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An Overview on Supply Chain Vulnerability and Resilience

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ABSTRACT

In this age of complexity of markets, uncertainty, and turbulence, supply chain has become vulnerable to different kinds of risks. As supply chains increase in complexity due to outsourcing, globalization and volatility in environment, the risk of disturbances may increase and variability is beyond a company's control. Being so, companies need to adopt disturbance-management practices at strategic, tactical and operational levels. Further globalization and recession has leaned the supply chain, causes more risks. The concentration of organizations is to minimize the risk; through designing a more resilient supply chain. Here different requisites of resilient supply chain are discussed, to mitigate the supply chain risks.
Key words: supply chain, risk, resilient, agility, disturbance, mitigation strategies.

INTRODUCTION

Christopher and Peck (2004) mentioned that, in an age of lengthening supply chains serving globe-spanning operations, recent events around the world have provided frequent reminders that we live in an unpredictable and changing world. Natural disasters, industrial disputes, terrorism, and sea pirates have all resulted in serious disruptions to supply chain activities. Today's marketplace is characterized by shorter product lifecycles, more competitive product introductions and a volatility in demand, which makes life-cycle demand more uncertain and difficult to predict (Christopher and Rutherford, 2004). Complex networks of suppliers, customers and third party service providers, as well as, large interdependencies among multiple organizations exist, making inter-organizational coordination of risks a critical requirement.

Supply chain managers strive to achieve the ideals of fully integrated efficient and effective supply chains, capable of creating and sustaining competitive advantage described by Christopher *et al*. (2002). Concepts such as Just-In-Time; supplier base rationalization; virtual inventory; outsourcing; customized and global networks; reduction of buffers in material, capacity and time; and reduction in the number of distribution facilities have lead to improvements in SC performance particularly in reducing costs. Actual competitive market requires more resilient organizations, that is, organizations with the ability to react to an unexpected chock – disturbance – and to return quickly to its original state or move to a new one, more desirable, after being disturbed. Most organizations when subjected to disturbances don't sustain their productivity level, and lose competitiveness (Peck, 2005; Ji and Zhu, 2008). If it doesn't happen, organizations are in risk of losing market (and bankruptcy).

The main objective of this paper is to propose a typology of strategies, identified in the literature, to mitigate supply chains disturbances under the supply and demand perspective.

Evolution of Supply Chain Management

When working effectively and efficiently modern supply chains allow goods to be produced and delivered in the right quantities, to the right places, at the right time in a cost effective manner. Until recently the term "supply chain" was not widely used beyond the confines of academia, specialist sectors of industry and the professional management community. Now, in the wake of a number of far reaching supply chain disruptions to

economic activity it has crossed over into the everyday vocabulary of politicians, general managers and the wider public.

Here we define a supply chain as described by Christopher and martin (1998): "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer".

The rest of the paper is structured as follows. Section 2 introduces the main concepts and the research methodology. In section 3, a review of mitigation strategies classification is done. Section 4, presents the supply and demand mitigation strategies typology proposed. The final section, section 5, gives the conclusions of the paper and the recommendations for further developments

2. Main Concepts and Research Methodologies

2.1 Concepts

In the literature the terms disturbance (Mason-Jones and Towill, 1998), disruption (Blackhurst *et al.*, 2005) and risk (Chopra and Sodhi, 2004) have been frequently used interchangeably, showing no consensus among authors about these concepts.
In the context of this paper it will be used the term disturbance, defined as a foreseeable or unforeseeable event, which affects directly the usual operation and stability of an organization or a supply chain (Barroso et al., 2008). This is similar to Hendricks *et al.* (2008) and Kleindorfer *et al.* (2005) Supply Chain disturbance definition, "an unplanned and unanticipated event that disrupt the normal flow of goods and materials in a supply chain". However, disturbance is a more general concept, as it includes foreseeable events which can be managed through risk mitigation strategies. Many of the literature that suggests strategies to deal with supply chain disturbances focus on the risk management area (Norrman *et al.*, 2004; Hendricks and Singhal, 2005a); Kleindorfer and Saad, 2005; Hillman, 2006; Picket, 2006; and Ji and Zhu, 2008). This is due to the fact that the SC disturbance risk management can become a supply chain ready not only to sustain its operations during a disturbance and to recover after that, but also to improve the efficiency of it (Ji and Zhu, 2008). Also, Kleindorfer and Saad (2005) argue that risk assessment and risk mitigation are fundamental to disturbance risk management in supply chains. Furthermore Kull (2008) defends that the supply chain outcomes could be improved by using risk management strategies since it contributes to a reduction in loss, probability, speed, frequency, and exposure of risk events.

In this context it is important also to clarify the risk concept in Supply Chain. Risk can be seen as an uncertain event or condition, which if it occurs, has a positive or negative effect on objectives (PMI, 2008). But, in this work it will be used a more traditional point of view and considered risk as an uncertain event or condition, that if it occurs, will produce a negative effect on supply chain performance. So, risk events will be considered as discrete occurrences that will affect negatively the supply chain flows.

2.2 Research Methodology

In this study it will be considered that a disturbance can have negative effects on one entity of a supply chain (a fire, for example, on the productive system of an organization, which can stop the organization work and, consequently, the supply of their customers, or a highest demand of a product from a customer, which cannot be satisfied) or on several supply chain entities (for example, a truck driver strike, on a country, which can break down the supply of materials along the supply chain, or a global economic crisis, which break down the demand of the product and/or of their components), A disturbance in the supply of an organization is characterized by delays or unavailability of materials from suppliers, leading to a shortage of inputs that could paralyze the activity of the organization. A disturbance in the product demand of an organization is characterized by a delay or disturbance downstream that can lead to the loss of demand temporarily or permanently, thus affecting all the organizations upstream. The study of supply chain disturbances has been the focus of many researches, mainly due to its consequences to supply chain performance. Indeed, and according to Hendricks and Singhal (2005b), disturbances are likely to affect negatively performance, profitability, operating income, sales cost structure, assets, and inventories. Also, Ji and Zhu (2008) consider that the supply chain disturbances

have significant impact on the whole supply chain short-term financial performance as well on the satisfaction rate of its downstream enterprise and end-customers. Moreover, Pickett (2003) also considers the following consequences of SUPPLY CHAIN disturbances: (i) loss of non-IT related assets, (ii) data loss, communication links to supply chain partners; (iii) inability to source a key component; (iv) inability to produce goods and or services for sale; (v) inability to move raw materials or finished goods throughout the supply chain; and (vi) loss of one or more key customers. In an attempt to avoid and mitigate the negative effects of Supply Chain disturbances some strategies and policies proposed and in use are identified.

2.3 Sources of the Supply Chain Risk

Reducing supply chain vulnerability and improving supply chain resilience requires categorizing and analyzing risks as well as requires understanding the effect of information sharing on visibility along the supply chain.

Categorizing the supply chain risks

A framework proposed by Mason et al. (1998) and Cristopher and Peck (2004) for categorizing supply chain risks subdivided in five different categories:

- Process risks internal to the company;
- Control risks internal to the company;
- Demand risks external to the company and internal to the supply chain;
- Supply risks external to the company and internal to the supply chain;
- Environmental risks external to the supply chain.

Note that a company is the union of different processes and activities that aim, in the long period, at increasing the value added of the business strategies. Process risks may affect all the activities carried out by the company, from the manufacturing production to quality levels, from warehouses management to transportation activities.

Control risks are related to Process risks. In effect processes and activities are governed by rules and controls. The warehouse management is performed by using inventory control policies, the manufacturing process in a job shop is ruled by shop orders scheduling, the quality levels depends (among the others) on the methodology being used for improving quality. In other terms each process inside a company has specific controls and rules. Wrong controls and rules act as risks affecting the performances of the company and its resilience (i.e. wrong inventory control policies and/or demand forecast methodologies, inadequate production planning, wrong corporate culture during the implementation of quality methodologies and systems, etc.).

Demand risks usually involve the flow of products, information and finances downstream the company being considered. Such risks are related to the powerlessness of the company (due to unpredictable events) to satisfy market demand and also include demand forecasts risks and Bullwhip effect. Note that among the consequences of markets globalization the most important affecting the demand forecasts risks are the growing products assortment and the shorter products life cycle. In such a context classical demand forecasting techniques may result inadequate. In effect numerous research works have been proposed in order to consider higher items aggregation levels and more reliable forecast models (two different examples are respectively reported in Dekker et al., 2004 and Zotteri et al., 2005).

Supply risks involve the flow of products, information and finances upstream the company being considered. Such risks are related to suppliers' reliability and suppliers' base selection. Note that suppliers should be able to deliver the right products at the right place and time.

Finally the environmental risks have to be regarded as uncontrollable and sometime unpredictable events that strongly affect the supply chain vulnerability and resilience. Among the others the most important are natural disasters, wars, terrorist attacks, political and social disorders. The 9/11 attacks in USA demonstrated the vulnerability of the U.S. economy to shutdown the transportation system, and especially the vulnerability of extended supply chains and trans-border just in-time manufacturing systems.

Another alternative framework for categorizing supply chain risks can be found in "Creating a Resilient Supply Chains: A Practical Guide",

(2003). The authors recognize four levels of risks, named as follows:
• Process and Value stream (first level);
• Assets and Infrastructure Dependencies (second level);
•Organizations and Inter-Organizational Networks (third level);
• Environment (fourth level).
The risks of the first level regard all the processes and the value added both upstream and downstream the company being considered. In effect in the first level the problem of the supply chain vulnerability and supply chain risks should be faced by considering the entire supply chain. For a better understanding of the first level risks consider that the "process risks", described in the framework proposed by Mason et al. (1998) and Cristopher and Peck (2004), have to be regarded as extended to the entire supply chain, applied to each actor of the supply chain. The reduction of the first level risks requires high levels of trust among the supply chain actors and in turn this means information sharing and high visibility along the entire supply chain.

The risks of the second level regard the assets and the infrastructure dependences. A supply chain is made up by links and nodes. In terms of products flows, nodes are distribution centers, plants, terminals, stores, whilst links are roads, waterways, rails, etc. In terms of information flows, nodes are ICT platforms while links are the communication networks that connect, at each level (national, international, intercontinental), the ICT platforms. The continuity of the operations in each node and/or link (risks reduction and resilience enhancement) should be assured by all the managers, operators and workers at each stage of the supply chain. The second level risks underline the importance of the human factor for supply chain management

The risks of the third level regard the supply chain strategic management. The relationships between the supply chain actors are ruled by the position of power of each actor. In a globalized market the high levels of competitiveness usually lead companies to fight each other even in the same supply chain, pursuing different objectives or abusing of the own position of power.

Finally the risks of the fourth level are the same as proposed in the framework by Mason et al. (1998) and Cristopher and Peck (2004) i.e. environmental risks.

A toolkit for supply chain risks categorization, analysis can be found in "Creating a Resilient Supply Chains: A Practical Guide" (2003). Among the others, the authors propose Scenario Planning, Brainstorming, Failure Mode and Effects Analysis, Flowcharting, Pareto Analysis, Modelling & Simulation as powerful tools that can help the managers in supply chain risks management.

3. Literature review for mitigation strategies

The strategies and policies for mitigation have been classified from different points of view:
A) The moment on which actions are taken for mitigating the disturbance effects.
A1) A Proactive strategy, can help a company to avoid or decrease the negative effects of certain disturbances types (Sourcing, for example, can be used to proactively cope with the disturbance effects) (Muckstadt *et al.*, 2003; Rice and Caniato, 2003a; Norrman *et al*., 2004; Herroelen and Leus, 2005; Kleindorfer and Saad, 2005; Hendricks and Singhal, 2005a; Hendricks *et al*, 2008; and Ji and Zhu, 2008).
A2) A Reactive strategy, can reduce the disturbance effect (Outsourcing, for example, can be used by organizations to react to an unexpected lack of capacity) (Hsieh and Wu, 2008; Kara and Kayis, 2004; Pitty *et al*., 2008).
B) The effect on Supply Chain resilience. Implementation of enterprise standards, for example, it can become much easier to transfer employees to alternate manufacturing locations in response to a disturbance (Picket, 2003; Rice and Caniato, 2003b).
C) The crucial areas to successfully managing supply chain disturbances, which are Disruption Disturbance, Recovery Disturbance, and supply chain Redesign (Blackhurst *et al.,* 2005). In essence, disturbance discovery leads to the ability to recover from the disturbance and redesign the supply chain systems.
D) Tomlin (2006) classifies strategies for managing the risk of disturbances into three categories, financial mitigation, operational mitigation, and operational contingency.
The first refers to insurance policies to protect against disturbance risk. Second mitigation involves using either inventory or sourcing

strategies. Lastly, operational contingencies refer to either rerouting products temporarily when disturbance risks ensure, or shifting demand to different products when disturbances affect production. Many disturbances management strategies are in conflict with the organization traditional goals and processes, and vice-versa (Sheffi, 2006). Consider, for example, the trade-off between efficiency and redundant inventory. Building redundant inventory in the supply chain will function as a buffer to maintain continuous operations. On the other hand, it will also drive up costs and may lead to lower efficiency. Other trade-offs occur when strategies that are needed to mitigate one type of disturbance, increase another kind of disturbance at the same time. Consider, for example, the centralized management of inventory. This allows for the pooling of forecasted demand, which is aggregating demand to obtain a more accurate forecast (Chopra *et al.*, 2007). Yet, at the same time, centralization increases dependency on a single facility, thus also increases the negative impact, in case a disturbance occurs at this facility. But also, the geographical diversification increases supply chain complexity making it harder for an organization to react to supply chain disturbance (Hendricks et al., 2008). The interconnectedness of these disturbances makes decision-making for disturbance management difficult (Chopra *et al.*, 2007) since they must balance the need of efficiency against the risks and expected costs of disturbances.

4. Proposed Typology for Supply and Demand Mitigation Strategies

The literature review allowed obtaining a huge number of strategies and policies that are used to mitigate the negative effects of Supply Chain disturbances from demand and supply side. As a result, we needed to aggregate them in classes, according with their application scope. After a deep analysis of mitigation strategies and policies concerning each one of the two perspectives, supply and demand, four classes are proposed, Structural, Operational, Product based, and Visibility based. The Structural mitigation strategies enclose the ones related with the decision making at the strategic level by an organization or a Supply Chain. The Operational mitigation strategies include the ones related with the operations management by an organization. The Product based class consists of the mitigation strategies directly related to the product. The Visibility based class comprises the mitigation strategies that are directly related to the sharing and exchange of information within the organization and/or among Supply Chain entities.

5. Conclusion and further developments

The paper proposes an exhaustive state of the art overview on supply chain vulnerability and resilience. In the last two decades Supply Chain Management practices have been developed toward more lean process approaches, in order to increase Supply Chain efficiency. These practices, considered by most authors as “best practices”, are becoming Supply Chains more vulnerable to disturbances. Considering that it is impossible to avoid their occurrence, a Supply Chain should be resilient, that is to have the ability to sustain operations during a disturbance and quickly recover to normal state after being negatively influenced by them. The supply chain disturbances are increasing, in number and frequency, and managers have to find ways for efficient supply chain disturbance management. In this paper, a review of some mitigation strategies classifications is presented and a mitigation strategies and policies typology is proposed.

The proposed typology considers the strategies to mitigate supply chain disturbances that have been identified in the literature, under the supply and demand perspective, and clusters them, according to their characteristics, in four classes: Structural, Operational, Product based, and Visibility based. The effectiveness of the mitigation strategies depends on how well the organization is able to cope with or recover quickly from the impact of disturbances.

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