AN INFORMATION PROCESSING VIEW OF THE IMPACT OF PRODUCT COMPLEXITY ON SUPPLY CHAIN DELIVERY PERFORMANCE

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ABSTRACT

Information processing view is used to examine the role of inter-organizational systems (IOS) in dealing with the impact of product complexity on supply chain delivery speed and reliability. Two types of IOS appropriations are proposed. Transactional IOS and Relational IOS are proposed to attenuate the negative effects of product complexity on supply chain delivery speed and reliability respectively.

Keywords: Product complexity, Supply chain delivery performance, Information processing view.

INTRODUCTION

Advances in manufacturing technology over the years have meant that organizations have been able to deliver products that are technologically complex and provide improved functionality. Increased product complexity has implications for the entire supply chain. Recent research has examined the downside of increased product complexity on various performance aspects of the supply chain (Ex: Vachon and Klassen 2002, Milgate 2001, Bozarth et al 2009). One of the views among supply chain researchers is that product complexity increases coordination requirements among supply chain actors and thereby adversely affects delivery performance of the supply chain. In this paper, we build on this view and take it further by examining how organizations manage this complexity. To conceptualize how the negative impact of complexity can be mitigated, we apply Galbraith's (1973) information processing theory which proposes that one way to deal with complexity and the resulting uncertainties is by increasing organizational information processing capabilities. In the supply chain context, information processing spans organizational boundaries, hence the role of Inter-organizational systems (IOS) is examined. We propose two appropriations of IOS to manage complexity. Transactional IOS is seen as the use of IOS for automating structured tasks and for exchanging and processing structured information. Relational IOS is seen as the use of IOS for developing relational ties and improving coordination among supply chain partners. These two IOS appropriations are said to reduce the negative effects of product complexity on supply chain delivery performance. Thus, two research questions are addressed in this paper: (1) How does product complexity impact supply chain delivery performance? (2) How does IOS appropriation alter the impact of product complexity on supply chain delivery performance?

In section 2, we present the theory development and follow up with a discussion of the proposed relationships in section 3. In section 4 we present the proposed research design. Contributions and implications are discussed in section 5.

THEORY

Product complexity

Product complexity has generally been conceptualized in terms of number of parts or components, interaction between the components, product novelty, technological intricacy, product decomposability and number of product functions. A product is said to be more complex when it is composed of a large number of parts or components and there is a close interconnection or interaction between the individual components (Novak and Eppinger, 2001; Vachon and Klassen, 2002). Product complexity is also high when the product and its associated architecture and technology are new (Novak and Eppinger, 2001; Singh, 1997). The inability to decompose a product into individual components makes it difficult to predict and manage component interactions (Khurana, 1999; Vachon and Klassen, 2002). Finally, a product designed for a large number of functions is inherently more complex that a product designed for fewer functions (Jacobs and Swink, 2011).

Seen from an information processing view, we can say that these aspects of product complexity drive the need for increased information processing. An increase in any of the above mentioned dimensions of product complexity will increase the information processing need within the supply chain. For instance, a product with a large number of components will mean that the buyer / manufacturer will have to ensure information transfer with a large number of suppliers for sourcing of the components. A large number of components will also increase the information processing requirement at the manufacturing stage. Products with close component interactions will require extensive coordination with external suppliers and various internal functional areas. A change in one part of the system may require a redesign of the entire system (Khurana 1999). Coordination requirements that result will also contribute to the need for increased information processing. Increased technological intricacy of individual components will increase the need to exchange detailed product based information (like technical specification, drawings etc). Product novelty and technological novelty is often associated with coordination problems. This is because of a lack of experience in dealing with various product and technology related issues. For new products and new technologies, the component interactions may not be stable and may not be well-understood (Novak and Eppinger, 2001). This leads to increased information exchanges within the supply chain. Product non-decomposability restricts the ability to divide a product into simpler components (Khurana 1999). The resulting complex product architecture drives the need for increased coordination and information exchange among supply chain partners. To summarize, all the mentioned drivers of product complexity essentially increase the information processing need.

Based on the information processing view, Grover and Saeed (2007) conceptualize product complexity in terms of the amount of information that has to be specified in buyer-supplier dyads for effective order processing. In the context of the supply chain, we take a more holistic view of product complexity and *define product complexity as a function of the amount of information that has to be specified to supply chain partners for effective planning, sourcing, making and*

delivering a given product. It can be seen as an indicator of the amount of information to be processed for effective coordination between supply chain partners.

Supply chain delivery performance

Delivery performance refers to the ability of the supply chain to deliver the product to the customer in a timely manner and as required by the customer. There are two commonly recognized aspects of delivery performance, namely ***delivery speed*** and ***delivery reliability***. Delivery speed refers to the degree of customer responsiveness (Milgate 2001). It is a measure of how quickly a product can be delivered (Karause et al 2001). It includes the order cycle time, from placement of an order by a customer to its shipment. Delivery reliability refers to the ability of the supply chain to follow through on a commitment to a promised delivery date (Krause et al 2001). Supply chain delivery reliability is defined as "the ability of the supply chain to deliver: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer" (SCOR Version 8.0, 2006). Delivery reliability is generally assessed in terms of percentage of late deliveries, percentage of correct or error free deliveries, percentage of on-time deliveries, tardiness and also service level (Koufteros et al 1997; Li et al 2005; Wong and Wong 2007; Cavalieri et al 2007).

Inter Organizational Systems (IOS) Use

Inter-organizational systems are information technology applications that span firm boundaries. IOS can be seen as information systems shared by two or more firms (Cash and Konsynski 1985). In the context of supply chains, IOS are seen as application systems that link supply chain partners and enable business transactions (Premkumar 2000).

IOS applications can be appropriated by users to suit their needs and organizational requirements. Based on previous research that proposes different patterns of IOS use (ex: Subramani 2004; Sanders 2008) and IT appropriation (ex: DeScantis and Poole, 1994), we propose two patterns of IOS usage.

The two patterns of IOS usage are – Transactional IOS and Relational IOS. Transactional IOS refers to the use of IOS for the exchange of structured information and automation of information flows between members of a supply chain. Relational IOS refers to the use of IOS to enable relational ties with the supply chain members, enable collaboration between SC members and for the exchange of unstructured information between supply chain partners. Transactional IOS includes EDI and similar information systems that enable structured information exchange between supply chain partners. Transactional IOS enables automation of tasks such as invoicing, release of purchase order, inventory tracking, inventory management etc. Relational IOS includes systems that are used for Collaborative Planning Forecasting and Replenishment (CPFR), Efficient Customer Response (ECR), Customer Relationship Management (CRM), decision support, knowledge management etc.

PROPOSITION DEVELOPMENT

In this section, we discuss the development of the proposed relationships. Propositions 1 and 2 discuss the relationships between product complexity and supply chain delivery speed and delivery reliability respectively. Propositions 3 and 4 discuss the moderating effect of transactional IOS and relational IOS on the relationships. Figure 1 illustrates the proposed relationships.

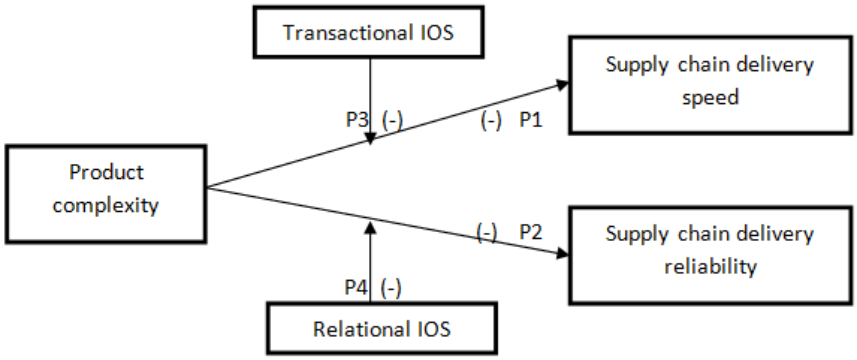

Fig 1: Proposed research model

How product complexity affects supply chain delivery performance

Product complexity calls for exchange of more information (volume), a variety of information and detailed information with a large number of supply chain partners. This requires more time and involves extensive coordination with supply chain partners. The increase in time and coordination requirements is seen at all stages of the supply chain, right from the planning stage to the delivery of the product, and hence affects both intra-organizational and inter-organizational processes. Increased information processing at each stage of the supply chain adversely affects the ability of the supply chain to achieve fast deliveries.

Information processing and coordination are time consuming. This is more so when the product in question is complex in nature. Complex products involve increased information processing from the product conceptualization to the point where it reaches the customer. At the design stage, increased product complexity drives the need for increased information processing between various functional areas of a firm and also with external suppliers. This ultimately affects the time to market of a product. For a complex product, any design changes made during the later stages of its product life cycle will also involve more information processing, thus affecting the time taken to realize those changes. Interactions among components of complex products will also drive the need for coordination and information processing. At the sourcing stage, product complexity increases the coordination requirements for the purchasing department (Vachon and Klassen 2002). A complex component involves more information processing for the purchasing department, thereby increasing order processing time. At the manufacturing stage, increased information processing load is experienced by shop floor managers because of increased effort in scheduling and coordination (Vachon and Klassen 2002). An increase in information processing requirement at every stage of the supply chain ultimately slows down the delivery of the product to the customer. Thus, we propose

P1: Product complexity has a negative effect on supply chain delivery speed.

Research has shown that delivery reliability is largely a function of an organization's ability to plan, predict, control and respond (Swink and Hegarty, 1998). Delivery reliability depends on inventory management, production scheduling performance and quality performance (Hanfield and Pannesi, 1992; Jayaram and Ahire, 1998).

In the case of complex products, greater coordination and information processing requirements contribute to a decrease in delivery performance. Increased information processing and coordination requirements increase planning and forecasting difficulty. It also makes inventory control and production scheduling more challenging. Increased processing and coordination requirements if not managed effectively will hinder process control thereby increasing process errors and quality defects. All these factors lead to lower service levels in the supply chain (Lee and Tang, 1997). Increased information processing requirements create ambiguity and generate uncertainty in the supply chain. High levels of uncertainty will ultimately decrease supply chain delivery reliability (Milgate, 2001). Thus, we propose

P2: Product complexity has a negative effect on supply chain delivery reliability.

How IOS impacts the relationship between product complexity and supply chain delivery performance

According to Galbraith's (1973) information processing theory, uncertainty generated by complexity can be tacked by increasing the capability to process information. The use of information technology to deal with various types of manufacturing complexities has been discussed in literature. For instance, Flynn and Flynn (1999) propose investing in information systems to deal with complex manufacturing environment. In the context of this research, the use of IOS is seen as a way to increase the information processing capability of supply chain partners and hence mitigate the adverse effects of product complexity on supply chain performance.

Transactional IOS - Transactional IOS enable automation of business processes between supply chain members and enable faster and more accurate flow of information. Automation of processes is essential when organizations are dealing with increased volume of information that has to be processed. This enables information processing with minimal human intervention. Improved speed and efficiency of information processing achieved by transactional IOS use helps minimizing the negative impact of product complexity on supply chain delivery speed.

Electronic Data Interchange (EDI) is a class of IOS that has been widely used for transactional purposes. EDI enables automated exchange of complex product information with a large number of supply chain partners. The use of EDI for sharing of information helps in reducing the total cycle time (Ng et al 1997). The use of EDI has been shown to reduce the time lag in communication and shipment (Banerjee and Golhar, 1994). EDI also enables automated handling of large amounts of complex product information and data. The use of EDI for various boundary spanning tasks speeds up the exchange of information between supply chain partners. EDI systems have standards and formats for the exchange of information. For example, the electronic industry follows the standards prescribed by RosettaNet and the auto industry has a similar set of standards prescribed by Covisint. EDI enabled standardization of information allows supply

chains to deal with large amounts of complex information and still maintain fast delivery speeds. Thus, we propose

P3: The use of Transactional IOS negatively moderates the relationship between product complexity and supply chain delivery speed.

Relational IOS: The use of IOS to foster relational ties and enable collaboration between supply chain partners is based on the relational view proposed by Dyer and Singh (1998). The use of IT to facilitate collaboration and foster relational capabilities has been discussed in literature (e.g., Grover and Malhotra, 1997; Walton and Marucheck, 1997).

We suggest that the use of IOS for relational purposes can be seen as a way to deal with complexity. The use of Collaborative Planning Forecasting and Replenishment (CPFR) tools is a manifestation of the extent of relational ties between supply chain members (Kim and Mahoney, 2010). CPFR tools are critical to building coordination capabilities within the supply chain. Product complexity calls for increased coordination between supply chain members. CPFR tools help achieve higher levels of coordination by making way for joint planning, developing production schedules and replenishment schedules. Improved supply chain visibility achieved through CPRF contributes towards maintaining required inventory levels and improves the ability to meet current and future delivery requirements (Aviv, 2001; Barratt and Oke, 2007).

The use of IOS tools with rich functionality such as groupware, group decision support systems, collaboration systems enable the sharing of complex unstructured information (Bowman, 2002; Sridhar, 1998). The use of rich media allows supply chain members to develop a shared understanding of product and customer requirements (Daft and Lengel, 1986). This is an effective way to deal with unstructured information such as intricate product design features, technology related issues, troubleshooting queries etc., which may pose problems when dealing with complex products. Shared understanding of requirements reduces unnecessary errors and improves delivery performance.

Knowledge management systems and shared database applications are useful in making sense of complex information flows. They allow supply chain members to learn from each other. Relational IOS tools thus contribute towards building closer relations with suppliers. Both buyers and suppliers benefit from having closer relations. The buyer firm or focal firm can provide operational and technical assistance to less competent suppliers thereby making them more capable. In the long run, suppliers benefit in terms of improved processes and buyers benefit in terms of improved delivery reliability.

The use of intranets, blogs and wikis are also employed by supply chain members in problem solving (Walters, 2008; Lancioni et al 2003). On the whole, relational IOS use improves capabilities and skill sets in the supply chain. This greatly contributes to delivery improvement by facilitating the delivery of the right product at the right time and in the right quantity and as desired by the customer. Thus, we propose

P4: The use of Relational IOS negatively moderates the relationship between product complexity and supply chain delivery reliability.

PROPOSED RESEARCH DESIGN

The relationships proposed in this research are in the process of being empirically tested using survey research methodology. The instruments to be used in this study will be developed based on modification of existing scales (ex: Grover and Saeed, 2007; Krause et al., 2001).

The data required to test the proposed relationships will be collected from manufacturing firms with more than 100 employees. An online questionnaire will be administered to a sample of potential respondents with the following job functions – CEO, VP, director, purchasing manager, and supply chain manager. The mailing list will be obtained from two sources – Institute for Supply Management (ISM) and Council of Supply Chain Management Professionals (CSCMP).

The relationships proposed in this study will be tested using Structural Equations Modeling (SEM).

CONTRIBUTION AND CONCLUSION

In this paper we propose that product complexity can adversely affect supply chain delivery speed and reliability. We also propose that this negative impact can be reduced by the use of IOS. Two patterns of IOS use are identified, namely Transactional and Relational IOS. Transactional IOS is identified to help deal with the negative impact on delivery speed. Relational IOS is identified to deal with the negative impact on delivery reliability.

This research contributes to theory by looking at the relationship between product complexity and supply chain delivery performance from the information processing lens. Researchers have previously discussed the negative implications of product complexity on performance. However the impact of product complexity on supply chain performance has not been examined from an information processing perspective. We identify from literature, the various drivers of product complexity and identify how each of these drivers contributes to the increased need to process information by supply chain partners and thus reducing delivery performance.

A second contribution is in identifying the role of IOS in dealing with the negative impact of complexity on performance. We identify two distinct patterns of IOS use. In doing so, we show that the appropriation of IOS is situational and can lead to different performance outcomes.

Third, we develop validated measurement instruments for product complexity, transactional IOS and relational IOS which have potential to be used in future studies.

In terms of implications for practice, the two appropriations of IOS presented here show the applicability of IOS in different contexts and for achieving different outcomes. Managers may benefit from the discussion of patterns of IOS use and look at IOS use as a means to manage the negative effects of product complexity.

Note: References available upon request from Prashanth Anekal at Prashanth.Anekal@utoledo.edu