A REVIEW OF SUPPLY CHAIN COMPLEXITY DRIVERS

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Abstract
Studies on supply chain complexity mainly use the static and dynamic complexity distinction. While static complexity describes the structure of the supply chain, the number and the variety of its components and strengths of interactions between these; the dynamic complexity represents the uncertainty in the supply chain and involves the aspects of time and randomness. This distinction is also valid when classifying the drivers of supply chain complexity according to the way they are generated. Supply chain complexity drivers (e.g., number/variety of suppliers, number/variety of customers, number/variety of interactions, conflicting policies, demand amplification, differing/ conflicting/ non-synchronized decisions and actions, incompatible IT systems) play a significant and varying role in dealing with complexity of the different types of supply chains (e.g., food, chemical, electronics, automotive).
This paper reviews the typical complexity drivers that are faced in different types of supply chains and presents the complexity driver and solution strategy pairings, in the form of a matrix, extracted from real-life supply chain situations gathered from multiple existing sources; such as reports, archives, observations, interviews. The decision matrix of complexity management approaches would assist decision-makers in formulating appropriate strategies to deal with complexity in their supply chains.

Keywords
supply chain complexity, supply chain complexity drivers, supply chain complexity management, good practices

Scope and Topics
Supply Chain Management & Logistics

1. Introduction

Supply chain (SC) is a complex network of business entities involved in the upstream and downstream flows of products and/or services, along with the related finances and information (Beamon 1998; Lambert et al. 1998; Mentzer et al. 2001). Supply chain management (SCM) is the systemic and strategic coordination of these flows within and across companies in the SC with the aim of reducing costs, improving customer satisfaction and gaining competitive advantage for both independent companies and the SC as a whole (Cooper & Ellram 1993; Cooper et al. 1997; Mentzer et al. 2001).

The complexity is inherent in the SC, in form of static complexity that is related to the connectivity and structure of the subsystems involved in the SC (e.g. companies, business functions and processes) and dynamic complexity that results from the operational behaviour of the system and its environment. The complex nature of SC adds to difficulty of managing the SC so that it becomes almost common sense to say SCM is about managing the complexity inherent in the SC. This paper reviews the complexity drivers, which provides us the necessary knowledge to complete the first step of a complexity management initiative. Understanding and analyzing the complexity drivers first, will be an effective way to proceed to develop a clear strategy to deal with complexity.

The aim of this paper is to review the typical complexity drivers that are faced in different types of SCs and present the complexity driver and solution strategy pairings. The remainder of the paper is organized as follows. Section 2 gives a review of the literature on SC complexity drivers and Section 3 presents solution strategies to deal with complexity extracted from various real-life SC situations. Section 4 concludes the paper and presents complexity management approaches that would assist decision-makers in formulating appropriate strategies to deal with complexity in their SCs and points out directions for future research.

2. Supply Chain Complexity Drivers

Complexity in a SC grows, as customer requirements, competitive environment and industry standards change, and as the companies in the SC form strategic alliances, engage in mergers and acquisitions, outsource functions to third parties, adopt new technologies, launch new products/services, and extend their operations to new geographies, time zones and markets (Deloitte Touche Tohmatsu 2003; A.T. Kearney 2004; PricewaterhouseCoopers 2006; KPMG 2011). The growth of SC complexity seems to accelerate with trends such as globalization, sustainability, customization, outsourcing, innovation, and flexibility (Deloitte Touche Tohmatsu 2003; BCG 2006; KPMG 2011).

We can distinguish between three types of SC complexity: static, dynamic and decision making. While static (structural) complexity describes the structure of the SC, the variety of its components and strengths of interactions; dynamic (operational) complexity represents the uncertainty in the SC and involves the aspects of time and randomness. The static-dynamic distinction has been primarily used to study complexity in manufacturing systems (see, among others, Deshmukh et al. 1998; Frizelle & Woodcock 1995; Calinescu et al. 1998; Calinescu et al. 2000; Huaccho Huatucoa 2009) and SCs (Sivadasan et al., 1999, Sivadasan et al,. 2002; Isık, 2010). Decision making complexity involves both static and dynamic aspects of complexity (see Calinescu et al. 2001a; 2001b; Efstathiou et al. 2002; Manuj & Sahin, 2011). From the static aspect, the SC system is made up of high number of elements, variety and interactions, and considering them all when making a decision goes beyond the capacity of the human decision maker (Miller 1956). From the dynamic aspect, the fact that the system is dynamic, non-predictable, and non-linear adds another layer of complexity to decision making in the SC. As a result, complexity of decision making in the SC is associated with the volume and nature of the information that should be considered when making a SC related decision (Serdar-Asan, 2009). One should note that the three complexity types are interrelated, and they should not be considered in isolation.

A SC complexity driver is any property of a SC that increases its complexity. The classification of types of SC complexity (i.e., static, dynamic, decision making) corresponds with the classification of complexity drivers *according to the way they are generated*: via physical situation (e.g., number of products), operational characteristics (e.g., process uncertainties), dynamic behavior (e.g., demand amplification), and organizational characteristics (e.g., decision making process, IT systems) (Towill 1999; Childerhouse & Towill 2004). Table 1 gives an overview of classification of SC complexity drivers.

Another classification of drivers is *according to their origin*: internal, supply/demand interface, and external/environmental drivers (Mason-Jones & Towill 1998; Wildemann 2000, p.3; Childerhouse & Towill 2004; Blecker et al. 2005; Isik 2011). Internal drivers are generated by decisions and factors within the organization such as the product and processes design. These drivers are relatively easier to leverage since they remain within the span of control. Drivers generated within supply and/or demand interface (in cooperation with suppliers /customers) are related to the material and information flows between suppliers, customers and/or service providers. These drivers are somewhat manageable since they remain within the span of influence and the level of coordination between SC partners plays a significant role when dealing with these drivers. Thus, power and trust mechanisms that affect the nature of supplier/customer relations are also important factors which need to be considered as complexity drivers. External drivers are generated through mechanisms that the company has little if any control over such as market trends, regulations and other various environmental factors. Figure 1 illustrates complexity drivers according to their origin. Different approaches may be adopted to cope with the complexity drivers (e.g., for the internal-static drivers approaches may be: product modularization, reducing the product variety, mass customization, business process reengineering). Decisions targeting any of the drivers may have a positive or negative effect on another driver which then would shift complexity of the SC from one driver to another, preferably on which they have more control. The companies make use of this property when managing the complexity in their SCs.

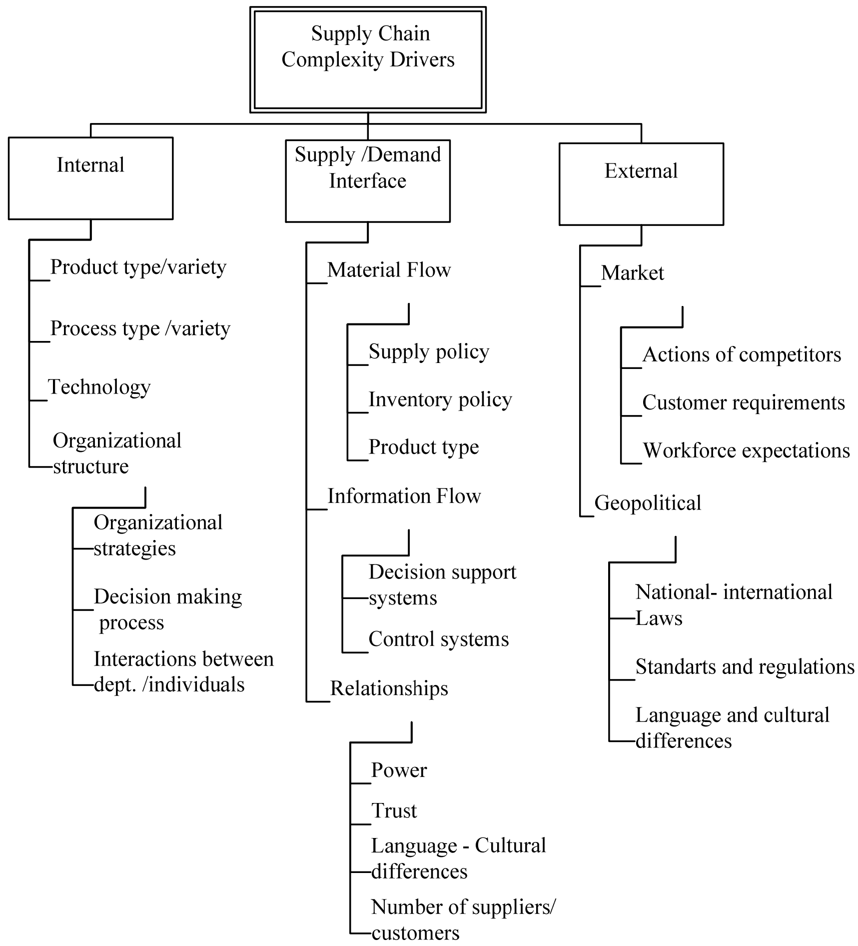

Figure 1. Classification of SC complexity drivers according to their origin

3. An overview of strategies for managing complexity in the supply chain

Analyzing and understanding complexity drivers enable us to implement right strategies when dealing with complexity. Without an idea of the drivers, it will be very difficult to develop a clear strategy to deal with complexity. An effective way of developing strategies is making use of good practices. Here, a good practice is defined as “any proven working practice which is far enough ahead of the norm to provide significant performance gains if implemented” (Zairi and Whymark 2000). Good practices of complexity management in the SC have been identified and gathered from various sources, compiled through an Internet search, such as reports of companies, consulting firms, technology providers and other knowledge bases (e.g. articles, books, case studies, industry reports, conferences). After an initial screening the 24 practices that are fulfilling the following criteria were further analyzed: (1) the complexity reported in the practice must be SC related; (2) the practice must have produced successful results; (3) the documents must be accessible and provide clear and detailed enough information to continue with the analysis The selected good practices were reviewed systematically and information on the following characteristics have been extracted: type of the company, type of SC, type of solution partner (if present), complexities involved in the SC, the goal or challenge the company is facing, necessary conditions to achieve the goal, problems related to the goal, complexity drivers of the problem, solution to overcome the challenge/problem, tools and techniques used, results achieved. Due to space restrictions, the list of the reviewed practices and their primary references as well as a full version of the systematic review results have been omitted from the conference paper submission. Table 1 gives the complexity driver–solution strategy pairings extracted from the reviewed practices.

Table 1. complexity driver–solution strategy pairings

Complexity drivers	**Solution strategies**
High number and variety of SKUs (*necessary complexity*)	• Improving demand management, forecasting, and logistics management abilities through a decision platform supported by SCM solutions.
High number and variety of SKUs (*unnecessary complexity*)	• Offering a limited range of products
Product complexity	• Measuring product complexity in terms of SC impacts, • Redesigning the products that have a high complexity index
High variety of requirements to be met by the IT solution	• Implementing a customized Software as a Service logistics solution
Incapable and incompatible planning systems	• Developing and implementing a new planning system • Making process and technological adjustments • Developing new performance metrics
Large planning models	• Implementing a SC planning software modified to handle planning requirements
Demand uncertainty/ demand volatility	• Profiling uncertain demand • Planning of operations on a daily basis
Incapable transportation management processes and technology	• Forming a partnership with a partner that has expertise in transportation management • Adopting new technology and processes
Incapable SC operations, incompatible SC design	• Redesigning the SC, • Reorganizing the distribution network, • Collaboration with suppliers
Outsourcing of manufacturing	• Supplier integration • Gaining visibility into operations through B2B platform
Lack of a well defined procurement system	• Developing an end to end procurement process • Integrating the procurement processes and systems with the ERP system
Lack of experience Lack of know how	• Forming a partnership with a partner that has the know how • Outsourcing the operations to a partner that has the experience
Lack of effective means of control over the processes	• Automating decision making process using a business rules management system
Lack of control due to outsourcing	• Reducing number of outsourcing partners • Working in close collaboration with the outsourcing partners
Changing requirements of the industry	• Adapting to changes by providing synchronized services
Market pressure and changing customer requirements	• Adopting adaptive SC strategies

4. Conclusion

The results of the analysis provide a general overview of SC complexity management initiatives that can be utilized to assist decision-makers in formulating strategies to deal with complexity. The solutions that have been implemented in each case in order to overcome the complexity related problems can be categorized according to type of complexity (see Table 2).

From the analyses we can deduce that when dealing with static complexity the companies tend to use strategies to reduce complexity while with dynamic and decision making complexity they try to manage the complexity and adjust their operations to cope with it. The use of tools and technologies to support complexity management is widely used and recognized. The analyses results can be used to develop a more sophisticated decision matrix as a further research. This would assist decision-makers in identifying and transferring these good practices as well as applying them in a new configuration which would match the requirements of their own problem.

Table 2. Categorization of the solutions according to type of complexity

	Solution strategy	**Supporting tools and technologies**
Static complexity	• Reducing the number of products • Reducing the options in the product and the SKUs (*product complexity*) • Reducing the number of outsourcing partners • Reducing the number of distribution centers	
Dynamic complexity	• SC integration • Collaboration with suppliers, customers, and service providers • SC visibility • Standardization of operations • Process automation • Synchronization of data • Information sharing • Logistics outsourcing • Planning on a daily basis • Process improvement and redesign	• VMI, CPFR • ERP software • Logistics management software • SC planning software, APS • SRM software • WMS software • Transportation optimization software • IT service management solution • B2B platform • EDI • Barcoding, RFID • Profiling uncertain demand
Decision-making complexity	• Centralized decision making • Automation of decision making	• Business rules management system • SCM software

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