

# **A Taxonomy of Supply Chain Risk Management Strategies: Antecedents and performance**

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## **ABSTRACT**

This paper develops a taxonomy of how companies develop SC risk management in term of two basic management approaches: one that emerges from internal actions and operations within companies; and another involving actions undertaken with external SC partners. The aim of this taxonomy is double: (1) predict a firm's performance with regard to the disruption occurrence and (2) identify the contextual antecedents (environment, focal firm and SC) for contingently specify the SC vulnerabilities that shape the SC risk management strategy. Using survey data from 909 firms representing 69, cluster analysis and analysis of variance the results suggest that the most effective SC risk management strategies require maturation in their SC relationships with SC partners.

**Keywords:** supply chain risk management, vulnerabilities, disruption, taxonomy

## **INTRODUCTION**

The dynamic and complex evolution of markets has encouraged many firms to implement various supply chain initiatives to try to boost efficiency [1]. Additionally, Supply chain (SC) has been evolving to a prevalence of outsourcing and globalization. As a result, aspects such as operational complexity and globalization are making SC more and more vulnerable to risks that may have an important negative impact on the company's profitability-and even its survival [2] [3] [4] [5] [6]. Consequently, academics and practitioners are reporting increased concerns about the rise of SC disruptions and their implications [1] [3] [7] [8] [9].

Literature on SC risks shows that there are two fairly distinct broad categories of risks affecting SC design and management [8] [10] [11]: risks arising from the problems of

co-ordinating supply and demand and risks arising from disruptions to normal activities. This paper pays special attention to the second type of risks -SC disruptions [8] and how the different categories of vulnerabilities impact on the threats of a final SC disruption occurrence. SC disruption is defined in the extant literature as an unplanned, unintended and exceptional situation that disrupts the normal flow of goods and materials within a SC [2] [8] [12] [13].

Major SC disruptions have significant negative impact on both short and long-term operational and financial performance. They can cause physical damage, threaten production and distribution, damage sales, reduce company's revenue, cut into market share, inflate costs and send it over budget. Such disruptions can damage company credibility with investors, which result in a devastating impact on shareholder value, thereby driving up the cost of capital. [12] [14] Hendricks and Singhal (2003, 2005) analysed the effects of SC disruptions and empirically showed that these events have a significant negative impact on shareholder value and on operating performance (i.e., sales, operating income, return on assets). Additionally, this study indicates that companies experiencing a SC disruption suffer a 33 to 40% decline in stock price compared with industry peers over a three-year period. As result, it is not surprising to see that a recent FM Global study of more than 600 financial executives around the world found that respondents identified SC risks, more than any other, as having the greatest potential to disrupt their top revenue driver.

The worrisome news here is not just that most firms ignore risks or fail to recognize risk sometimes with dire consequences. Rather, it is that even among those that do, too many do not go deeper with the SC assessment and mitigation, i.e., reducing the likelihood of the occurrence, of a particular risk, reducing its potential impact, or both. Cisco, Pfizer, Boeing or DHL claimed that poor or inadequate risk management policies could have a severe impact on their performance and clients [15] [16]. It seems that managers are unable to create contingency rules and procedures for complex, high-risk business situations. For example, strategically focused business continuity plans are often not complemented with implementation plans at the operational or tactical levels, which enable organizations to respond quickly and efficiently to crisis situations. Or short term focus on the operations and their results can lead to significantly low importance of SC risks, which finally will have negative consequences in the SC [17].

Since SCs are vulnerable to disrupt, a better understanding of SC risk management is critical for both practitioners and researchers [6] [17] [18]. The development of a solid literature on SC risk management is still in progress and, specifically, there has been little effort to consolidate findings in a unifying picture [1] [19] [20]. The existing literature has discovered a wide range of SC risk management practices [17] [21], but findings remain disconnected, so there is no clear understanding of what SC risk management implies, which are the more adequate strategies and how to deploy them together. In addition to this, some recent theoretical studies have explained the importance of distinguishing between SC risk management and its possible antecedents [17] [22].

Accordingly, based on a sample of 909 firms representing 69 countries, the aim of this paper is empirically to examine types of SC risk management strategies that can be implemented within a SC and contingencies that impact the strategies that are selected. A related research objective is to analyze how the different strategies prevent a

disruption from occurring or respond quickly to contain the damage. To pursue this objective, we postulated that there are two main SC risk management approaches for avoiding SC disruptions: one that emerges from internal actions and operations within companies; and another involving actions undertaken with external SC partners; both implemented to reduce the probability of adverse events occurring or to diminish the effects of these adverse events [2] [7] [23] [24]. Considering these two approaches we propose a taxonomy that suggests four types of strategies –passive, follower, internal and collaborative.

Appropriate strategies are contextual and designed based on characteristic of a given situation [17] [21] [25]. SC vulnerability has long been identified as an important contingency variable that shapes the type of strategy employed [9] [26] [27] [28]. However, SC vulnerability cannot be observed directly [25]. It is determined by certain organizational and structural SC characteristics and the environment in which the SC is embedded (e.g. globalization of the sourcing network, customer or supplier dependence, SC complexity, among others). For our research, we follow Wagner and Neshat, [25] who identify three sources of vulnerabilities -environmental, the focal firm and the SC- that need to be understood in order to propose adequate management strategies. Consequently, this research adopts a contingency perspective and investigates the importance of a range of contextual antecedents, thus adopting a contingency perspective, as drivers of risk management strategies in a SC.

In doing so, we offer three main contributions to the literature. First, previous studies have limited the analysis of SC risk management to its reactive internal initiatives [8] [29]. However, in the present era of globalization, where organizations are increasingly expanding across international boundaries [18] [30], firms have to be able to manage disruption practices jointly with suppliers and/or customers in order to reduce the effects of disruptions [7] [5] [29] [31]. This paper takes the SC risk management literature beyond the internal focus by considering both the internal and interorganizational efforts and their interactions in a single model. Second, we observe that some existing publications argued that SC vulnerability is determined by certain structural characteristics and the environment [21] [25]. This study develops a more complete contingency-based research and extends the scope of the contextual antecedents incorporating the SC alignment issues since the attitudinal predisposition of the partners to align forces in the case of risk event is considered important to avoid the disruption occurrence [17] [4] [32]. Third, there is a shortage of empirical work in the area of SC risk management [1]. Most of the studies are qualitative, based on single or multiple case studies. Accordingly, typologies, which have often been used in the extant literature to describe the phenomenon underlying SC disruptions [11] [21], have a strong descriptive and prescriptive orientation. This literature lacks an explanatory and predictive orientation. This research focuses on a predictive orientation and provides empirical evidence linking a taxonomy of SC risk management strategies with contextual antecedents and the potential SC disruption occurrence.

The paper is structured as follows: in the next section we briefly review existing literature on SC risk management practices, their contextual antecedents and performance. This analysis allows us to provide a theoretical backdrop to our hypotheses. Research methodology is introduced before presenting the main results derived from the empirical analysis. Finally, we suggest theoretical and managerial implications and offer suggestions for future research.

## **SUPPLY CHAIN RISK MANAGEMENT**

From the Industrial Revolution until present, SCs have had to face important changes, evolving from high volume simple business models to extended SC networks. The consequences of these patterns of changes have been quite relevant and nowadays SCs are being stretched extensively to significant levels of SC dependence on globalization and efficiency.

But this opportunity for efficiency is not free. Efficiency helps in smoothing the SC operations but it also opens new sources of vulnerability if unexpected circumstances happen [33]. The tsunami catastrophe that struck Japan in March 2011 demonstrated the disturbing consequences of SC disruptions. The ripple effect of the stoppages to supply and production in Japan was felt in many areas of the world, because numerous key parts are exported to global operation from this region. Take, for example, the impact on Apple, which relied on suppliers in Japan for 25% of the components used in its new iPad 2 product. Moreover, many of these contractors were sole-source suppliers. The iPad 2 went on sale just hours after the tsunami hit, and the subsequent shutdowns caused stock shortages and long delays in deliveries. The fallout not only frustrated Apple's customers but also its shareholders since the company's share price declined by 8% due to the disruptions that followed the disaster.

Due to the current firm's dependence on customers and/or suppliers and inventory reduction trends, the severity of such an event will be amplified [34] [2]. Thus, the need to ensure continuity of the flow of goods along the SC, as well as shorter periods of time to return to its original or improved operations status, have motivated an emerging body of research in SC risk management [8] [21] [31] [35]. The effectiveness of SC risk management in dealing with SC disruptions depends on how well the organization is able to cope with or quickly recover from the impact of disruptions. Some authors pose that first an organization needs to understand the potential disruptions that may occur, and then it will be able to select mitigation approaches to diminish its potential effects [23]. According to the existing literature and within the context of a potential SC disruption, we can define SC risk management as the identification of potential sources of risk and implementation of appropriate strategies through a coordinated effort among the SC risk members to reduce the effects of a SC disruption [17] [36].

While the companies were not dependent on the actions of their SC members, they traditionally centred their risk management efforts on internal practices that entailed only functions within a single company. Recently, however, mature companies, known for their excellence in SC operations, have widened the focus of their SC risk management efforts to encompass factors external to the firm in order to align internal efforts with key suppliers and/or strategically important customers [17] [37]. Therefore, two perspectives for managing SC risks can be recognized: one that emerges from internal actions and operations within companies; and other involving actions undertaken with external SC partners. Both approaches can be complementary and are implemented with the objective of diminishing the effects of SC disruptions [2] [7] [23] [24].

Internal SC risk management practices contribute to the creation of more resilient firms through the deployment of risk preventive practices such as business continuity plans,

formal security procedures or emergency operations centres, all of which can serve to limit or mitigate the negative consequences of a disruption [17] [29]. This preventive efforts go together with other practices that deal directly with the SC operations within the company, which directly reduce the effect of disruption and indirectly also may reduce their vulnerability, such as postponement, flexibility, visibility, velocity or lean operations [17] [20] [21].

Inter-organizational SC risk management, on the other hand, require the deployment of practices that necessitate active cooperation upstream with the firm's SC partners, (suppliers of products or services, such as logistics service providers), and downstream with customers. Such approach implies the alignment of a firm's SC risk management practices with its most strategic SC actors. This alignment can be seen from the operational point of view, supporting smooth flows in efficient SCs, or from the more strategic point of view, including long term agreements based on knowledge integration or joint product and process innovation [21]. The SC risk management practices involving interorganizational interaction ensure that changes caused by a disruption can be absorbed by the SC through an effective response. It includes the SC partners' willingness to share even sensitive risk-event information [38] (Faisal et al., 2006). Thus, these management practices are important actions if the companies want to diminish the disruption effects on the SC dimensions that span corporate or even international boundaries [3].

### **A Supply Chain Risk Management taxonomy**

In order to examine the dual perspective SC risk management we use a configuration approach that establishes patterns or profiles capturing, in that sense, the complexities of organizational reality [39] and thus facilitating a holistic analysis of the phenomenon under investigation [40] [41] [42]. Instead of the pairwise relationships that the conventional econometric research focuses on, our approach focuses on relationships as simultaneous combinations of multiple dimensions [43].

Since companies may place differing emphasis on SC risk management practices (either internal or interorganizational) or on both approaches, various configurations of SC risk management can exist. Hence, we develop a parsimonious taxonomy that reveals insights into the underlying approaches of SC risk management and their relationships with the contextual antecedents and disruption occurrence that are useful in discussion, research and pedagogy [44]. Said taxonomy organizes and consolidates all information about group configurations so that it is easier for us to comprehend the differences in the composition of the two basic approaches that characterize SC risk management.

Figure 1 highlights how the two SC risk management approaches result in four extreme configurations. Where there are low levels of internal and interorganizational risk management practices, there is *passive SC risk management strategy*. This type of management is perceived as something that slows down the major objectives of cutting cost and inventories. Then, managers will strive to achieve these objectives at the cost of disproportionate risks. Contrary to the former situation is a *collaborative SC risk management strategy* where there are both high levels of internal and inter-organizational risk management. In this configuration, managers are not willing to mitigate and reduce risks alone. They are willing to connect processes and align forces to provide a more coordinate response to high levels of environmental and operational

risks inherent in global and complex SCs. In this case, SC risk management practices such as business continuity analysis or security procedures are developed jointly in collaboration with the SC partners. This configuration builds holistic and interorganizational capabilities to cope with threats to supply continuity and to quicken the restoring of the SC after a disruption [7].

-----Insert Figure 1 Approximately Here-----

When there is a bias towards high levels of internal SC risk management, there is an *internal based management strategy*. This configuration mainly trusts internal capabilities to cope with the consequences of unavoidable events of risk and guarantee the continuity of the material and information flow within the SC. However, decisions at this level might fail without effective coordination with the firm's SC partners. Finally, when SC risk management is biased toward inter organizational perspective, a *followers risk management strategy* exists. The companies which decide to take this strategy follow other SC partners in their attempts to look out for the effects of a potential disruption in their SC. The SC partners act as leaders in defining which strategies to employ so as to cope with the risks. In this configuration, firms attempt to deal with disruption issues with the external network. SC risk management priorities are established by different and complementary managers that have a key role in the SC. However, this configuration produces a limited opportunity to deal with the internal risk that demands mechanisms with the ability to take control of internal operations (e.g. reducing process variability, fixing the root causes or advance warning system that identify deviation to expectations and automatically identify corrective actions to be taken immediately). Consequently, we propose the following hypothesis:

**H1.** *An emergent taxonomy of SC risk management can be developed based on the company's internal and inter-organizational SC risk management efforts.*

## THEORETICAL MODEL

Existing contingency theory claims that organizational actions should be adapted depending on the context in which they are applied. Consequently, organizations should adjust their actions, structures, or processes to their context with the main purpose of maximizing performance [45] [46] (Lawrence and Lorsch, 1967; Thompson, 1967). If this "fit" is not achieved, "opportunities are lost, costs rise, and the maintenance of the organizations is threatened" [47]. This entails recognizing the factors motivating the choice of a particular SC risk management strategy for a given situation. This reasoning brings us to the assumption that decision makers must reconsider their actions and align their organizations to this changing environment in order to achieve a better fit [48].

Applied to the SC disruption arena, structural contingency theory [45] [49] posits that organizations should match their management practices to the SC vulnerabilities with the main objective of diminishing SC disruptions and subsequently control their effects on undermining SC performance [45] (Wagner and Bode, 2008). For our research, we follow Wagner and Neshat who state that vulnerabilities are determined by three factors: environment, focal firm and the SC [25]. This combination of structural and organizational characteristics and environmental factors are antecedents of SC vulnerabilities that affect the selection of certain SC risk management strategy. Additionally, SC risk management is expected to determine the frequency of SC

disruption occurrence. Consequently, a SC manager implementing SC risk management practices will take full advantage of the specification of these antecedents in order to achieve lower frequencies of SC disruption. The theoretical model postulated is shown in Fig. 2.

-----Insert Figure 2 Approximately Here-----

### **Contextual antecedents**

Normal Accident Theory (NAT) provides the theoretical support for exploring the structural and organizational characteristics and environmental factors that determine the level of SC vulnerability. This theory holds that accidents become inevitable or even normal in complex and tightly coupled technological systems [50]. While this theory has not been widely employed to frame SC research, its focus on normal accidents provide a meaningful lens from which to examine SC disruptions [18]. Given this theory, it is not surprising that lengthy and complex SCs, working with faster speeds, have become more prone to disruptions.

#### *Environment*

The environment for contingently specifying SC vulnerabilities is being created by factors outside the SC. We suggest further dividing these factors into two types: natural hazards and the socioeconomic environment. Natural hazards consist of issues due to “force majeure” such as hurricanes, tornados, earthquakes, or tsunamis. The socioeconomic environment transcends market features, encompassing broader socioeconomic forces such as recession, labour instability, political events or currency devaluation. While the first ones mainly present themselves in discrete circumstances, the others appear as continuous vulnerabilities. It should be noted that our model also includes the dynamics of a competitive environment or market as an exogenous characteristic of a whole SC, since it has long been identified as an important contingency variable in conceptual and empirical studies in operations management [51]. This model entails issues and problems that can arise from price or sales collapse due to the effect of competition.

Firms experience complex interactions with their environment when faced with unanticipated and/or unfamiliar events. Such events are not clearly visible, and the impact of these events on their SC processes cannot be immediately nor fully comprehended [50]. Because such firms have an increased risk of experiencing a SC disruption, they are more likely to make efforts to better prevent, detect, respond and recover from any risk. They are more likely to aggressively manage their SC risks. Such firms can manage some complex interaction with the environment by increasing the information sharing to increase overall SC visibility [18] or creating SC resilient capabilities to proactively respond to the environment [27]. For instance, when an external source of vulnerability manifests itself (e.g., market drop or earthquakes), a management practice oriented toward the inter-organizational context of the SC regarding suppliers, customers or other stakeholders may lead to a more efficient reduction of the SC disruption effect.

A recent example that illustrates this occurred just after the March 2011 tsunami in Japan. In order to avoid market collapse, a manufacturer of batteries for electronic

products located in the region proposed, with its more strategic customers, Philips and Sony, both relevant competitors in the electronics industry, to share out the scarce batteries available for their products. Philips and Sony agreed to cooperate. This strategy takes into account not only the approach of the originating company—the battery supplier—but also internal and external factors for its SC partners, since the two big competitors had to cooperate with each other about apportioning the available supply while simultaneously adapting their assembly schedules to this situation.

Cases like this highlight the relevance of implementing efforts to adjusting the management practices to a specific and unique environment created by the combination of the following sources of vulnerability: natural hazards, the market and the socioeconomic environment. Hence, we formulate the following hypothesis that argues that external environment is the base and antecedent for SC risk management.

***H2: Natural hazards, market, and the socioeconomic environment determine the supply chain risk management strategy.***

#### *Focal Firm*

According to the NAT, firm size and production type are considered structural antecedents of SC vulnerability [25]. Larger firms will be more often involved in SCs that are complex and tightly coupled. Studies have suggested that large organizations have likely targeted a broader set of customers and they will deal with higher degrees of outsourcing and off-shoring activities. Larger organizations may also be harder to integrate in a SC. On the contrary, small organizations are likely to have sources placed locally and nationally rather than internationally, which makes SC relationships closer [52] and therefore structural vulnerability is lower [25].

Thus, we expect a relationship between firm size and SC risk management strategy. Specifically, large organizations, characterized by having global sales, distributions and manufacturing activities, are more involved in collaborative SC risk management approaches than small organizations. For example, following 9/11, Continental Teves, a unit of Continental AG, which supplies automotive, industrial and agricultural products, had to make tough decisions regarding which of its customers would get parts that were in short supply. It looked at how many parts it had in stock for each customer and divided that by the customer's known production rate to determine how many days of production the customer would have before it ran out. Continental Teves then equalized the "days of production" metric across all its customers.

Different types of processes often have different types of operating characteristics, as proposed by NAT. While most manufacturing processes can be distinguished from one another on several dimensions, two are of primary importance: the volume of product produced and the tightness of connection or fit between the various parts of the operating system. These two dimensions are related to the role that the focal firm plays in the SC. Processes in manufacturing firms (either buyer or suppliers) are more tightly coupled systems and the interactive complexity of their processes is rather high. Consequently, in manufacturing firms problems propagate widely and rapidly through the operating system. Compared with manufacturing firms, other intermediate SC roles, like retailers, wholesalers or logistics service providers, are loosely coupled and the



interdependencies within the firm are less complex, indicating that vulnerability will be rather low [25] [18] [50].

Accordingly, we expect that manufacturing firms will implement more active SC risk management practices, such as collaborative or internal oriented strategies, than firms that occupy other roles in the SC. For example, in manufacturing firms with a tightly coupled system, visibility and traceability are key attributes for coping with vulnerability [18]. In this situations, it is often that one key member of the operational process has no detailed knowledge of what goes wrong in other parts of the process -e.g. finished goods inventory, production plans, capacity, actual demands or forecast, among others. So, with more connected and transparent processes, small and seemingly independent failures could be anticipated and detected and, consequently, disruptions avoided. Sharing real time information might be critical to smooth operational transactions.

***H3: Firm size and its role in the SC determine the supply chain risk management strategy.***

#### *Supply chain vulnerability*

Finally, SC vulnerability will also trigger a firm's concern about SC risk management activities. Given the more demanding contexts on outsourcing and off-shoring of activities [53] (Schoenherr, 2010), suppliers, customers, and logistics service providers are key actors in order to have leaner and more efficient SCs [54]. Accordingly, a SC also has to deal with disruptions when the source of vulnerability is about operational contingencies inside the SC, such as raw material supplier failure, finished goods manufacturing problems, transportation carrier failure or product quality issues [8] [55].

For example, SC risk management measures, such as working on the Business Continuity plan with the most important suppliers or with the most reliable ones in operational terms can help to reduce complexity and risky coupling. Under the NAT perspective, [50] state that the network of small- and medium-sized firms in Northern Italy where firms are linked through local and very controlled sourcing arrangements to develop and produce machinery and scientific instruments are less likely to experience a SC disruption than those with relationships of high interactive complexity. Furthermore, industries that require tighter coupling supply are more likely to reduce their vulnerability with a proper and proactive relationship with a supplier, using methods like information sharing, relationship development, joint reviews, etc. [56]. In the automotive industry, Robert Bosch experienced in 2005 a failure in detecting a defect in a coating built into pumps supplied to BMW or Audi. The strong dependence on suppliers in the auto industry and the tight coupling between the SC nodes usually brings low buffer inventories or lack of inspections that affect their SC operations. As a consequence Bosch's SC had to deal with a high degree of SC vulnerability and the small failure was not detected until final product failures were reported, resulting in a SC disruption [25].

Besides the operational contingences, the alignment between buyers and suppliers also can be a source of vulnerability. SC alignment in a context of risk management expresses the degree to which buyer and supplier share a common understanding of SC

risk management issues. Karl Weick has discussed how systems of sense-making are vitally important when specialization and decentralization results in the segregation of people and differentiation of processes [57]. Because SCs require coordination and alignment among buyers, suppliers and services providers, all SC members must be able to make sense of SC vulnerabilities so that they can be jointly aware of the potential consequences. A clear understanding of the impact of disruptions facilitates the way of re-taking the control over the SC operations in a shorter period of time, so they may continue with their normal activities and responsibilities, which is a key factor in SC operations. That is especially relevant since the perception of risk rather than objective assessment of risk guide decision-making behavior [58]. Similarly, subjective judgments of risk are a significant determinant of managerial choice [22] [31] [59]. Even when objective data is available to support decision-making, issues related to interpretation may interject bias into the risk assessment process [60].

Therefore, we adopt the view that SC joint sense making might better see the logic of mutual adjustment and enact coping mechanisms to provide the required agility for dealing with SC disruption. SC alignment is essential in harnessing collective actions within SC [61]. Dow Chemical illustrates this view. They have worked together with their suppliers to reduce the levels of hazardous materials to be transported, by means of integrating processes related to combining chemicals. As a result, a joint understanding of the sources of SC vulnerability reduced the exposure to potential SC disruptions [18]. Therefore, we hypothesize:

***H4:** Supply chain alignment and operational contingences determine the supply chain risk management strategy.*

### **Disruption occurrence**

One major goal of this research is to determine whether the use of different SC risk management strategies reduces the frequency with which firms experience the effects of disruptions. Although we propose that the SC context will have an impact on the importance that a firm gives to the different SC risk management approaches, we further believe that these differences significantly and differently affect the frequency of SC disruption occurrence.

Proponents of the High Reliability Theory (HRT) argue that firms can apply various strategies and organisational remedies to cope with interactive complexity and tightly coupled processes in order to create reliable organisations. These strategies involve the concern about failure, redundancy and slack in the systems, sensitivity to operations, decentralisation of authority, and commitment to resilience [62] [63] [64] [65].

As discussed in the SC risk management section, firms can become more reliable through internal or inter-organizational SC risk management strategies. In order to anticipate SC disruptions and to recover quickly, awareness systems, which provide assessment of potential SC disruptions, become key elements for SC risk management [7]. One example of creating awareness of risk involved the use of supplier financial appraisal reports at J&L Aerospace. These reports provided information about suppliers such as growth and profitability ratios, dependency ratios, liquidity and working capital management, and an overall financial rating of the supplier. The financial reports created internal awareness of financial risk that can arise at the supplier firms. An

awareness system would have helped to identify the liquidity and cash-flow problems that the Chrysler supplier Plastech had and that later lead it to bankruptcy. It caused a temporary shutting down of four Chrysler plants in 2008 that resulted in Chrysler losing millions of dollars.

Also, if business continuity plans or control systems for SC operations are in place and executed, they can lead to a reduction in a number of disruptions as well as the severity of disruptions, specifically if they are jointly developed with key SC partners [29] [66]. For example, an effective tool that boosts the control attribute is an emergency operations center. Its implementation helps to standardize the procedures about how to coordinate all the functions affected by a disruption. It facilitates the way of re-taking the control over the SC operations, so they may continue with their normal activities and responsibilities.

The response to disruptive events used to require that collaboration goes beyond the operational processes of SCs and spans management relationships in a more distant perimeter from the SC focal point, which provides the core value to final products. Collaboration across all the public and private actors, from companies to logistic providers or port authorities, is essential in achieving an efficient solution. Risk management priorities and paradigms should be jointly established with different and complementary stakeholders that have a key role in the SC external environment, like political authorities, customs, banks, shareholders or strategic customers and third party logistics. This collaboration requires the development of trust and transparency to ensure that disruptions are handled with agile and effective responses, while sharing culture towards active SC risk management.

Cisco Systems, the communication equipment manufacturer, has been working for a decade on maturing a robust SC risk management system [66]. This was stated by its Chairman and CEO John Chamber, “Cisco’s proactive approach and leading supply chain risk management capabilities were key to ensuring minimal impact to our customers during the Japan earthquake crisis”. They involved SC risk planning activities ranging from supplier monitoring and information exchange with suppliers and customers to contingency plans to control for SC vulnerabilities.

Furthermore, collaboration has been suggested as the “glue that holds SC organizations in a crisis together” [32, p. 623]. SC collaboration avoids opportunistic behavior on behalf of individual interests which would negatively diminish the response capability of the whole system. Cisco Systems was fully aware of that and the internal SC risk management team worked closely together with manufacturing operations, suppliers, logistics and transportation service providers and other partners to identify network nodes that are out of risk qualification tolerances as well as to develop resiliency plans [66]. Even after the disruption occurrence and subsequent SC recovery, collaboration is equally important with the main objective of continuously learning after these experiences [4]. This post disruption collaboration will improve the SC capabilities to deal with further disruptions: before, throughout and after the event. Thus, the implementation of SC risk management strategies implies some patterns of activity and subsequent coordinated actions that enhance the SC (a) to mitigate the potential effect of an event that may normally disrupt the SC operations, or (b) to recover from a manifested disruption. Consequently, we hypothesize:

*H5. SC risk management strategies determine the frequency with which firms experience the effects of disruption.*

**METHODOLOGY**

**Data Collection**

Survey-based research [67] [68] was used as the main empirical research methodology of this study. A group of academics and researchers led by the Center of Transportation and Logistics, MIT (CTL) under the MIT Global SCALE Risk Initiative designed and developed the questionnaire tool based on a thorough literature review. The questionnaire was then validated through a pre-test carried out with four academics, five SC executives, and two senior consultants in the field of SCM. These interviews allowed us to purify our survey items and rectify potential deficiencies. Minor adjustments were made on the basis of specific suggestions. Finally, the survey was reviewed and approved by MIT’s Committee on the Use of Humans as Experimental Subjects (COUHES). All the facets of this project adhered to COUHES regulations and protocols.

A large-scale, worldwide online survey was used as the base. The target respondents of our survey consisted of SC professionals at decision-making levels and in strategically oriented positions from different cultures, countries, and industries. Respondents were asked to provide information about their SC risk management experience, attitudes and opinions, major disruptions on their site, and SC practices. This study thus analyzes how the SC risk management and different sources of vulnerabilities, beyond their respective direct effects, can also interact and diminish the effect of a disruption within a SC, using the firm as the unit of analysis. It evaluates our hypotheses based on the action that the respondents companies take to deal with SC disruptions. To ensure the validity of our data, we also evaluated the respondents’ competency and knowledge of the subject at hand. Table 1 shows the profiles of the respondents. We measured respondents’ backgrounds: age (63.2% were older than 40), gender (82.2% males and 14.4% females, having no response for the rest), and education (62.1% held a university or master’s degree). Respondents averaged 12.9 years of experience in their industry (median = 13 years); 32.5% of them were middle managers, 32.8% senior managers, and 8% held the position of vice president. Collectively, the selected respondents were proven to be competent enough to complete the survey.

-----Insert Table 1 about here-----

Due to the global scope of this study, the survey was formally translated from English into eight languages or dialects (Portuguese, Brazilian Portuguese, Mexican Spanish, Castilian Spanish, German, Greek, Italian, and Mandarin Chinese) following a homogeneous and rigorous procedure for subsequent testing and further distribution to the target audience. In each of the different regions, a SC management professional association was key in reaching a larger number of SC professionals. For example, the Association for Operations Management – American Production and Inventory Control Society (APICS) and the Council of Supply Chain Management Professionals (CSCMP) collaborated in the United States, as did the Spanish logistics association Centro Español de Logística (CEL), among others. They sent out emails to their members asking them to participate in the survey. The data-gathering process took two

months (December 2009 through January 2010) with information collected simultaneously in all of the countries. The average time required to complete the survey was twelve minutes.

The webpage where the survey was posted reached 2240 visits and 1460 persons answered the survey. After screening out spurious and incomplete responses (less than half of the questions answered on the survey) conducting a missing value analysis (with a result of 1.5% overall) and deleting responses from countries not sufficiently represented, there were 909 valid, complete survey responses for the study. Table 2 shows the diversity that exists among the participating firms based on the number of employees and the different roles each of the companies have in their SCs. Likewise, Table 3 displays the variety of countries to which the participating firms belong. Before examining the data, every member of the research team who would have contact with the survey results had to take a basic online course on social and behavioural research and pass an exam. This course was provided by the Collaborative Institutional Training Initiative (CITI) Program for the Protection of Human Research Subjects.

-----Insert Tables 2 and 3 about here-----

Since we collected the information on the variables of interest from a single respondent within a single firm, common method bias could present a problem. The potential for common method bias was assessed based on Harman's test [69]. It consists of loading all of the variables into an exploratory factor analysis and examining the unrotated factor solution. Results revealed 7 distinct factors with eigenvalues above 1.0, which together explain more than 63.7% of the variance. The first factor accounted for only 20.9% of the variance. Since a single factor did not emerge and the first factor did not account for most of the variance, common method bias should not be an issue in the data.

## Measures

The measurement for the study is based on the multiple-items method, which enhances confidence in the accuracy and consistency of the assessment [68]. Table 4 presents the measurement items. We classify contextual antecedents as environment, the focus firm and SC, as explained in the theoretical section of this paper. Three variables were included to provide a comprehensive understanding of the *environment*. According to [3], market measures risk environment due to a price or sales collapse when faced with new competition. Natural hazards are very well identified in the extant literature and are defined as hurricanes, tornados, typhoons, earthquakes, tsunamis, floods, or mudslides [3] [7] [8] [35]. The socioeconomic context entails issues that affect the overall business context across industries: economic recession, protracted labour disputes, or sudden currency devaluation [3] [7]. The *focus firm* vulnerability is assessed by size, and the role of the firm in the SC. Firm size was measured as the number of employees and the annual revenues of the firm for the year 2009 [25]. The SC role ranges in manufacturer, retailer, wholesaler and logistics service provider. Finally, *the SC* vulnerability entails SC alignment and operational contingencies. Two items express the SC alignment; one measures the alignment with suppliers and other with customers [2] [18]. Operational contingencies are due to supplier, manufacturing, transportation, or product quality failures [8].

Pursuant with the extant SC management literature, we assess *SC risk management* through two different managerial dimensions: internal-operational and interorganizational strategies. Internal practices refer to the management strategies applied within the focal company and include having a risk manager, implementing a business continuity plan, following a formal security strategy, or managing emergency operations [8] [29]. Inter-organizational practices refer to the activities carried out jointly with suppliers or customers in order to reduce the final effect of such a disruption [7] [5] [29].

Finally, *SC disruptions* occur when the normal flow of goods and materials within a SC is disrupted, when internal operations are interrupted, when the company cannot communicate with SC participants, when the goods supply is lost, or when products cannot be delivered or shipped. According with [11] and adopted from [10], we base the measurements on the frequency with which the company has experienced these different types of SC disruptions.

The validation process for the survey instrument involved two steps: construct validity and reliability. Construct validity was measured with exploratory factor analysis (EFA) where 0.3 is considered to be the lowest significant factor loading to define constructs [64] (Hair et al., 1998). Our exploratory factor analysis for all the items of multi-item scales resulted in theoretically expected factor solutions. We then computed the reliability coefficients (Cronbach's alpha) [70], which ranged between 0.67 and 0.85, well exceeding the minimum limit of 0.6 [71] . We also computed the average variance explained (AVE) [68], which was in the range of 52.5 and 66.1.

-----Insert Table 4 Approximately Here -----

## Analysis Approach

There were two stages to our analysis: first the identification of the patterns/profiles of SC risk management and later the comparison of contextual antecedents and performance outcomes in the groups. In the first case, we employed cluster analysis to classify the firms based on their internal and interorganizational SC risk management practices, thereby identifying SC risk management configurations. In the second case, we used ANOVA and Turkey comparison tests in order to identify significant differences across the SC risk management clusters in terms of the vulnerabilities and occurrence of the disruption.

## RESULTS

Table 5 shows the differences in SC risk management in terms of the utilization of internal and inter-organizational SC risk management practices among each of the four clusters. Cluster 1 includes 312 firms with low levels in both internal and inter-organizational SC risk management practices, while high levels in these two dimensions characterize cluster 3, with 231 cases. Hence cluster 1 represents a pattern of passive SC risk management while cluster 3 presents a pattern of active SC risk management in both of the strategies. These two clusters represent strategies that combine either high or low levels across the two integrative mechanisms. On the contrary, cluster 2 and cluster 4 present a focused SC risk management strategy compared with cluster 1 and cluster 3. They highlight the importance of only one of the SC risk management strategies.

Furthermore cluster 2, with 218 cases, is characterized by low levels of internal risk management practices and high levels of inter-organizational practices, while cluster 4, with 148 cases, has high levels of internal practices and low levels of inter-organizational practices. Hence cluster 2 corresponds to companies which only follow practices with SC partners, what we term as *followers* of SC risk management strategies, while cluster 4 has been termed as internal biased . These results provide support for hypothesis 1.

-----Insert Table 5 Approximately Here -----

Next, we used ANOVA and Tukey comparison tests in order to identify significant differences across the clusters in terms of contextual antecedents. We also tested the assumptions of homogeneity of variance (Levene’s test and Brown–Forsythe test).Table 6 shows descriptive statistics (mean and deviation values) and the results of ANOVA test, Levene test, and Brown–Forsythe test for each cluster. Hypothesis 2 states that environmental vulnerability determines SC risk management strategies. Our results did not find any difference in SC risk management due to the vulnerabilities coming from factors outside the SC and did not support this hypothesis. Hypothesis 3 states that vulnerabilities come from firm’s structural characteristics such as firm size and its role in the SC, determine SC risk management strategies. The results show that collaborative SC risk management strategies (cluster 3) are associated with the largest companies. Significant differences in size, both from annual revenues and from the number of employees point of view, are also found between those firms that follow more active strategies (collaborative or internal) and those that do it at a lower level (passive and follower). So, firms choosing active strategies (cluster 3 and 4) are bigger than the other 2 groups. In the case of the SC role of the firm, our results show that manufacturing firms tend to follow their SC partners’ strategies regarding SC risk management (cluster 2) more frequently than those that execute internal strategies (cluster 4). Thus hypothesis 3 was supported.

Finally, hypothesis 4 states that SC vulnerability influences SC risk management strategies. Table 6 presents significant differences in terms SC Collaborative and followers SC risk management strategies (cluster 2 and 3), considered similar in terms of SC alignment, show a bigger fit with their customers and suppliers than do the passive and internal SC risk management strategies (cluster 1 and 4). In the case of the SC operational contingency , results show that firms operating under collaborative SC risk management strategies (cluster 3) present lower levels of SC vulnerability than internal (cluster 4), followers (cluster 2) and passive (cluster 1) SC risk management strategies . These results provide partial support to Hypothesis 4.

-----Insert Table 6 Approximately Here -----

Finally, we followed the same procedure for examining the relationship between SC risk management strategies and disruption occurrence. Table 7 also shows significant differences in terms of frequency with which firms experience the effect of disruption as a result of variations in SC risk management, thus providing support for hypothesis 5. As indicated by the ANOVA test, results reveal that distinctions in terms of occurrence of disruption is particularly salient between firms characterized by followers or collaborative SC risk management and the remaining firms. Although, firms typified by a collaborative SC risk management are the best performing (lowest mean value) in

terms of disruption occurrence, these firms and those characterized by followers strategies can be considered homogeneous in terms of occurrence of a disruption. Figure 3 shows how the four clusters were differentiated from each other by the two SC risk management basic approaches and the final effect on disruption occurrence, whose degree is represented by ball's diameter.

-----Insert Table 7 and Figure 3 Approximately Here -----

## **DISCUSSION AND CONCLUSIONS**

Regardless of how extensively it is mentioned in the literature, SC disruptions and related issues continue to challenge academics and industry executives worldwide. In fact, the value of the SC begins to decay and the rate of benefits slows down as unanticipated incidents hinder the normal flow of goods and materials within a SC. This section provides research implications as well as managerial implications with regard to the role of different SC risk management strategies and how they are determined by certain sources of vulnerability, provoking relevant effects in how SC disruptions occur.

### **A Taxonomy of SC risk management strategies**

This paper uses a configuration approach to examine the role of SC risk management strategies. This study has helped to shed light on the emergent taxonomy as it relates to the multidimensional character of SC risk management. This holistic analysis has demonstrated a clear structure of four different configurations of how companies manage SC risk in terms of two basic approaches: internal and/or inter-organizational. One configuration of companies faces the lowest activity of risk management. The companies classified within this cluster, termed as passive, are the most risky ones since they don't show any prediction or prevention in terms of SC disruptions. They will simply improvise once an important contingency will potentially impact them and consequently the SC in which they operate will suffer important and frequent interruptions that will damage their competitiveness.

Within the middle of the range between the more passive and more active companies in terms of SC risk management, there is a group of companies that follows only internal risk management practices, like business continuity plans, assigning clear responsibilities and roles in terms of risk management teams, as well as deploying formal emergency and security procedures. This option of managing the vulnerability implies a greater control of the internal operations but the company also needs to be alert about how the other SC players control their own operations, which is not easy without additional effort on the SC risk awareness.

There are other relevant group of companies that simply follow what their leaders, in terms of SC knowledge, market dominance or even operational experience, dictate about how to deal with SC risks. Although these companies are dependent on the decisions from other SC actors, this SC risk management strategy seems to perform well in order to diminish the effects of a potential disruption. Although, this strategy seems to require low effort to get implemented since it resides on the SC partner's efforts, it requires additional effort in terms of alignment with suppliers and customers in SC design and management, especially with customers, as our results have shown.



Surprisingly this strategy has been taken mainly by manufacturers, instead of other SC roles, like retailers or logistics service providers.

On the range extreme we found the most active and complex SC risk management strategies which require maturation in their SC relationships with SC partners. This strategy, termed as Collaborative, will support a smoother functioning and more efficient SC. Collaboration between customers and particularly suppliers, as our results demonstrate, helps ensure that business continuity plans and security procedures are aligned and all parties are better positioned to respond quickly and efficiently in even the most difficult circumstances. This research also shows that firm size is also important in determining the implementation of collaborative SC risk management strategies, since usually these companies have to deal with more complex and tightly coupled SC operations and more broaden markets, which require more active and comprehensive procedures expanding the whole SC. Companies within this configuration establish coherence between the supply chain design and the supply chain risk management as well as their co-evolution. Usually, the way they configure and design a supply chain brings additional vulnerabilities and therefore an additional effort for better managing risks is needed from the very start of the supply chain design. This requires the combination of reactive-proactive approaches. This group of companies matured their understanding about resiliency by taking a next step into the evolution of their supply chain risk management. This means integrating the resiliency concept as part of product innovation as well as supply chain process innovation. This implies a significant cultural change internally within the companies for the organizational engagement required, as well as externally in its expanded and diverse value chain, in order to be prepared when an important incident could damage them. The effectiveness of this collaborative strategy in reducing the effects of disruption occurrence, seems to be in conflict with the apparent reluctance of companies to collaborative under risk situations, as supported by previous research [20] [72].

Summarizing, this taxonomy has shown to be reliable in order to understand how a broad range of companies from all over the world, dealing with complex and global SCs, assess the mix of SC risk management in order to deal with different sources of vulnerability that threaten their business and ultimately the competitiveness of their SCs.

### **Limitations and future research avenues**

The study must be viewed in the light of some limitations. First, although the main focus of the study regarding SC risk management is on two basic approaches—internal and interorganizational—to shed light on their complementary effects on diminishing a potential disruption, a more detailed research should be developed in order to understand the interaction with SC management strategies and their implications. This would imply expanding the study to specific practices recognized by the literature for building resilience, such as redundancy in the supplying base, extra capacity, SC flexibility deployment, postponement strategies, customization, holding extra inventory, lean SCs, among others [7] [34] [31]. Most of these practices are closely related to how a SC is designed and consequently how it is operated.

As suggested by several relevant scholars in this field, the investigation of how organizational culture affects the perceptions of risks and the way different national

cultures would react to diverse sources of threats is awaiting future research [73] [31]. Considering the worldwide scope of the data gathered for this empirical study, they may be very pertinent to an investigation of the universality of management applicability in the SC disruption context.

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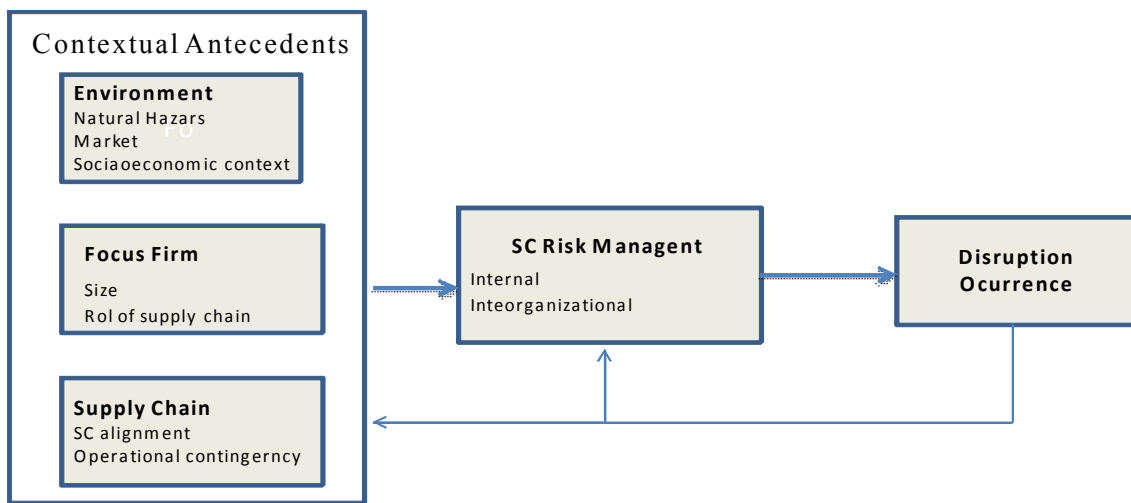
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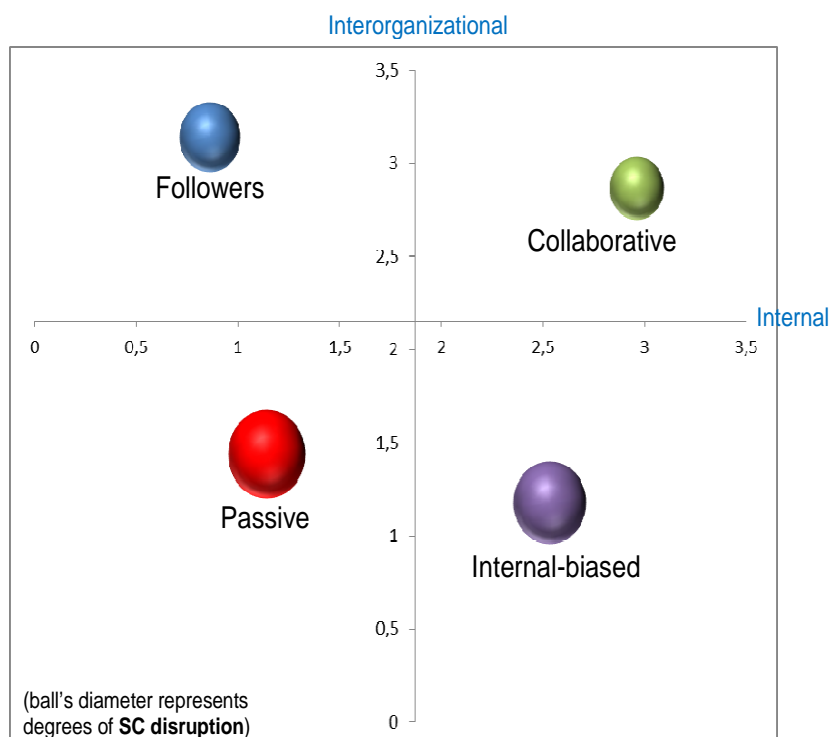
**Figure 1. SC Risk Management Taxonomies**

		INTERNAL STRATEGIES	
		Low	High
INTERORGANIZATIONAL STRATEGIES	Low	Cluster 1: <b>Passive</b>	Cluster 4: <b>Internal</b>
	High	Cluster 2: <b>Follower</b>	Cluster 3: <b>Collaborative</b>

**Figure 2. Theoretical model**



**Figure 3. SC Risk Management Taxonomies and SC Disruption**





**Table 1. Profile of Respondents**

<b>Job Level</b>	<b>%</b>	<b>Age</b>	<b>%</b>
Worker	11.3%	20–39	36.78
Team Leader	6.5%	40–59	58.33
Supervisor	7.1%	60 +years	4.89
Middle Manager	34.5%	<b>Gender</b>	<b>%</b>
Senior Manager	32.8%	Males	82.2
Vice President	8.0%	Females	14.4

**Table 2. Profiles of Responding Companies by Size**

	Total	Manufacturer	Retailer	Wholesaler	3PL	Other
Total number of employees	909	66%	5%	6%	9%	15%
1–100	26%	23%	19%	31%	37%	38%
101–1000	35%	36%	28%	42%	36%	30%
1001–over2000	39%	42%	53%	28%	27%	33%

**Table 3. Variety of Countries Participating in the Research**

<b>Country</b>	<b>%</b>
Brazil	4.1
Canada	1.6
Colombia	1.2
China	3.8
Germany	1.0
India	4.6
Italy	5.1
Mexico	2.6
South Africa	10.8
Spain	8.0
Switzerland	9.2
United Kingdom	1.5
United States	33.1
Other	13.4
Total	100.0

**Table 4.Measurement Items**

VARIABLES	FACTOR
<b>Environmental Vulnerability</b>	
<b>NATURAL HAZARDS Alpha= 0,75</b>	
How often has your supply chain (at your site) been disrupted by these events?	
1 Hurricanes, tornados, or typhoons	0.82
2 Earthquakes or tsunamis	0.85
3 Floods or mudslides	0.74
<b>MARKET Alpha= 0,79</b>	
How often has your supply chain (at your site) been disrupted by these events?	
1 Price collapse due to a new competitor	0.86
2 Sales collapse due to a new competing product	0.87
<b>SOCIOECONOMIC Alpha= 0,67</b>	
How often has your supply chain (at your site) been disrupted by these events?	
1 Economic recession	0.67
2 Protracted labor disputes	0.75
3 Sudden currency devaluation	0.78
<b>Focal Firm Vulnerability</b>	
<b>SIZE</b>	
Tell us about your company: Number of people worldwide	
Size of Annual Revenues (Globally) in USD	
<b>SC ROLE</b>	
Manufacturer	
Retailer	
3PL	
<b>Supply chain Vulnerability</b>	
<b>SC alignment</b>	
How well do your most important suppliers share your company's sense of urgency for on-time delivery?	-
How well does your company share the same sense of urgency around on-time delivery as your most important customers?	-
<b>OPERATIONAL CONTINGENCY Alpha= 0,76</b>	
How often has your supply chain (at your site) been disrupted by these events?	
1 Raw material supplier failure	0.71
2 Finished goods manufacturing failure	0.81
3 Transportation carrier failure	0.72
4 Product quality Failure	0.74
<b>SC Risk Management</b>	
<b>INTERNAL Alpha= 0,80</b>	
Tell us about Supply Chain Risk Management at your company	
1 We have a "risk" manager or group	0.75
2 We have a business continuity plan	0.77
3 We have a formal security strategy	0.69
4 We have an emergency operations centre	0.75
<b>INTERORGANIZATIONAL Alpha= 0,79</b>	
Tell us about Supply Chain Risk Management at your company	
1 We actively work on supply chain risk management	0.69
2 We work with customers on supply chain risk management	0.79
3 We work with suppliers on supply chain risk management	0.89
<b>Disruption OccurrenceAlpha= 0,70</b>	
How frequently have you experienced the following types of supply chain disruption?	
1 Your own internal operations are interrupted (e.g. power failure, machine breakdown, fire, etc.)	0.78
2 You cannot communicate with vendors, customers or other sites (e.g. systems fail, Internet down, etc.)	0.79
3 You lose supply of quality materials (e.g. supplier fails or cannot deliver, bad product quality, etc.)	0.75
4 You cannot ship or deliver your products (e.g. no transportation, ports closed, roads blocked, etc.)	0.78

	Cluster 1: Passive	Cluster 2: Follower	Cluster 3: Collaborative	Cluster 4: Internal	Total	F (anova)
Internal	1,14	0,86	2,96	2,53	4,96	1167.31***
Inter-organizational	1,44	3,14	2,87	1,18	7,45	675.72***
N	311	218	231	148	909	7,80***

**Table 6. Results of Cluster Analysis and ANOVA Results for Contextual Antecedents. Mean (Standard Deviation)**

[illegible]

**Table 7. Results of Cluster Analysis and ANOVA Results for Disruption Occurrence.** Mean (Standard Deviation)

	Cluster 1: Passive	Cluster 2: Followers	Cluster 3: Collaborative	Cluster 4: Internal	Total	F (anova)	Levene's Test	Brown- Forsythe
Disruption occurrence	2,29 (1,08)	1,99 (0,88)	1,89 (1,04)	2,20 (1,03)	2,09 (1,03)	7,80***	3,25*	7,92***
Main Group differences (Tukey Test):								
Disruption occurrence	(1-2)** (1-3)*** (3-4)*							
*p<0.1 **p<0.01 ***p<0.001								