Editorial

Networked manufacturing and mass customization in the ecommerce era: the Chinese perspective

1. Introduction
Recent rapid developments in computer and network technologies have profoundly influenced manufacturing research and practice as well as human society. Opportunities have been provided for conventional manufacturing companies to transform themselves with emerging patterns in order to meet quickly expanding demands of global customers. Networked manufacturing and mass customization (MC) highlight two important milestones in the development of computer integrated manufacturing. They have been making profound contributions to the society, economy, technology and science. Networked manufacturing is a new manufacturing pattern that can help enterprises improve their business management and enhance their competitiveness in the market. Since networked manufacturing covers the whole product lifecycle, it enables the circulation and integration of information and knowledge from product design to manufacturing and enables resource sharing among geographically distributed enterprises, thus equipping enterprises to respond to the market quickly. MC is a production pattern integrating enterprises, customers, and suppliers. It enables the efficient delivery of customized products or services with the virtues of low cost, high quality, and high efficiency. Under the direction of system theory and global optimization, MC supports various technologies such as standardization technology, modern design methodology, information technology, and advanced manufacturing technology.

This special issue is dedicated to the area of Networked Manufacturing and Mass Customization. An emphasis is placed upon the E-Commerce and E-Business technologies. The focus is on reporting the recent Chinese developments in the Internet technologies to enhance the manufacturing research and practice. Most papers have been selected from outputs resulting from national projects including National Science Foundation of China (NSFC) and 863 CIMS HiTech programme respectively. This special issue takes a snapshot of the progress and challenges achieved and encountered in the Chinese context.

The rest of this extended editorial is organized as follows. Section 2 gives literature reviews of networked manufacturing and MC. Section 3 investigates the key technologies that are important and common in networked manufacturing and mass customization. Section 4 introduces the papers in this special issue and describes the research status in China. Section 5 points out future research directions in this field. Finally, a summary is presented in section 6.

2. Recent developments in networked manufacturing and mass customization
2.1. Networked manufacturing
Computer and network technologies have evolved rapidly over the last few decades. Their advancement has ushered in a new era for manufacturing methods. As an advanced manufacturing pattern, networked manufacturing was born out of industrial demands as well as information technologies (Fan et al. 2003).

2.1.1. Development of networked manufacturing. The earliest prototype of networked manufacturing appeared in the mid-1980s. Since then, numerous research departments and great corporations have undertaken their own research projects on related theories and methods. In recent years a collection of concepts, definitions, and frameworks on networked manufacturing have been presented, such as agent-based networked manufacturing by Yang (2000) and distributed networked manufacturing by Chen et al. (1999) and Zhang (1998).

With the development in academia, a number of projects sponsored by governments, research institutions, and enterprises have been carried out. In 1985, American researchers presented Computer Aided Logistics Systems (CALS) in order to enhance the capability of weapon
design and manufacturing. Ever since then the concept of CALS has been under constant modification. In the early 1990s, the American government presented a plan called “Advanced Manufacturing Technology” which included the project of Factory American Net (FAN), led by Lehigh University. The project’s main goal is to integrate all the manufacturing enterprises. Until now, there have been many other American projects such as Next Generation Manufacturing (NGM) by MIT, National Industrial Information Infrastructure Protocols (NIIIP), CSCCM, which aims at computer supporting collaborative management, the X-CITTIC project, etc. Furthermore, Korea, Japan, and Canada are also executing their own networked manufacturing plans. In China the National High Technology R&D Program (863 Program) has also supported research projects on the subject of networked manufacturing. We will discuss this in section 2.4, and more information can be found in the references (Fan et al. 2003).

2.1.2. Networked manufacturing concept. By applying network, manufacturing, and other related technologies, networked manufacturing can provide many kinds of business activities (such as product design, manufacturing, sale, stock, management, etc.); integrate information and decision making among data flow (of machine/process level), information flow (of factory and supply system level), and capital flow (of business system level); and realize multi-enterprise collaboration and the sharing of many kinds of social resources (Montreuil 2000). Supported by the networked manufacturing system, the enterprises can construct systems that fit the special requirements, and they can respond quickly to the market (Yan 2000), thus seizing the opportunity to thrive in the dynamic and open business context of the 21st century (Liu et al. 2000).

Yang (2000) points out that, because of rigid organization structure and centralized resources, traditional manufacturing patterns are inapplicable to the new requirements of a networked economy. Therefore, it has become urgent to develop a market-driven networked manufacturing pattern, which is crucial for manufacturing enterprises to break away from their current predicament and pursue new market profits. Networked manufacturing involves new forms of manufacturing organization such as network organizations, extended organizations, and virtual organizations. Thus, collaboration and partnership become the keystones of organization management. More information can be found in the references (Wright et al. 1997, Cloutier et al. 2001; Huang and Mak 2000).

Liu et al. (2002) defines networked manufacturing as a set of manufacturing activities (including market control, product design, material management, manufacturing process, sales, and after-sales service), manufacturing technologies, and manufacturing systems. Yan (2000) considers that networked manufacturing enables the circulation and integration of information and knowledge from product design to manufacturing and that it facilitates resource sharing between geographically distributed enterprises, thus endowing enterprises with the ability to respond to the market quickly.

2.1.3. Application of networked manufacturing in China. The National High Technology R&D Program of China (863 Program) realized the importance of and the opportunity brought by the new production trend of networked manufacturing as early as 1998. At present, the 863 program has supported many projects to study and implement networked manufacturing. All these projects have played a very important role in the research and application of networked manufacturing technologies. In recent years a great many achievements have been made, and many applications have been implemented. This paper will just give one example.

The regional networked manufacturing system in the Pearl River Delta in Guangdong province was chosen as an example based on the requirements of the industrial enterprises in the Pearl River Delta. The Chinese Manufacturing Collaboration Net (CMCN) was developed and implemented to provide a supportive, Internet-based platform for collaboration on business, techniques, and production for small- and medium-sized enterprises in this area. With the CMCN large numbers of small- and medium-sized enterprises can make sufficient use of the Internet to share manufacturing resources and dynamic collaboration of business with the lowest costs. As a result, the total manufacturing capacity in the Pearl River Delta has been enhanced greatly. There are currently about 20,000 enterprise members registered in this system, among which more than 3,000 have already been certified. The CMCN has won a good reputation in the manufacturing field and has received broad attention from all over the world.

2.2. Mass customization

In recent years individuality has been strongly advocated, and customers often desire products specially designed for them. Mass production by Ford and Sloan at the beginning of the 20th century could not meet the increasing requirements of different customers. In order to provide better services, manufacturing enterprises changed their emphasis from products to customers. Mass customization (MC) appeared under this circumstance, aiming to provide customized products as well as maintain short delivery time and low cost.

2.2.1. Mass customization concept. The term “Mass Customization (MC)” was coined by Davis in his book, Future Perfect (Davis, 1987). Since the history of MC is short, scholars from different countries have different
knowledge about it. Generally, MC can be defined either broadly or narrowly. In the broad view MC is defined as a paradigm that can provide individually designed products and services to customers. It can best serve customers’ needs while maintaining nearly mass-production efficiency through high-process agility, flexibility, and integration (Pine, Victor and Boyton 1993, Eastwood 1996, Hart 1995). MC systems may thus reach customers as in the mass market economy, but they will treat them individually as in the pre-industrial economies (Davis 1989, Silveira 2001). MC integrates enterprises, customers, suppliers, and market environment, maximizing the efficiency of the whole manufacturing system with the aid of advanced and modern methodologies.

Many authors presented similar but narrower, more practical concepts. They define MC as a system that uses information technology, flexible processes, and organizational structures to deliver a wide range of products and services that meet specific needs of individual customers at a cost near that of mass-produced items (Hart 1995, Kay 1993, Kotha 1995, Ross 1996 and Jonesja 1998). The golden rule of MC can be summarized as “any time, any place, any people and any product” (Pine 1993). The changes from mass production to MC include the increase in product variety and the decrease in product batch (Tseng et al. 1997); thus, the kernel task of MC is to coordinate all the flexible units of a manufacturing system to build an efficient production network (Lau 1995).

Generally, MC is regarded as a systemic notion covering all aspects of product design, manufacturing, sale and delivery, and full life cycle from the customer option up to his or her receipt of the finished product (Kay 1993, Jiao et al. 1998). The preconditions for the development of MC systems involve three criteria (Ahlstrom 1999). First, advanced manufacturing and information technologies enable manufacturing systems to deliver higher variety at lower cost. Second, there is an increasing demand for product variety and customization (Kotler 1989). Finally, shortened product life cycles and expanding industrial competition has led to the breakdown of many mass industries, increasing the need for production strategies focused on individual customers.

2.2.2. Theory foundations of mass customization. Different from mass production, which elicits high efficiency under stable control, MC provides customers with various customized products by dynamic and quick response. In order to implement a MC system effectively, some principles are fundamental, such as Similarity principle, Reusability principle, and Systematicality principle.

1. Similarity principle. The pivotal procedure during the implementation of a MC system is to recognize similar characteristics between different products or processes. Through recognizing the geometry similarity, structure similarity, function similarity, or process similarity, manufacturing enterprises can increase production efficiency by reducing the variation of products or processing machines (Qi et al. 2003). The most commonly used methods, according to similarity principle, include standardization and modularization. For example, one product needs 20 types of bolts during its built-up process, which burdens the manufacturer with a great cost and complicated problems of management. On the other hand, the customer’s only concern is with the functions and appearance of the product, rather than how many kinds of bolts are used. If applying MC systems, the factory needs only one standard model of bolt for representing the 20 types. Whenever the application of a specific bolt is required, designers can modify the standard model easily to adapt to individual needs. By this means, the data volume stored in the database decreases tremendously, and management is simplified.

2. Reusability principle. Many units, including single parts or combinations of parts, can be reused in a variety of customized products. These reusable units can be assembled in different ways to compose different products. As we know, Motorola mobiles are famous for their variety of styles, allowing customers to choose their favourite styles freely. Although Motorola has such a big product library, the workload of its database management is mainly focused on several primary reusable parts, including the main circuit board, the signal acceptor module, and the battery. In fact, the principle of reusability has been a trend in the industry field. In complicated products there can be more reusable units, thus adding more value (Jiao et al. 2003). Furthermore, reusability also means recyclability. When a product is discarded as useless, some durable parts can be back-processed, thus lowering the cost.

3. ‘‘Systematicality’’ principle. Implementing MC is a heavy-loaded and also stubborn systems-engineering (Gu et al. 2002). It covers many aspects from manufacturing and management technologies to human train of thought and cognition of values. In other words, MC implementation involves major aspects of operations including product configuration, value chain network, process and information technology, and the development of a knowledge-based organizational structure. Therefore, systematic planning is essential before taking action.

2.2.3. Application of mass customization in China. MC has recently been applied broadly in industrial realms to produce customized products such as engineering goods,
electronic products, costumes, buildings, and software. In the field of engineering goods, many car companies of the West, including BMW, Volkswagen, Ford, and GE, have the most successful implementation of MC systems; however, in China MC is in its starting phase. Few MC systems are applied in this field, but many can be found in production of electronic household appliances, costumes, and so on. The representative case of household appliance customization is Haier (Qi et al. 2003), whose customers can browse its Web site and enjoy its individualized customization service online. For example, if a customer wants to buy an icebox from Haier, he or she can submit the requirements on the Web, such as “the volume of the icebox should be 220L” and “it should be silent and energy efficient.” Since August 2000, when Haier began its customization services, its productive capacity has increased tremendously, and Haier has achieved great economic benefit from this. Another case is Xinlang, which provides a customization service of business suits to its customers. Only one or two days are needed from measuring, planning, and evaluating to finishing so that Xinlang attracts a great number of clients and builds up its trademark reputation in a short time.

3. Key technologies in networked manufacturing and mass customization

The key technologies commonly involved in the implementation of networked manufacturing systems and mass customization can be categorized as overall technologies, fundamental technologies, enabling technologies, and application technologies.

3.1. Overall technologies

Overall technologies aim to study the structure, management, and application of the manufacturing systems from a systematic point of view. They include manufacturing pattern, architecture, infrastructure, system operational mode, and system management, as well as some important technologies such as the Collaborative Product Commerce (CPC), the Product Lifecycle Management (PLM), and concurrent engineering technology. Since overall technologies mostly emphasize the theoretic level, they give directions to the designers and developers of the manufacturing systems. The use of overall technologies is justified by their inherent capability to improve manufacturing efficiency and remove barriers to product flexibility (Meredith 1987).

3.2. Fundamental technologies

Fundamental technologies are the common technologies used not only in networked manufacturing systems or mass customization systems but also in many other information systems. They include standardization technology, enterprise and product modeling technology, knowledge management technology, network protocols, workflow management, virtual enterprise and organization, and multi-agent technology (Huang et al. 2000). Fundamental technologies do not solve problems directly, but they play an important role in both networked manufacturing and mass customization.

The most typical fundamental technologies are communication and network technologies. The main motivation behind the extensive use of communication and networks based on information technology is to provide direct links between work-groups (e.g. design, analysis, manufacturing, and testing) and to improve the response time to customer requirements. Communication and network technologies are tools to integrate previously isolated components of a productive chain into coherent and coordinated competitive weapons. Bally (Pine and Pietrociini 1993) is an example of using intensive information technology to implement MC concepts. It employed advanced information technology based on artificial intelligence methods to move from CIM to CDIN, a computer-driven intelligence network; this system links their sales representatives and suppliers in one single information network.

3.3. Enabling technologies

Enabling technologies are pivotal common technologies used in design, development, and application implementation of manufacturing systems. They include the development of design/manufacturing resource libraries and knowledge bases, enterprise application integration technology, integration platform technology, the Application Service Provider (ASP) technology, e-business and the Electronic Data Interchange (EDI) technology, intelligent information searching technology, web technology (Huang and Mak 1999) and other supportive technologies such as CAD/CAE/CAM/CAPP, ERP, PDM, and CRM. Supply chain management (SCM) and customer-driven design and manufacture (Spira 1996) are the two most common enabling technologies. Supply chain management concerns the coordination of resources and the optimization of activities across the value chain to obtain competitive advantages (Boyton et al. 1993). Efficient supply chain management is one of the key success factors in systems. Customer-driven design and manufacture is at the core of today’s manufacturing systems. Jagdev and Browne (Jagdev and Browne 1998) define this business practice as “to actively consider the market trends in general and individual customer requirements in particular during the design, manufacturing and delivery of the products.”
3.4. Application technologies

Application technologies support the implementation of networked manufacturing systems. They include the approaches of networked manufacturing application implementation, basic data library building and management technology, resource (equipment) encapsulation and interface technology, and cooperation technology in virtual enterprise and network security technology.

4. Overview of the papers

This special issue includes 17 papers including this extended editorial. They report on the latest progress of research and practice relevant to networked manufacturing and mass customization in China. These papers were selected from submissions from grant-holders and project teams. Although networked manufacturing and mass customization technologies are in their early stages in China, these papers have made significant progress in different research aspects.

Until now, there have been many organizational modes of enterprises for networked manufacturing, such as virtual enterprise (VE), extended enterprise, and manufacturing grid. These organizational modes need to be deployed in detail when they are actually implemented. The first paper in this special issue by Chen et al. is entitled “Qualitative search algorithms for partner selection and task allocation in the formulation of virtual enterprise”. The paper presents three qualitative search algorithms for partner selection and task allocation in a VE environment. The authors survey the relevant studies first and formulate the problems including background assumptions, optimization indices, and relational table of manufacturing capabilities and manufacturing requirements. Then a logical model is defined, based on which the authors present three search algorithms for three different optimal goals. A theoretical analysis about the computational complexities of these algorithms is carried out, and finally an example is given to demonstrate the effectiveness and reliability of the algorithms.

The second paper is provided by Jiang et al. and it is entitled “e²-MES: an e-service-driven networked manufacturing platform for extended enterprises”. The paper presents a framework for extended enterprises, attempting to establish the theoretical foundation for implementing networked manufacturing. Furthermore, the authors develop an e-Service-driven networked manufacturing platform termed e²-MES (Manufacturing Executive System for Extended Enterprises), which indicates that their idea is feasible and practical.

The next paper by Kang et al. entitled “A fixture design system for networked manufacturing” introduces a Networked Manufacturing-oriented Fixture Design System (NMFDS) of the Guanzhong networked manufacturing system project in South China. The authors propose the hybrid Case & Knowledge-Based Reasoning Model of fixture design and develop an accordant system. The system is an important part of “Networked Manufacturing System Developing and Applying in Advanced Technology Industry Area of GuanZhong,” an Advanced Technology Development Project of China (863 Program), and it has achieved a good effect.

Zhao and Fan present a paper entitled “Implementation approach of ERP with mass customization” proposes an implementation framework that bridges the gap between the traditional ERP system and the emerging requirements of a dynamic and competitive environment of enterprises. The authors introduce the basis of this framework, an enterprise total solution based on enterprise modeling, and suggest an approach of function deployment in the framework. The toolset architecture to support the framework and some developed tools are presented.

Besides the research on architecture of manufacturing systems, researchers also study different phases and facets of the operation process: for example, resource management and production management. The fifth paper entitled “An implementation of modeling resource in a manufacturing grid for resource sharing” summarizes the development of a manufacturing grid in Chinese research and analyses the problem of resource sharing in detail. The authors design and develop a manufacturing Resource Hierarchy Model (MRHM) for managing manufacturing resources based on XML and Web Service technologies. In the MG system, functions such as registering, deploying, querying a grid service, and managing the lifetime of a grid service are implemented.

The sixth paper entitled “Applying mass customization to the production of industrial steam turbines” focuses on implementing mass customization of steam turbines. The authors investigate the principles and methods of mass customization based on existing literatures and materials, analyse the core strategy-internal and -external variety of mass customization, and explore the causes of internal variety and the key to decrease internal variety. Furthermore, the organization structure, business process, product family structure, and manufacturing units are also analysed in order to build efficient strategies to lower the cost of customized steam turbines and shorten the lead-time. Through theoretical study and practical application, several fundamental principles and methods for mass customization are summarized.

Implementing a manufacturing system is the premise of the efficient operation of the manufacturing industry; however, finishing the implementation just means having the skeleton. To increase the intelligence and improve the performance of the manufacturing system, the “brain” is also needed. This means that evaluation and optimization algorithms should be developed for system management.
The next paper entitled “An extended GRAI model for enterprise process diagnosis” presents a systematic extended GRAI model for enterprise process diagnosis. The diagnosis model is composed of extended GRAI Grid view, extended GRAI Net view, and workflow model view, which enhance the description ability and constraint ability of the model. The enterprise diagnosis model has been proved feasible by applying it to a tool running in an alcohol manufacturing enterprise.

Paper eight in the issue is entitled “A framework of order evaluation and negotiation for SMMEs in networked manufacturing environments” presents a framework of order evaluation and negotiation of collaboration manufacturing for Chinese small- and medium-sized manufacturing enterprises (SMMEs) in networked manufacturing environments. The authors suggest the approach to apply the evaluation methods based on the profit and due date to evaluate the orders and present an order negotiation model framework combined with an order evaluation model.

The paper by Song et al. is entitled “The networked manufacture application service platform for the equipment manufacturing industry base in north-east China”. The paper proposes the modes, architecture, and platform to support the networked manufacturing of large-scale equipment manufacturing enterprises and regional special industry enterprises under the background of the north-east industry base.

Paper ten is contributed by Shen et al. and the paper is entitled “Resolving heterogeneity of Web-service composition in network manufacturing based on ontology”. It deals with the issue of heterogeneity in complicated Web-services composition, which is a key problem in e-Manufacturing fundamental technologies. The paper gives an ontology-based approach for resolving the conflicts in a composite service.

The eleventh paper by Yu et al. is entitled “Development and application of Internet-based remote monitoring and diagnostic platform for key equipment”. It discusses the remote diagnosis of equipment. It intends to integrate various data acquisition, storage, and analysis methods with standard software development to meet different maintenance requirements for large-scale equipment.

The twelfth paper entitled “A cooperative process-management system based on the manufacturing grid” is contributed by Ye et al. The paper deals with the problem of collaborative process management. It develops a Grid-based cooperative process management system (GCPMS) to cope with the complexity of worldwide production across the product life cycle.

In the paper by Zhang et al. entitled “Realization of a development platform for Web-based product customization systems” a development platform is proposed for networked product sale and customization systems for enterprises, especially for those medium and small enterprises.

The paper by Tian et al. is entitled “CoDesign Space: a collaborative design support system in network environment”. The paper proposes a multi-mode collaborative design method in order to satisfy the various application requirements in a network environment and discusses the implement method of product data sharing and integration based on XML and VRML technology. A general type net-based collaborative product design support system, CoDesign Space, is designed.

The fifteenth paper in the special issue is entitled “Extended QFD and data-mining-based methods for supplier selection in mass customization”. It presents a method for supplier selection based on extended Quality-Function-Deployment (QFD) and data-mining (DM) techniques. Association rule mining algorithms for supply selection are presented. Customer requirement analysis is also studied, and transcendental and empirical customer requirement analysis methods are presented.

In the final paper entitled “A generic and extensible information infrastructure framework for mass-customizing platform products” an information infrastructure is presented for customizing platform products on a mass scale, based on Mass-Customizing concepts and the latest Information Technology constructs. The resulting framework provides a technology forum for the Mass Customization (MC) and Platform Product Development (PPD) communities to deploy their most advanced tools and techniques as online services.

5. Future research directions

The development of networked manufacturing differs from that of MC. Future research on networked manufacturing should focus on the manufacturing network protocols that can enhance the integration of various manufacturing resources, and future research on MC should focus on the formulation of methodologies that enable rapid reconfiguration of existing organizational structures and processes into a mass-customized production system; however, there are some common research issues that both networked manufacturing and MC should address:

1. **Normalization.** The resource space should be normalized so that people or services can efficiently and correctly operate them. Networked manufacturing aims at easily sharing different kinds of resources. If the resources are described in various formats or models, a great amount of work will need to be done to convert information from one format to another. As for MC, we have emphasized the similarity principle which prefers a normalized presentation system.

2. **Coordination.** Coordination between multiple manufacturing units is important in implementing an advanced manufacturing system. High performance
of coordination among the versatile resources can raise the effectiveness of the enterprises production.

3. **Intelligent knowledge/information management.** In the next generation of the manufacturing industry, the sharing, visualization, and use of knowledge and information will be the most important development direction. Enterprises will greatly benefit from an intelligent knowledge/information management system. The efficient use of knowledge or information can help an enterprise not only strengthen its kernel competence but also exploit new capabilities.

### 6. Concluding remarks

Networked manufacturing and mass customization have become important manufacturing paradigms. Agility and quick responsiveness to changes have become mandatory to most enterprises in view of current levels of market globalization, rapid technological innovations, and intense competition; however, they should not be viewed as monolithic solutions. Manufacturing processes are too complex and context-sensitive to generate flexible, agile, and focused systems. To implement networked manufacturing or MC systems, it is necessary to integrate different manufacturing technologies into a structured framework capable of combining human and technological factors.

Although this special issue exhibits various research situations, some important problems at the forefront may be left out. In fact, there are many more advanced theoretical studies and working applications in China that have not been included in this issue due to the variety of research. Therefore, this issue only provides readers with partial information on networked manufacturing and MC development in China, though from this issue it is not difficult to see that in China the two paradigms are evolving and growing steadily as China emerges as an economic powerhouse of the 21st century. Meanwhile, we also realize that the relative research in China has a long way to go.

### Acknowledgements

This work was supported by the National Hi-Tech. Program Project of China under grant no. 2005AA411910. The Guest Editors would like to thank Dr. Liqing Zhang and Dr. Chen Huang for their help in preparing this editorial paper. The Guest Editors are particularly grateful to authors for their patience in revising and improving their papers and to the IJCIM editorial office for the continuous support.

### References


