which is a kind of agent-based system that facilitates autonomous and cooperative units of production, was derived from the term 'holon' coined by Arthur Koestler in late 1960s [35]. Then this term 'holon' was utilized to represent manufacturing systems that require autonomous, cooperative and self-reliant activities and later HMS project was initiated as one of the five IMS (intelligent manufacturing system) projects in 1993 to explore the feasibility of low-volume, high variety production system with agility. During its 10-year programme, the HMS Project has developed specifications for holonic



architectures, methodologies to reuse and integrate holonic systems technologies, and demonstrated the applicability of holonic manufacturing systems to derive agility, flexibility and re-configurability in-order to create next generation production systems [36].

Computer Integrated Manufacturing (CIM)

CIM uses information system technology to integrate these manufacturing and business objectives. CIM integrates major functional area (including marketing, design, process and production planning, plant operations, physical distribution, management and etc.) of the manufacturing enterprise. Although the concept of HMS tried to solve the issues that arose out of hierarchical structures and rigid implementation architectures wrongly perceived as a result of CIM implementation. The CIM concept itself did not enforce the rigidity and master–slave relationships among the manufacturing systems. The CIM implementation projects utilized the technologies available at that time and resulted in some limitations in providing flexibility. However, with the new technologies and tools that are available today, the CIM concept is alive as it was in early 1970s. In order to invigorate the CIM and the reach the organizations beyond the geographical boundaries, researchers proposed the concept of VCIM and have developed an architecture to make this system a reality[37].

A virtual enterprise

A virtual enterprise is a temporary coalition of enterprises that come together to share costs and skills to address business opportunities that they could not undertake individually [36]. Through the effective integration of the core competencies owned by member enterprises (MEs), the virtual enterprise can implement the product design and manufacturing efficiently with high quality and low costs, thereby making new products come into the market quickly. Nowadays, the virtual enterprise is considered one of the most promising paradigms for future enterprises [38].

Standard for exchange of product data

Standard for the exchange of product (STEP) is the international standard (ISO) (ISO 10303) that is being developed as a result of international collaboration between organisations such as CAD*1 (ESPRIT) project 322) and IGES/PDES Organizations in the USA, those who have been developing current formats, to produce a formal specification, testing and implementation aids, together with documented procedures, so all the objectives to the current formats are met. The product data description is developed using a formal method to define all ideas and concepts uniquely and consistently. Therefore, ISO 10303 is a set of international standards for the computer sensible representation and exchange of product data. The language that is used to support this method is express (ISO 10303 part 11). A formal specification language such as EXPRESS, which is used to specify the representation of the product information, enables precision and consistency of representation and facilitates the development of implementations.

Communications

The delivery of manufacturing data to different functions, systems, devices and people, is an important aspect of the future product development, because new industrial environment brings together a wide range of technologies, systems, Agents, suppliers, customers and computer systems.

Data management

Data management in future is very particularly critical in today's enterprise environment, since there are so many different databases, formats, and storage and access techniques in manufacturing Corporation. Data management includes how data is defined, how different data elements are related, where data is stored and who has access to that data. In the future many functions are used to convert raw material to finished products. In this regard a wide range of devices and information requires producing different types of products. The required information for manufacturing corporation in the future must have a consistent way to distribute and present information to different functions, Agents and people at computer terminals or workstations, machine, tools, robots, sensors, bar code readers, automated guided vehicles, and part storage and retrieval systems. The range of this information covers everything from simple messages between people to large data arrays for engineering design applications and data show on displays and many user utilize it. As a result, the same information is often used by different applications. Many different databases for properties of different types of materials, tools, machines, factories, dies, fixtures, customers, suppliers, markets, agents, technologies, processes etc are used

Intelligent system

Intelligent system contains expertise gathered from experiment and from general knowledge about a subject or a problem that can be used to guide us to solve the problem. Number of intelligent system will used in design, process planning, manufacturing, marketing, sales, cost, evaluation of design, Quality of product, management and etc

Decision support system

in the future. In the future, all functions are supported by Decision supporting systems. It support for accessing, summarizing, selecting and analyzing the data required to manage enterprise functions. The common support functions is divided into following three individual areas: 1) administrative support which provides general business or office support such as creating documents, communicating with suppliers, tracking finance, scheduling meeting and etc. 2) decision support which clarifies and presents critical information to decision makers and product designers and manufacturing engineers. 3) Application

development support which creates the applications necessary to keep all aspects of the enterprise functioning smoothly and efficiently.

VARIOUS SOFTWARE APPLICATIONS

Various vendors produced software applications 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.

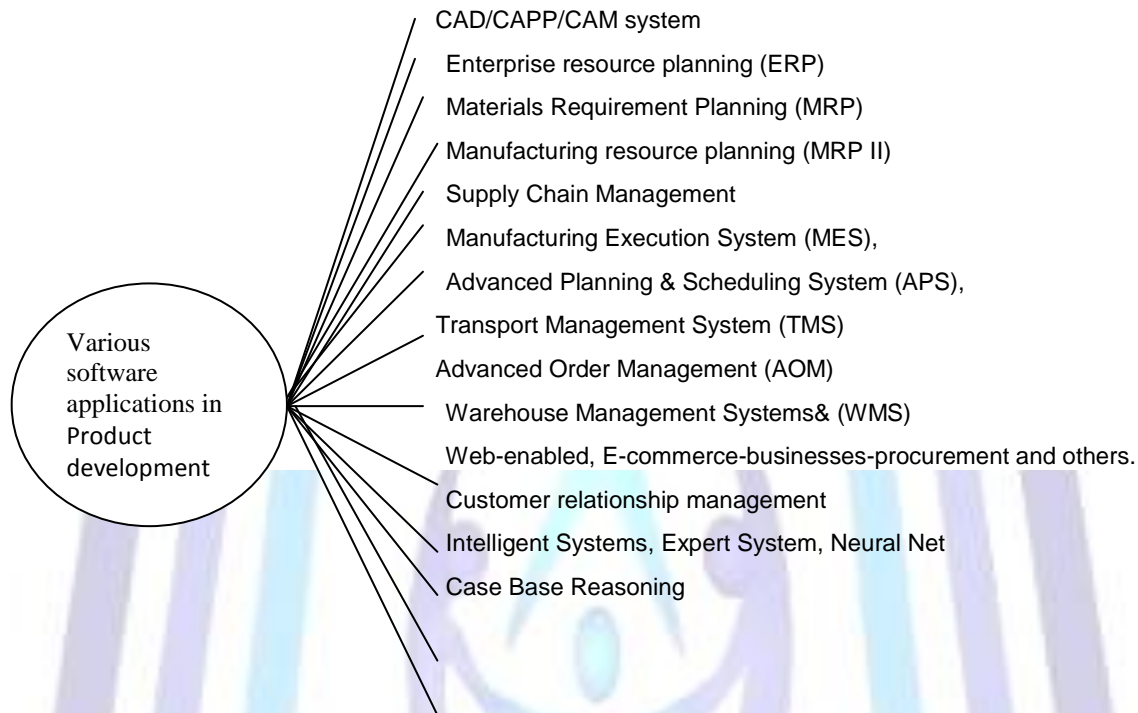


Fig.2. Various software applications in product development and management strategy

CONCLUSIONS

Today the manufacturing enterprises are experiencing high pressure of competition. In addition, the advancement in computer software, hardware, networks, information technologies and integration has been gradually reshaping the manufacturing companies by shifting from the industrial age to the information and knowledge era. Due to these elevated competitiveness and advanced computer technology, a number of new manufacturing and management strategies (e.g., Lean production, Just in time, Kaizen, Concurrent Engineering (CE), Cellular Manufacturing (CM), Agile manufacturing, Business process re-engineering (BPR), Agent-based systems (ABS), Computer Integrated Manufacturing (CIM), virtual manufacturing system) have emerged for the innovation of manufacturing industries. This paper addressed a Reference Model and vision for future manufacturing enterprise for 2030. It supports the inter-enterprise functions/resources integration and collaboration over the networked environment.

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