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ABSTRACT

Research in supply chain management and strategic management suggests that inter-organizational knowledge sharing is a crucial enabler of any supply chain or network. One of the keys to understanding build-to-order supply network complexity is to recognize and assess the conflicts in such a network that results from mixing lean and agile manufacturing objectives in the *same* network. The theoretical results formalize the supporting roles of two dominant forms of knowledge content shared in a BOSN so that the network can achieve its objectives. The theoretical propositions suggest that different Knowledge Communication Systems are suitable for different build-to-order supply network objectives. Based on these theoretical results, we identify and conceptualize a conflict that can be present in a BOSN, and offer approaches to alleviate them.

Keywords

Supply chain management, Inter-organizational knowledge sharing, Build-to-order.

INTRODUCTION

Intense market pressure to cut costs and produce high quality products has caused many organizations to adopt lean manufacturing in their supply chain. However, as markets become more volatile and unpredictable, efficiency gains from lean manufacturing alone are not enough to compete in such markets (Fisher, 1997). Companies need also flexibility and responsiveness to cope with these market changes, and a Build-to-Order Supply Network (BOSN) is one way of achieving them.

A BOSN refers to a configuration of firms that maximizes flexibility and responsiveness to changing market/customer requirements in a cost effective manner (Gunasekaran, 2002). The cost-efficiency and responsiveness have long been seen as divergent concepts; i.e., a supply network can excel in cost-efficiency, but then lacks responsiveness, or vice versa. BOSN exploits characteristics of both lean and agile manufacturing (Gunasekaran, 2002) and is thus attracting attentions from academics and industries.

Due to its attractive dual objectives, many companies have tried to adapt to BOSN. However, without a full understanding of BOSN, companies may fail to achieve their objectives. Computer manufacturers encountered difficulties in imitating Dell's BOSN (Holweg and Pil, 2001). One of the keys to understanding BOSN is recognizing and assessing the conflict in the network that results from mixing lean and agile manufacturing objective in the same network.

Although interest has been growing in the management of BOSN, the supply chain research into BOSN is still in its infancy. Much remains to be learned about its behaviors, characteristics (e.g., knowledge sharing), as well as its inherent conflicts and why they happen. It has been pointed out, however, that inter-organizational knowledge sharing (IKS) is one of the crucial enablers of any supply chain (Choi, Dooley and Rungtusanatham, 2001) including BOSN. In this paper, we examine these conflicts along two dimensions: different forms of IKS and the dual objectives of BOSN. We analyze what supporting roles two different forms of knowledge content can play in a BOSN so that the network can achieve its objectives. Based on these analyses, we identify and conceptualize the conflict in a BOSN. By conducting a thorough analysis of the conflict, we offer approaches to reduce or alleviate it.

REQUIREMENTS OF BUILD-TO-ORDER SUPPLY CHAIN: LEANNESS AND AGILITY

Leanness

An agility whose characteristics are flexibility and responsiveness should base on the leanness, as van Hoek (2001) argues "… the agile mindset is at variance with the lean production model …" Lean production technique originated in Japan and became popular as an enhancement of mass production (Katayama and Bennett, 1999). Flexibility and speed serve as advantageous capabilities, which enable companies to compete well in the volatile market. However, before acquiring such characteristics, supply chain needs solid foundations, which are low system-wide cost, high quality, reliable and durable products, and dependable delivery. These foundations are a must to just enter the market and to start the competition, not necessarily to succeed. Such foundations can be achieved by lean production whose main goal is eliminating waste in a supply chain. Flexibility without leanness may lead many processes of supply chain to chaos. As a result, BOSN has characteristics of lean production with fewer constraints and more capacity.

Agility

The market condition of BOSN is unstable customer demand. When the demand uncertainty is high, either responsive supply chain or agile supply chain is needed, depending on the uncertainties in supply process; if supply is stable (unstable), responsive (agile) supply chain is more suitable (Lee, 2002). While both agile and responsive supply chains share the characteristics of responsiveness and flexibility to handle high demand uncertainties, responsive supply chain, unlike agile supply chain, does not have to have high inventories to deal with supply uncertainties due to its stable supply process. The environment of BOSN has stable supply process; consequently, the need of pooling inventory for hedging the risk is greatly reduced. Thus, BOSN can be interpreted as an agile supply chain without inventory piling. As the main goals of lean production are just-in-time delivery and low inventories (Levy, 1997), BOSN can lower its inventory level by employing leanness. However, Christopher (2000) argues that leanness alone cannot handle the volatile customer needs quickly, which is required in the environments of BOSN; thus, agility is also needed. In other words, BOSN has characteristics of both lean production and agile supply chain. However, the environments of these two strategies are greatly different. Christopher (2000) argues that the environments of lean supply chain and agile supply chain are different as follows:

> "Agility" is needed in less predictable environments where demand is volatile and the requirement for variety is high. "Lean" works best in high volume, low variety and predictable environments."

In a true BOSN, every part will be built and final products will be assembled only after the orders are received. However, such supply network may be very unrealistic at least in a current market, because the lead-time to make the products from the scratch will become unacceptably long for some customers. Thus, a BOSN has inventories of components in some points in its network, and the final products will be assembled using these inventories. Since the characteristics of components are low variety, relatively accurate predictability and volume production, lean production can be applied to making components. On the other hand, finished goods have very different characteristics compared to the components such as unstable demands and high product variety. As a result, agile supply chain is more suitable for assembling the part to make finished goods. To analyze the impact of knowledge transfer in the BOSN, analyzing lean and agile supply chain can be one of better ways.

TWO FORMS OF INTER-ORGANIZATIONAL KNOWLEDGE SHARING CONTENT AND BOSN OBJECTIVES

A major source of the challenges in building and managing BOSN lies in the duality of its objectives. That is, BOSN has to achieve agility and leanness simultaneously. Such divergent objectives can be better supported by different levels of knowledge contents, namely, data, information, and knowledge form, which are shared inter-organizationally within a BOSN. In this paper, we use the term knowledge as a superset of data and information, and then recognize two conceptually separable forms of knowledge: (1) data and (2) information/knowledge. In the following, we first investigate the characteristics of these two forms of knowledge sharing, followed by characteristics of agile and lean manufacturing objectives. We then develop propositions that characterize the types of support and the relevance that forms of knowledge contents can have in managing each of the dual objectives of BOSN (Figure 1).

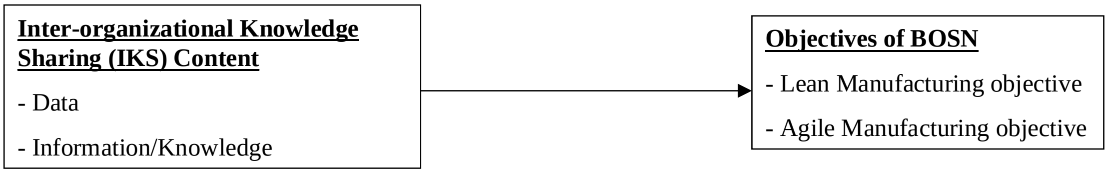

Figure 1. IKS content and dual objectives of BOSN

Data Form of IKS

Data are defined as objective observed facts about events in organizations or the physical environment of the organization arranged in a form that people can understand and use (Laudon and Laudon, 2002). For example, production schedule, point of sale (POS) data and inventory level can be classified as data. Data sharing is arguably the simplest yet the most common type of informational exchanges in a supply network, because it is one of the enablers of material flow in the supply network. Inventories in a supply network may not move without data (at least order data) sharing. Electronic data interchange (EDI) is a commonly referenced form of data sharing, which can be defined as computer-to-computer transmission of standardized business transaction (Hill and Scudder, 2002). The most important aspect of EDI may be that it can shorten the time and lower the costs of inter-organizational business transactions, and it, in turn, brings suppliers, producers and customer closer together (Takac, 1992), which helps companies to achieve efficiency in their supply network.

Information and Knowledge Form of IKS

Information can be viewed as data that have been transformed, by adding relevance and purpose, into a shape that is meaningful and useful to human beings (Davenport and Prusak, 1998; Laudon and Laudon, 2002). An example of information could be customer behavior when a production schedule is delayed by several weeks; customers may leave or wait. Knowledge can extend the information further. It's a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information (Davenport and Prusak, 1998). To illustrate, consider the knowledge required to respond to customer behaviors in the example above and to understand what the consequences of such decisions might be.

Sharing information and knowledge will help to cope with many external uncertainties[1] by broadening the understanding of external phenomenon, such as unstable customer demand. This understanding leads to the creation of innovative capabilities, such as product and process development. For example, fast product development has become a competitive advantage in a market where the product life cycle is short. Griffin (2002) and Ittner and Larcker (1997) argue that knowledge sharing can help to build these innovative capabilities. New product development typically requires customer and supplier involvement to ensure that the resulting products satisfy customer needs (Stalk and Webber, 1993). Ittner and Larcker (1997) point out that product development cycle time can be reduced considerably by sharing the knowledge of the various components needed in the development steps with suppliers. These involvements facilitate information and knowledge sharing and, in turn, improve the customer understanding and the ability to cope with uncertainties.

Lean manufacturing objective and requisite knowledge content

A typical market environment of lean manufacturing can be characterized by predictable demand, which means low external uncertainties and low need of agility (Christopher, 2000; Sharp, Irani and Desai, 1999). The main goal of lean manufacturing, thus, is efficiency; i.e., doing more with less. To achieve this goal, the production schedule of lean manufacturing has to be stabilized.

Due to the need of this stability, lean manufacturing leads to the development of very distinct supplier relationships, whose characteristics are a low number of suppliers, high level of trust, long-term relationships, and co-operation (Sharp et al., 1999). The processes of lean supply network can be summarized as flexible and automated (Sharp et al., 1999). These predictable demands, tight coordination with partners and smooth processes reduce many internal uncertainties, including partner, product and process uncertainty. In such stable environments, many processes become routine and standardized, and therefore less innovation occurs. This, in turn, reduces the need of sharing information/knowledge. However, in order to

[1] By the external uncertainties, we refer uncertainties caused by factors outside of a supply network.

ensure smooth and rapid production, sharing of simple data including customer orders, inventory levels and production schedules is crucial in lean manufacturing.

One of the main goals of lean manufacturing is low inventory, which is accomplished mostly by just-in-time (JIT) manufacturing. JIT manufacturing requires rapid shipment of goods and tight coordination of production schedule data (Levy, 1997). To enable this, continuous data sharing is often required so that every member of the supply network has the same status information about the process. For instance, Lantech of Louisville, KY ensures that the process data (as captured in process diagrams and charts) are transparent and available to each manufacturing cell or entity:

> "By design, either the whole cell was working smoothly at the same pace or everything came to a halt. For that reason, every task needed to be carefully described in a posted diagram so that everyone in the production cell could understand what everyone else was doing." (Womack and Jones, 1996)

> **Proposition 1:** *Lean manufacturing objective of a BOSN will be supported by data form of IKS.*

Agile manufacturing objective and requisite knowledge content

The market environment of a BOSN can be characterized by unpredictable demand with low volume, short life cycle and high product variety, (Lee, 2002; Sharp et al., 1999). The high variety of the products, typical of an agile manufacturing process, can create various undesirable consequences including high complexity. To handle well such ill-effects of high product variety, Child et al. (1991) contend that a thorough understanding of the requirements of all downstream customers is the first step, which can be done through IKS. Next, frequent and fast product development expertise is required to manage the current trend toward a short product life cycle, and Vekstein (1998) argues that innovative activities, such as product development, require sharing of information/knowledge more than sharing of just simple data.

High external uncertainty is another headache that a BOSN has to deal with. In order to cope with many uncertainties in such market, agility becomes a necessity (Sharp et al., 1999). Since customer demand is not controllable, companies must be able to either anticipate early or respond quickly. However, accurate anticipation is much more difficult to achieve than rapid responsiveness. To achieve such responsiveness, processes should be flexible. The employees should be well-trained and multi-skilled in order to handle the dynamic workload imbalance. (Yao and Carlson, 2003).

In order to increase responsiveness, agile manufacturing often employs a decentralized structure and modular designs to decouple individual supplier contributions. In such supply network environment, each supplier may optimize locally and therefore the environment can become "rugged" (Choi et al., 2001). To overcome the many uncertainties imposed by this unpredictable environment, exploitation of existing knowledge and exploration of new knowledge is required (Choi et al., 2001). For instance, consider General Motors' (GM) product innovation activities related to creating GM's OnStar telematics service. The need (as dictated by customer demand) to include new telematics software in the existing physical product console has forced the automaker to change its new product development process (Joglekar and Rosenthal, 2003):

> "… We took this [OnStar] product that literally didn't exist until 10 months before it was being sold through GM dealerships and ran it through the process, and literally went through about 40 revisions of software while we did that. So the company was very interested in being fast, being agile, and doing some things that they hadn't done before."

As Joglekar and Rosenthal (2003) report, in order to achieve this compressed innovation cycle, GM created new product development teams made of suppliers, software vendors, and GM's product engineers and designers. The leaders of such team were given more autonomy to deal with enforcing development in the innovative and knowledge intensive process. Divergent sets of knowledge/information as conveyed through concepts, experience, and influence on the physical product were disseminated through team meetings and development sessions. Due to the newness of the project and processes, prior data (even if available) could not obviate the need for new knowledge. Consequently, the content of knowledge sharing consists of knowledge/information forms including experience – all of which go beyond data in their richness.

Similar exchanges of knowledge and information contents are also present in managing an otherwise established production process that has to achieve an agile objective. For instance, consider the process improvement session that Textron, a top tier supplier of console assemblies to the DaimlerChrysler (DCX) Corporation, experiences in order to achieve new performance targets:

> "When Textron looks for savings from the second-tier suppliers, it is looking to relieve the burden of the cost-reduction targets imposed by DCX. Textron receives an official performance review once every year. However, there are other ways of getting feedback from DCX such as through daily interaction with DCX personnel, weekly meetings to address "major" issues, and the meeting that occurs every 6 months where executives form "leading"

> supplier come together for an open forum. The major second-tier suppliers (e.g., Leon) get a performance report once a month from Textron." (Choi and Hong, 2002)

This yearly performance review is an example of data exchange. However, this exchange is just the beginning of the complete process through which Textron actually achieves the performance improvement. Processes are augmented by exchanging ideas, understandings, complex information with interpretation, and not just data that Textron receives from DCX.

Proposition 2: *Agile manufacturing objective of a BOSN will be supported by information/knowledge form of IKS.*

DISCUSSION AND FURTHER REFINEMENT

Data sharing may be sufficient for achieving lean objectives. Whereas, knowledge and information sharing, which exchange richer contents than data sharing, may be needed for achieving agile objectives. This means an IT infrastructure that is more data-centric such as EDI and ERP may not be sufficient for effectively managing the agile portion of the network. The latter will require rich communication media that can foster knowledge and information exchanges, which can help the situations of problem solving, negotiations, and conflicts.

Most supply networks initially aim to achieve lean manufacturing objectives by streamlining their processes. During this initial process of improvement, they will put in place requisite IT and communication capabilities that are mostly expected to handle data sharing very well. However, in order to become a BOSN, which embeds agility in its downstream sites, a supply network should build a communication capability that can handle rich information/knowledge well. Otherwise, a mismatch or conflict will be created between the communication requirement by agile network and the communication system in place for the lean manufacturing. However, such conflict has been faced for instance by Honda networks when they tried to implement decentralized design process for exploiting innovation within the context of an otherwise centrally controlled lean supply network:

> "Not obvious in the structure of the supply network is Honda's penchant for centralized control when it comes to the design of the product. For instance, even when a supplier sets up a design shop on its own premise, Honda, through its "guest engineer program", retains a lead role throughout the product development stage. CVT is engaged in "white-box sourcing" with Honda. JFC is engaged in more of a "gray-box sourcing" because it holds the patent for the damper. Even then, Honda will get intimately involved in the design of the overall cup holder subassembly." (Choi and Hong, 2002)

Programs such as Honda's guest engineer allow visible presence and face-to-face regular interaction for rich exchanges of knowledge and information. In order to resolve this conflict, the dominant organization will need to put in place knowledge management processes that allow data-centric knowledge communication to support the member organizations who are assigned to carry out lean objectives. On the other hand, the member organizations that are working to achieve agile objectives of the network should be provided with knowledge communication capabilities that allow rich exchange of ideas, concepts, and discussions in geographically and organizationally distributed environments. The concept of communication media richness has been studied in relation to group decision making process (DeSanctics and Gallupe, 1987; George, 1991) and is useful for our purpose here. By extending their works and by the implications of Propositions 1 and 2, we propose that such processes will need to balance BOSN task characteristics with communication media richness, as suggested in the Knowledge Communication System (KCS) and BOSN objectives matrix in Figure 2. Essentially, the left top corner of the diagonal of the matrix identifies a good fit between more structured and stable tasks of lean objective and requisite KCS in the form of computer system with flat data and text. Conversely, on the other extreme of same diagonal a face-to-face KCS is proposed for agile objective tasks where the latter is more unstructured and innovative.

FUTURE RESEARCH

The theoretical development and the propositions presented here enhance understanding of the intricacies of BOSN structures and the network's knowledge sharing levels. We also analyze the requisite form of knowledge sharing, the richness of KCS with different objectives of a BOSN. With the help of these theoretical developments, a systemic inherent conflict of a BOSN are characterized, and ways to reduce them are discussed. The theoretical developments presented here can serve as an initial ground to conduct future research into the complex concept of BOSN and offer several additional research opportunities. First, future research should seek to test the theoretical propositions hypothesized in this paper with a help of case-based and survey-based research design. Second, future research should seek to develop testable hypotheses, which are guided by the conflict identified and analyzed above. Further study is required to identify and design suitable knowledge communication and management technology infrastructure that can fit the communication need of both lean and agile manufacturing.

Media for BOSN Communication System

Increasing potential richness of information →

BOSN objectives (Lean ↕ Agile)

Example Tasks	Computer system: Flat data & Text file	Computer System: Chart and Graph	Audio/Video systems	Face-to-face communications
Exchanging Production Schedule (Lean)	Good fit Proposition 1	Marginal fit Info too rich	Poor fit Info too rich	Poor fit Info too rich
Adjusting shipment quantity: intellective tasks	Marginal fit Medium too constrained	Good fit	Good fit	Poor fit Info too rich
Choosing delivery method: judgment tasks	Poor fit Medium too constrained	Good fit	Good fit	Marginal fit Info too rich
New Product/Process Development: Innovative tasks (Agile)	Poor fit Medium too constrained	Poor fit Medium too constrained	Marginal fit Info too lean	Good fit Proposition 2

Figure 2. Communication media and BOSN objectives

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