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STRATEGIES TO MITIGATE SUPPLY CHAIN DISTURBANCES¹

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Abstract

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.

The main objective of this paper is to propose a conceptual model on strategies to mitigate supply chains disturbances under the supply-demand perspective. A literature review on disturbance-management practices is presented. Also, a qualitative approach is used to identify some strategies used by actual supply chains to mitigate the disturbances that have occurred.

Keywords: Disturbance, Supply chain management, Mitigation strategies

1. INTRODUCTION

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.

In the last 20 years, Supply Chain Management (SCM) practices have been developed toward more lean process approaches, in order to increase Supply Chain (SC) efficiency (reducing costs and eliminating inefficiencies). 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. These practices considered by most authors as "best practices" are becoming Supply Chains (SC's) more vulnerable to disturbances (Christopher and Towill, 2000; Norrman *et al.*, 2004; Tang, 2006a).

Most organizations when subjected to disturbances don't sustain their productivity level, and lose competitiveness. 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 (Peck, 2005; Ji and Zhu, 2008). If it doesn't happen, organizations are in risk of losing market (and bankruptcy).

To become a resilient organization, that is an organization with the ability and the means to reduce the negative disturbance effects, adequate mitigating strategies must be defined. Since different organizations/SC environments will give rise to different approaches to assessment and

mitigate, characteristics and requirements of the decision environment must be considered (Kleindorfer and Saad, 2005).

Some authors (Mason-Jones and Towill, 1998, and Christopher and Peck, 2004) classify in four categories the disturbance sources inside the SC: Process, Supply, Demand, and Control. Others, like Tang (2006a) and Ji and Zhu (2008), consider Supply Management, Demand Management, Product Management, and Information Management, the four basic approaches to mitigate the impact of SC risks. In the context of this paper, it will be analyzed the strategies to mitigate SC's disturbances under the supply and demand perspective.

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. The research underling this paper is being developed, in Portugal, in the context of a project, named "Supply Chain Management: Design for Resilient Systems" (Carvalho *et al.*, 2007).

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 METHODOLOGY

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 SC (Barroso *et al.*, 2008). This is similar to Svensson (2000), Hendricks *et al.* (2008) and Kleindorfer *et al.* (2005) SC disturbance definition, “an unplanned and unanticipated event that disrupt the normal flow of goods and materials in a SC”. 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 SC disturbances focus on the risk management area (Norrman *et al.*, 2004; Hendricks and Singhal, 2005a); Kleindorfer and Saad, 2005; Hillman, 2006; Pickett, 2006; Kumar *et al.*, 2008; Kull, 2008; and Ji and Zhu, 2008). This is due to the fact that the SC disturbance risk management can become a SC 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 SC 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 SCs. 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 SC (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 can not be satisfied) or on several SC entities (for example, a truck driver strike, on a country, which can break down the supply of materials along the SC, or a global economic crisis, which break down the demand of the product and/or of their components), (Figure 1).

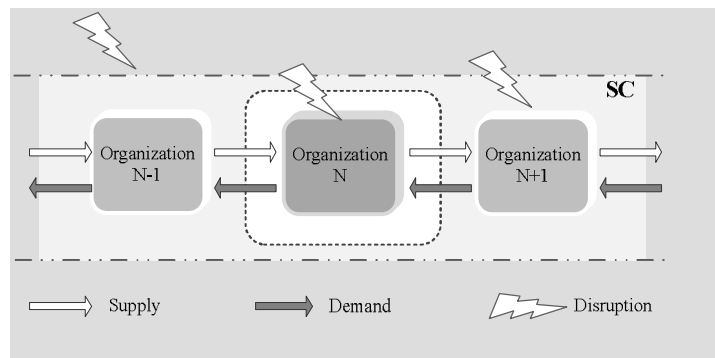


Figure 1. Disturbances on SC Network

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 SC disturbances has been the focus of many researches, mainly due to its consequences to SC 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 SC disturbances have significant impact on the whole SC 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 SC disturbances: (i) loss of non-IT related assets, (ii) data loss, communication links to SC 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 SC; and (vi) loss of one or more key customers.

In an attempt to avoid and mitigate the negative effects of SC disturbances some strategies and policies proposed and in use are identified.

The study presented in this paper, was developed in two steps.

First, a review of the papers published on scientific journals, concerning strategies and policies to mitigate disturbances was made. Some keywords were used in the crossed research, namely, Disruption, Disturbance, Mitigation Strategy, Policy, Risk mitigation, Risk management, SC, Resilient SC, Robust strategies. It was obtained 89 papers, published from 1997 until now. The aim of this step of this study was to identify the strategies and policies proposed by different authors, and applied by different organizations.

After, the papers were analyzed, and selected the ones that get all the purposes of the study. The strategies and policies proposed in the literature were classified according with the supply and demand perspectives. In the supply and demand perspective, and according with strategies and policies characteristics, they were classified in four classes, Structural, Operational, Product based, and Visibility based.

3. MITIGATION STRATEGIES REVIEW

The mitigation strategies and policies have been classified from different points of view:

- A) The moment on which actions are taken to mitigate 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 SC 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 SC disturbances, which are Disruption Disturbance, Recovery Disturbance, and SC Redesign (Blackhurst *et al.*, 2005). In essence, disturbance discovery leads to the ability to recover from the disturbance and redesign the SC systems.
- D) Tomlin (2006) classifies strategies for managing the risk of disturbances into three categories, financial mitigation, operational mitigation, and operational contingency. Financial mitigation refers to insurance policies to protect against disturbance risk. Operational 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 SC 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; Sheffi, 2005). 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 SC complexity making it harder for an organization to react to SC 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. SUPPLY AND DEMAND MITIGATION STRATEGIES TYPOLOGY PROPOSED

The literature review allowed obtaining a huge number of strategies and policies that are used to mitigate the negative effects of SC 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, Figure 2.

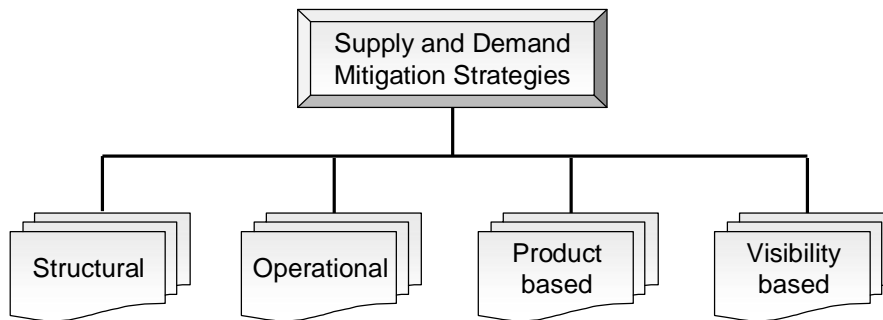


Figure 2. Supply and demand mitigation strategies typology

The Structural mitigation strategies enclose the ones related with the decision making at the strategic level by an organization or a SC.

The Operational mitigation strategies include the ones related with the operations management by an organization.

The Product based class comprises 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 SC entities.

4.1 Supply mitigation strategies

The Structural supply mitigation strategies and policies class encloses the strategies and policies that are identified in the literature and related with the decision making at strategic level. In turn, the supply mitigation strategies and policies were classified as Organizational culture, Strategic management, and SC redesign strategies sub classes (Table 1).

Table 1. Supply mitigation strategies classification

Supply mitigation strategies			
Structural	Operational	Product based	Visibility based
Organizational culture	Components diversification/ Interchangeability	Component Standardization	Advanced EDI
Business Continuity Planning	Coordination among supply and demand	Customer influence choice	CPFR
Collaborative Relationships	Coordination among SC entities	Product redesign	Sharing Information
Disaster Recovery Planning	Cycle time reduction	Product range rationalization	VMI
Educate/Trainee Human Resources	Inventory Models	Responsive pricing	
Insurances	Lead time reduction	Shift demand across products	
Supply incentives	Postponement	Silent product rollover	
Strategic Management (Flexibility)	Procurement Emergency		
Capacity	Rescheduling		
Facilities Geographic Localization	Redundancy		
Make and buy	Capacity		
Production Systems	Inventory		
Sourcing	Operational slack		
Transportation	Transportation		
Agility	Single sourcing		
Leanness	Streamlined processes		
SC redesign			
Decoupling point establishment			
Strategic inventory			
Vertical integration			

One of the structural strategies that could be adopted is to build a resilient culture. This allows that SC organizations be constantly alerted for potential disturbances (Pickett, 2003; Rice and Caniato, 2003a). Timely identification of disturbances it is crucial to a successful recovery. According to Rice and Caniato (2003a) a resilient culture could be reached through an intensive training and education of human resources.

Human resources training programs, a base of the organizational culture of an organization, are focused primarily on increase efficiency. However, when human resources are trained they are also resilient. To be resilient, with cost effective approaches, it is essential to have a disturbance management culture (Tsiakouri, 2008). Additionally, a better understanding and relationship with human resources can help avoid some disturbance sources, namely those that have basis on internal resources organization, for instance, strikes (Stecke and Kumar, 2006). In the same way, to hold collaborative relationships with the others SC entities ensures that the response alternatives to a disturbance are more effective (Muckstadt *et al.*, 2003).

Most of mitigation strategies and policies related with the strategic management of the resources are built on flexibility. Flexibility refers to developing capabilities within the organization to respond to disturbances (Christopher and Peck, 2004) and becomes the organization/SC with the means capable to offset the losses in a part of the organization or the SC by gains from available options. The flexibility point of view were referred by different authors, namely: Capacity flexibility (Rice and Caniato, 2003b; Oke and Gopalakrishnan, 2008), Facilities geographic localization (Rice and Caniato, 2003a; Rice and Caniato, 2003b; Stecke and Kumar, 2006; Kleindorfer and Saad, 2005), Make and buy (Tang, 2006b), Sourcing (Ji and Zhu, 2008; Hendricks and Singhal, 2005a; Norrman *et al.*, 2004; Rice and Caniato, 2003a; Rice and Caniato, 2003b; Kumar *et al.*, 2007; Manuj and Mentzer, 2008; Pickett, 2003; Oke and

Gopalakrishnan, 2008), and Flexible transportation (Rice and Caniato, 2003b; Chopra and Sodhi, 2004; Tang, 2006a; Tsiakouri, 2008).

Agility is approached as a disturbance management initiative that enables an organization to respond rapidly to marketplace changes, as well as anticipated and actual disturbances in the SC. Christopher and Lee (2004) consider that agility is a basic element for managing SC disturbances. Leanness may be an element of agility. In certain circumstances, namely, when the events have high occurrence probability and low impact, leanness allows to decrease the vulnerability to SC disturbances, and increase the responsiveness of the system (Marley, 2006).

The frequency of natural calamities, as for example hurricanes and earthquakes, varies across geographical regions. Also, terrorist attacks occur more in some countries than others. For that reasons, the probability of disturbance occurrence can be reduced by choosing locations for facilities/plants less subject to adversity (Stecke and Kumar, 2006).

The SC redesign is another way to better respond to the potential negative disturbance effects, balancing the tradeoffs between costs and benefits (Blackhurst *et al.*, 2005).

The Operational supply mitigation strategy class encloses several strategies. One subclass strategies is the redundancy. Redundancy involves maintaining excess resources organization to respond to disturbances (Christopher and Peck, 2004; Sheffi, 2006). Redundancy on capacity (Gaonkar and Viswanadham, 2007), inventory (Christopher, 2002; Hillman, 2006; Norrman, *et al.*, 2004; Rice and Caniato, 2003b; Tomlin, 2006; Schmitt, 2008), transportation (Christopher, 2003) and/or operational slack (Hendricks *et al.*, 2008), makes an organization/SC less vulnerable to disturbances.

A SC is more vulnerable to disturbances when the lead time is long (Tang, 2006a), so lead time reduction is a strategy to face the negative effects of disturbances.

Enhance coordination in a SC can also reduce the vulnerability to disturbances that can affect any SC entity (Hendricks and Singhal, 2005a; Hsieh and Wu, 2008; Kleindorfe and Saad, 2005; Oke and Gopalakrishnan, 2008). Coordination may be at the vertical and horizontal level. Vertical coordination can help avoid a disturbance from disrupting multiple SC stages. Moreover, horizontal coordination can also allow organizations to foresee disturbances. In fact, a lack of horizontal coordination may increase the production lead time resulting in SC disturbances.

The postponement strategy contributes to improve the resilience of SC since considering that a production process is splits on a general and a customized one, and that the customization point is moved as backward as possible along the SC it will be possible a quick production' adjustment (Ji and Zhu, 2008).

Procurement emergency is another strategy to mitigate supply disturbance associated, for example, with a shortage of products or components. This strategy is coupled with sourcing and intends to find quickly in the market a substitute product (Pitty *et al.*, 2008).

Others strategies to mitigate supply disturbance are cycle time reduction (Christopher and Lee, 2004), adoption of stochastic inventory models that include supply disturbances (Schmitt, 2008), and SC operations rescheduling (Adhitya *et al.*, 2007).

The responsive pricing strategy, a product based supply mitigation strategy, consists of a shift demand across products by using price as a response mechanism. When an organization sells several products and faces a disturbance, it can offer to its customers the available products by adjusting products' prices to ensure its loyalty. By this way, the SC resiliency will be improved (Ji and Zhu, 2008). This strategy is identified by Tang (2006b) as revenue management.

The product based supply mitigation strategy class encloses several strategies, namely, component standardization (Tsiakaouri, 2008), also referred by some authors as common parts (Tang, 2006); customer influence choice (Stecke and Kumar, 2006); product redesign to use standard components (Rice and Caniato, 2003b; Stecke and Kumar, 2006); product range rationalization (Christopher, 2002); shift demand across products (Tang, 2006a), and silent product rollover (Tang, 2006b). The focus of most of these supply mitigation strategies is to have the possibility to get an alternative standard product/component when a disturbance affects the organization supply of a product.

The visibility based supply mitigation strategy class encloses several strategies, namely, Advanced Electronic Data Interchange (EDI) (Christopher and Lee, 2004; Christopher, 2002), Collaborative Forecasting and Replenishment (CPFR) (Tang, 2006a; Wilson, 2007), Sharing information (Grabowski and Roberts, 1997; Ji and Zhu, 2008; Ritchie and Brindley, 2007), and Vendor Management Inventory (VMI) (Tang, 2006a; Wilson, 2007).

The using of the CPFR strategy allows a better integration of information flows and improves the SC visibility on their vulnerabilities among all SC entities (Kleindorfer and Saad, 2005).

The organizations need to be more open in sharing information related to disturbances with SC partners and to accept risk jointly instead of individually. Enhance visibility in a SC can reduce the vulnerability to disturbances that can affect any SC entity, and to reduce the bullwhip effect. With greater visibility between the SC levels, an organization can anticipate a problem at a supplier or customer that may affect them (Stecke and Kumar, 2006), and improve the SC responsiveness to market (Ji and Zhu, 2008).

Wilson (2007) analyzed the effect of a supply disturbance on SC performance, comparing a traditional SC and a VMI system and concludes that the impacts are less severe for the VMI

structure.

4.2 Demand mitigation strategies

The literature analysis on strategies and policies used to mitigate the negative effects of SC disturbances from demand side showed that most of these strategies and policies are similar to the ones that are implemented or proposed (by the same or different authors) from the supply side (Table 2).

Then, it will be analyzed the demand mitigation strategies and policies that have been identified in the literature and which do not match with the ones from supply side. The mitigation strategies analysis done to the disturbances from the supply side (section 4.1) is valid for the matching strategies to mitigate the disturbances from demand side.

Once an organization understands its SC risks, it can select mitigation strategies and policies to cope with risks. So, a communication strategy that aimed to educate customers (Oke and Gopalakrishnan, 2008) is a strategy associated with the organizational culture and classified in the structural demand mitigation strategies and policies class.

Delivery time (Kara and Kayis, 2004) is another strategy referred in the literature to avoid or minimizes the effects of a disturbance on an organization that comes from demand. This mitigation strategy is related with the strategic management area and, therefore, is enclosed in the structural class.

Labour flexibility is a strategy referred by Gerwin (1989) to manage demand disturbances. This strategy can be implemented through numerical (adjusting the workforce number) and financial (compensating the workers for their overtime input) points of view.

These specific strategies (educate customers, delivery time and labor flexibility) are crucial to cope with risk and promote the competitiveness of the SC or organizations.

Table 2. Demand mitigation strategies classification

Demand mitigation strategies			
Structural	Operational	Product based	Visibility based
Organizational culture Collaborative Relationships Educate Customers Educate/Trainee Human Resources Supply incentives	Coordination among supply and demand	Silent product rollover	CPFR
	Coordination among SC entities	Responsive pricing	Enterprise-wide
Strategic Management Agility Capacity Delivery time Labour Sourcing Transportation	Supply optimization models		Sharing Information
	Postponement Demand Product		VMI
SC redesign Strategic inventory Vertical integration	Rescheduling		
	Redundancy Inventory Transportation		

When a SC organization implements a demand postponement strategy, according to Ji and Zhu (2008), it intends to persuade some customers to accept their shipments or service in delayed periods. This strategy may be conjugated with another strategy, the responsive price, for instance, a pricing discount. In fact, an organization can offer different prices at different times, increasing the profits of the SC by capturing customers in different periods that are willing to pay different prices.

Robust optimization has been developed in several areas characterized by uncertainty and risk. Considering the uncertainty market demand, some authors developed stochastic models, applying linear programming (Wu, 2006) and multiperiod mixed integer nonlinear programming (You and Grossmann, 2008).

5. CONCLUSION AND FURTHER DEVELOPMENTS

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 SC 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.

From the analysis of the mitigation strategies classification proposed for supply and demand perspectives it is possible to conclude that most of them match.

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.

During the work development it was pointed out the existence of trade-offs between some disturbances mitigation strategies. It will be interesting to develop a deeply survey about this subject. Also, it will be interesting to study the contribution of information and communication technologies to help organization and supply chains to avoid or minimize the effects of disturbances.

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