

Review

Flexibility of service-oriented manufacturing: A literature review

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Flexibility is an effective means which help service-oriented manufacturing (SOM) hedge against uncertainty in a swiftly changing business environment. However, flexibility remains largely abstract in the SOM field, because flexibility often has different meaning to different people. Whereas very little systematic research has been directed towards the study of flexibility issues associated with SOM, a rich and burgeoning literature on manufacturing flexibility has accumulated over the past years. In this paper, we review the existing classical literatures on manufacturing, service and supply chain flexibility, which provide a background for SOM flexibility, and extract from them guiding principles for creating, measuring, and managing SOM flexibility. The article concludes with suggestions for some possible future research directions.

Key words: Service-oriented manufacturing (SOM), manufacturing flexibility, flexibility measurement, literature review.

INTRODUCTION

Service seems increasingly becoming a dominant mode of production and consumption nowadays. Service component in GNP of most OECD countries expanded rapidly in the past decades of the 20th century (Gao et al., 2011). A large number of research applications in developed countries show that service-oriented manufacturing (SOM) industry contributes to the growth of the entire service industry and economic growth. Recent innovation surveys indicate that the share of innovative firms in some service industries, especially financial intermediation and business services, exceeds that of traditional manufacturing (Science OECD, 2006).

The manufacturing services in most developing countries, such as China, India and Africa countries, are still underdeveloped. The slow development of producer services plus other factors, including rising energy and raw material prices, labor costs, intellectual property disputes and the financial crisis, have had an enormous effect on their export of manufacturing products. The Chinese manufacturing is facing a sudden increase in

external pressure. It is especially meaningful to answer such questions as how to upgrade the traditional manufacturing and how to expand from manufacturing to service sectors (Chen, 2011). Transforming to intensive, high value-added SOM industries and carrying out economic restructuring is necessary to solve the mentioned problem.

Due to the economical context involving more and more customization, enterprises have to adapt their organizational strategy: while focusing on their core business, outsourcing or collaborative strategies must be set to fit the customer needs (Gao et al., 2009). Many researchers have pointed out that manufacturing and services have become blurred boundaries (Demirkan et al., 2008; Cherbakov et al., 2005). Manufacturing appeared obviously service trend, to strengthen the competitiveness of enterprises and service as an important source of value has already become an important trend of manufacturing. Research into the SOM is necessary to address the problems in the transformation of the manufacturing industry to improve the core of service-based competition.

Indeed, a massive hidden service sectors exist in the traditional manufacturing industries, much proportion of

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whose expenses and revenues represents pre- and after-purchase services in the form of product design, system planning, installation support, repair, maintenance, delivery, collection, logistics, consultation, and so on. Some specialists considered that when service competition is the key to success, the product has to be defined as a service and every business is a service business (Gronroos, 1999). The main objectives of this article are:

- i) Highlight the main contributions of flexibility in SOM;
- ii) Draw up some guidelines to measure and improve flexibility in SOM;
- iii) Suggestions for future research in SOM flexibility.

Further discussion summarizes key concepts and perspectives on SOM and the difference between SOM and traditional manufacturing; SOM special requirement for flexibility is analyzed. Then, a literature review is offered, which focuses on flexibility measurement in manufacturing, service and supply chain. Finally, the article concludes with a summary and suggestions for further research on SOM flexibility.

SERVICE-ORIENTED MANUFACTURING

The integration of service and manufacturing has changed the product pattern and manufacturing paradigm. These changes can be summarized as: i) physical product is integrated with services to form product service system (PSS). To satisfy customers' demands, manufacturers no longer sell products via one-off transaction. They tend to provide comprehensive solutions and gain revenue from service transactions all along the PSS's life cycle. And so, more services are consumed during the consumption of a product; ii) in order to offer better PSS's with lower cost, many manufacturers involved in production of a PSS deepen their labor division. They cooperate intensively and provide manufacturer services for one another to improve the production and innovation efficiencies. That is, more manufacturer services are used in producing of a product; iii) the exchange between service offer and receiver is getting more frequent and complicated. For this reason, collaboration and cooperation among partners are critical to success (Janssen, 2008); (iv) in this new product pattern and manufacturing paradigm, enterprises can break away from the homogenization competition, to form the product differentiation and avoid non-price competition. Here, the new product pattern and manufacturing paradigm is called SOM, which combines manufacturing with both manufacturer and consumer services. In short, it is based on service and oriented to service.

The conception of SOM roots in applications of service oriented architecture, service oriented infrastructure, business process and other areas of applied and theoretical research (Fu et al., 2009). Comparing with service

oriented architecture or infrastructure, SOM extends beyond the technical scopes, considers services at business level apart from IT level, and focuses on the new characteristics of strategy, operation and management. SOM offers kinds of benefits, such as improving efficiency, reducing cost and risk, creating flexibility and enabling reuse.

These autonomic systems should be flexible in order to manage themselves, and they should be self-configuring, self-optimizing, self-protecting and self-healing (Wang and Fan, 2011). In this paper, SOM broadly refers to organizations that operate by providing services, which constructs business units into business components by offering various services, cooperates by means of service provision and consumption throughout the value chain, manages quality of services by promissory service level agreements, and responds to demand changes rapidly and flexibly, to obtain maximal profits for the enterprise and the value chain. SOM is a holistic operation model of enterprise, rather than a single kind of architecture supporting it. SOM aims at providing available solutions, to more precisely satisfy customers' requirements, rather than providing products with certain function alone. This makes an essential difference between SOM and traditional business model.

As shown in Figure 1, with the increase of interaction intensity and the number of interaction variables among service based production, production based service and customers, the relationship between scheduling and organizational performance in SOM is non-linear, non-deterministic and shift with time. Meanwhile, original equipment manufacturers, contract manufacturers, service-based company and production-based company break the boundaries of the existing enterprises and generate a network dynamically and spontaneously, and all these units provide services for others.

In an open network environment, SOM is a complex adaptive system in the social and ecological conditions of the market (Timothy, 1994). Its ultimate goal is to achieve economic, social and ecological effects to be a unity. The SOM networks are not born with the ability to generate synergies. Manufacturing companies provide each other services, and thus form a multiple links among each enterprise nodes, which are highly dynamic and vulnerable. In summary, content, character, internal and external environment uncertainty of SOM, causes the measurement and improvement of flexibility in SOM to become a critical scientific issue.

CONCEPTS AND PERSPECTIVES OF FLEXIBILITY

For businesses of all sizes and in almost every industry, service orientation has become a key interface among organizations, their suppliers and customers (Shi and Daniels, 2003). Many factors, for example, functionality, integration, and scalability contribute to success service.

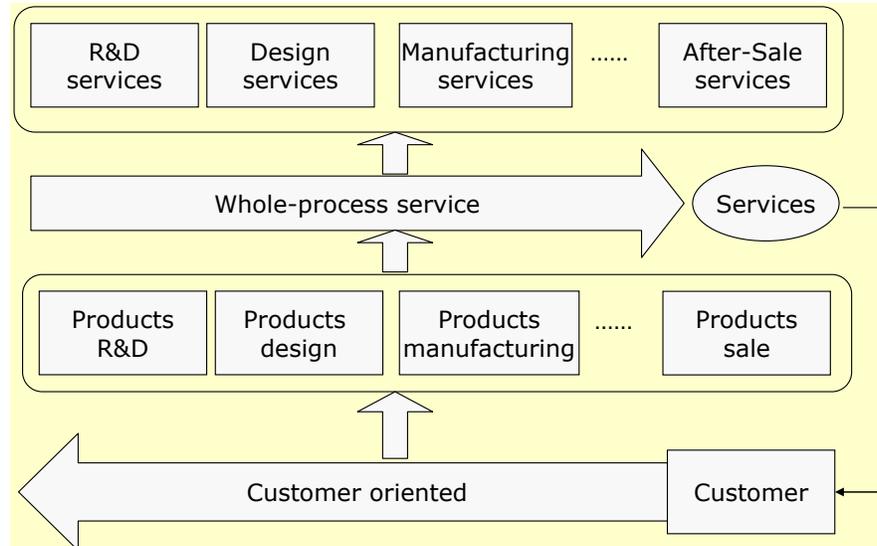


Figure 1. The SOM model (Gao et al., 2009).

One of the most important success factors is flexibility, that is, the ability to hedge against the uncertainty that is an inevitable consequence of the complexities generated by dynamical uncertainty. Flexibility is particularly important in an increasingly volatile business environment characterized by intense, global competition, short product life cycles, increased technological innovation, and time-sensitive customer demand.

Flexibility is a word that is broadly used, but its concept remains vague (Shi and Daniels, 2003). Moreover, alternative definitions of flexibility are imprecise and often inconsistent. There are three reasons why flexibility is so poorly understood. The first is the overlap in scope of terms used by different authors to define flexibility. Secondly, some terms used to define flexibility aggregate others. And the last, even when different researchers use the same term to define flexibility; they may attach entirely different meanings to the term (Swamidass, 1988). For these reasons, a universally consistent concept of flexibility has yet to be developed. In this section, we discuss several views on flexibility from the literature, with the objective of developing a well-rounded perspective on flexibility for SOM decision makers.

Manufacturing capability can be classified as dedicated capacity and flexibility. Dedicated capacity is fit for mass production for only one or several products in lower unit costs. Flexibility is most suited for small batch production of different products in customization. By more easily accommodating design changes, demand uncertainties, and shifts in the product mix, flexibility provides enterprise with the ability to rapidly develop new products, reducing the need for inter-period inventories and expanding product scope to assist competing in new markets (Fine and Freund, 1990). Flexibility reflects a system's ability to deal with changing circumstances or business environmental instability. It has the following

three dimensions, first, the range of possible configurations a system can adopt, second, the cost of migrating from one configuration to another, and the third, the time needed to make the transition (Slack, 1984).

The concepts of flexibility described earlier help to characterize what SOM flexibility might mean for an organization. The focus of competition in global marketplaces is increasingly shifting from cost, quality, service, delivery and innovation. Understanding of the meaning, sources, and uses of flexibility is critically important. Despite this, very little systematic research has been directed towards the study of flexibility issues associated with SOM. In this context, SOM flexibility determines an organization's ability to adapt to changes and uncertainties in its internal and external business environment. In addition to general business flexibility, SOM flexibility reflects an organization's ability to react to those environmental variables that are particularly associated with services cling to product and new ways of doing business which are enabled by IT. The ability to respond quickly and dynamically to an ever-changing environment represents additional facets of SOM flexibility. The following is the main characteristics of SOM and its requirements for flexibility, first, from the perspective of the market, the demand is moving from simple product manufacturing to a "product + service" offering comprehensive solutions, which made the tangible products added more services. Therefore, the intangibility of services, no storage and other features lead to its flexibility requirements. Secondly, from the perspective of the value chain, high value is transforming from the manufacturing sector to offering products with rich content and services rely on product until the overall solution for the customers. The customer transaction relationship shifts from a simple buyer-seller to provide customers with strong life-long exclusive services.

Therefore, SOM value added process is longer than the traditional product life cycle. Thirdly, from the perspective of operation mode, enterprise can better perceive or discover potential requirement with customer full participation and provide products or services initiatively to realize the purpose service and manufacturing work together. Therefore, multiple rounds of interaction or communication exist among customer, service offering and manufactures in SOM. Finally, from the organizational mode, though the coverage of SOM is beyond the traditional manufacturing and services, it dose not go for vertical integration. What it concerned is about the different types of subjects (customers, service offer, and manufacturing) to participate in service-oriented network collaboration initiatively by value perceiving. In a dynamic collaboration among the spontaneous formation, optimally assign resources to emerge a stable structure of SOM system. Therefore, SOM needs to have a certain dynamic adaptability and self-adjustment mechanism.

With the help of internet, a proliferating myriad of devices becomes part of the SOM infrastructure, allowing manufacturers to contact with employees, customers, and suppliers. Manufacturers today must manage products, IT systems, business processes, and extended services that function well beyond conventional corporate boundaries. The associated connections, dependencies, and interacting SOM systems require flexibility so that systems can adapt themselves to changing technologies and business circumstances.

In short, service based production in SOM make the pre-service function into the manufacturing process, and production based service in SOM penetrates the service into personalized process, which takes the manufactured products as a carrier. Both service based production and production based service complement each other in SOM. One important feature of SOM is customer's initiative participation the whole process of manufacturing or service, and the blend of knowledge among employees, manufacturer and final customer.

FLEXIBILITY MEASUREMENT REVIEW

Flexibility measurement in manufacturing

The literature on manufacturing flexibility is extensive. Of this literature, we review the portion that provides insight into how SOM flexibility should be developed and managed.

Gerwin (1993) proposed three main difficulties in flexibility measurement as the following: lack of a unified understanding about flexibility types, without a comprehensive, multi-dimensional quantitative index, and flexibility has different levels which are both cross and different. Ronald et al. (2003) considered that flexibility measure should start from the essential nature of the system, rather than operational performance. Flexibility can be measured from outside environment change to

depict the inherent flexibility, and use the time frame to describe the operational flexibility (Huang et al., 1999). Flexibility of one system can be expressed as a function of hardware elements, software elements and external environmental change (Wang et al., 2003). An integrated optimization model was established, which take economic indicators as a standard to measure the overall level of flexibility. And several types of factors have been discussed on the influence to overall flexibility to determine the impact of one type flexibility on the whole system (Gong and Shi 2003). Fuzzy theory was used to quantify the flexibility in one advanced manufacturing system (Ahmet, 2004).

Existing methods of manufacturing flexibility measurement reflects the following two views: the first view is that flexibility is an inherent property of a system and it can be measured by functions reflected system character; the second view is that flexibility is a relative property about external demand, and it can be measured by discounted cash flow, etc. (Chryssolouris, 2006). Then, flexibility measurement methods can be divided into two categories according to above mentioned views. The first category is to measure the inherent flexibility of one manufacturing system based on its multi-attributes. Typical representatives of such multi-attributes includes multi-index and transfer index, etc. Multi-index is defined as one of machine flexibility attributes, which takes output types of one machine group for consideration (Chang, 2008). Alexopoulos et al. (2007) proposed a measure method based on discounted cash flow, which use the sensitivity to external changes to reflect the flexibility. This measure method can show one system's performance to environmental changes, but it ignores inherent properties of the system, which make it hard to find some general rules for flexibility improvement. The second method takes the combination of inherent properties and external demand character for consideration to measure system flexibility, such as mechanical systems analogy and PF matrix method (Vokurka and O'Leary-Kelly 2000). Mechanical system analogy takes system response to demand as one mechanical system response to pressure, and the flexibility of system is defined as the ability to respond to dynamic needs (Georgoulas, 2007; Alexopoulos, 2008). This kind of method takes system as mechanical system, and offers a potential for general rules of flexibility improvement.

John (1998) concerns developing a framework and classification scheme for use in defining and classifying the various terms regarding flexibility found in manufacturing. The framework consists of six attributes: level of manufacturing requirements specification, manufacturing system specification, manufacturing environment specification, flexibility dimension, flexibility measurement approach, and time frame. A six-field hybrid classification scheme is developed based on this framework. The framework serves as a guide for developing new flexibility terms, whereas the classification scheme provides a

mechanism for summarizing the important aspects of and assumptions behind a given term.

Flexibility measurement in service

Since the 1990s, as business environment changes rapidly and competition becomes more intense, flexible service began to attract much attention. Harvey et al. (1997) studied flexible issues in banking services and pointed out traditional business pattern is facing an intense competition. The competition is mainly from such two aspects as changing of customer requirement and service instability. On the one hand, service is a high-stress business, and this pressure comes from customer requirement changing. On the other hand, service business has to face the increasing instability of service. Fitzsimmons (2001) has emphasized the importance of service flexibility from service organization adaptability view. And he insisted successful service organization need to dynamically adapt to changes in demand characteristics or quantity, and service organizations to adapt to what extent depends on how much flexibility elements blended into its operations. Chen (2006) studied service flexibility based on the theory of competitive advantage in customer value and he built a conceptual model of service. Jin et al. (2009) thought enterprises should concern about the product after-sales service when selling products. In order to identify the individual needs of different customers, a framework includes fuzzy clustering and association rules are offered in his paper. Yang et al. (2011) apply importance-performance analysis (IPA) approach to empirically study the service quality of mobile application stores based on the customers' perspective.

The reason why traditional service business model is facing challenges because its operation is different from tangible products properties, such as service intangibility, simultaneous production and consumption, customer involvement in the production process and so on. All these unique properties of service operations result: on the one hand, environment of service business is more dynamic, competitive and heterogeneity than tangible product. On the other hand, service transferring speed and reliability will influence its performance consistency, response speed and customer satisfactory. Therefore, service flexibility should pay more attention to the competitive environment instability for its operation in addition to build a service flexibility strategy.

Flexibility measurement in supply chain

Research on supply chain flexibility can be described in full swing in recent years. Despite the importance of flexibility has been widely recognized, the combination of theory and practice, manufacturing flexibility enhancement and service value have not been fundamentally

advanced. Klibi et al. (2010) analyzed uncertainty in supply chain and the source of risk exposure, reviewed some critical random environment factors and its essence to supply chain network. All these contribution have been the foundation for methodological framework to supply chain network. Yan et al. (2010) discussed the relation between service-oriented architecture and service-oriented logic, and proposed a service-oriented collaborative ontology to organize concepts and knowledge between them. Zhu et al. (2010) offered a two-stage supply chain model facing for uncertain demand in agile manufacturing environment. Das (2010) constructed model includes design flexibility, product assembling flexibility, delivery flexibility and supply flexibility. Tan et al. (2010) verified how to match product, service and business strategy with specific business evidence. Pan and Nagi (2010) studied supply chain design issues facing for uncertain demand in agile manufacturing environment. And he set up a robust optimization model includes such following three variables as expect cost, cost shift and expect punishment. Patel (2010) suggested that an enterprise should have a duality structure of rigidity and flexibility to adapt to the dynamic environment of uncertainty, while maintaining high productivity.

The flexibility study in the fields of manufacturing, services, and supply chain provide a reference for SOM flexibility. However, the integration of services and manufacturing has brought some new issues that can not be solved in perspective of manufacturing or services respectively. At the same time, SOM and supply chain have much difference in their operation (Table 1). Therefore, the existing flexibility method can not be used in SOM without improvement. New flexibility measurement method and enhancement approach should be studied with consideration of SOM content and its special requirement.

CONCLUSIONS

Principles extracted from the significant literature on the design and management of manufacturing flexibility, service flexibility and supply chain flexibility is summarized. Our goal is to stimulate theoretical and applied research on SOM flexibility. Comprehensive coverage of the various perspectives on flexibility should help SOM enterprises more intelligently evaluate and invest in the flexibility of their business operations. Solution providers in SOM increasingly promote flexibility as a major value proposition to their customers. For manufacturers to invest significantly to achieve high levels of flexibility, the relationship between flexibility and business performance must be clearly understood. Acquiring adequate flexibility doesn't ensure an organization a competitive edge; SOM flexibility is a function both of technology and of how effectively an SOM system is managed. Although flexibility should be appropriately designed into processes, flexibility must also be well managed, in order to fully

Table 1. Difference between SOM and supply chain.

	Supply chain	SOM
Focus	Product	Service
Profit mode	Take product as the main means of profit	Take the value-added service cling to the product as the main means of profit
Transferring	Raw materials and intermediate products	Service schemes cling to raw materials, intermediate products
Organization form	Static hierarchy around a few core businesses	Uncertain dynamic topology changing hierarchy
Value assignment	Static assignment along the value chain	Snatch value initiatively to the downstream nodes
Flow content	Materials, cash and information	Materials, cash, information, value and service

realize the associated performance benefits.

In summary, SOM has been concerned by many scholars in recent years. But, no widely accepted and referenced SOM flexibility definition has been found up to the present. Furthermore, content of SOM flexibility, impact factors and its mechanism, flexibility measurement and enhancement approach are even fewer. SOM is the future trend of manufacturing industry, and its content and characteristics determines its special requirements of flexibility. The following issues need further study:

i) Most of the literature considers that SOM should have some flexibility. But, the discussion started only in the qualitative level, and lack of quantitative analysis or theoretical calculation support. Similarly, little research focus on influence factors of SOM flexibility and its logical relationship of each factor, which is the basic foundation of understanding and resolving the problem of SOM flexibility.

ii) In order to consider flexibility properly during decision-making process, the measurement of flexibility need to be quantified in the form of its definition. Given the special requirement of SOM flexibility, measure indicators and methods requires in-depth study.

iii) The purpose of flexibility measurement is to balance matching relationship between flexibility and environmental change in order to effectively improve SOM to adapt to the dynamic and uncertain environment. Therefore, the improve path of SOM flexibility needs to be studied.

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