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Part I

## Part One



# Supply chain disturbances and resilience strategies: a secondary data study\*

Helena Carvalho<sup>†</sup>, Meysam Maleki, Vladimir Trajkovski, V. Cruz-Machado

UNIDEMI, Department of Mechanical and Industrial Engineering, Faculdade de Ciências Tecnologia da Universidade Nova de Lisboa, Caparica, Portugal

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**Abstract** — This paper is a review over a variety of events which lead to disruption conditions in supply chains and identifies correspondent resilient strategies for each condition. The paper objective is to make a link between the problems created by events and strategies that managers can use to avoid or mitigate the negative aspects of those problems and improve post-event recovery. To attain the paper objectives it was use archived media news to collect empirical data about disturbances (events), their negative effects (problems), and resilience strategies. In the data collection phase, the aim was to keep diversities and be comprehensive. Using empirical evidences from the sample is developed a graph to show the links between supply chain disturbances, problems and resilience. This research provides supply chain managers with some alternative strategies to opt for the best available decision, improving the post-event management process.

**Keywords:** supply chain, resilience strategies, supply chain disturbances, secondary data

## 1 Introduction

A “supply chain” it is usually defined as “the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer” (Christopher, 1992 [5]). According to Zarandi et al. (2007) [38] the main focus of supply chain management is organizing internal and external resources of an economic enterprise comprehensively. Duarte et al. (2010) [8] referred the type of supply chain strategies deployed by managers will influence the supply chain performance. A set of supply chain strategies is proposed by Carvalho and Cruz-Machado (2004) [4] including lean, agile, resilience and green paradigms.

The uncertainty associated with supply chain events is recognized as one of the major problems in managing and controlling supply chains (Vorst and Beulens, 2002 [7]). Some efforts, like improving forecasting accuracy and process variation reduction could be made in order to minimize the uncertainty presents in the decision making process (Field et al., 2006 [13]). However, there is another type of uncertainty, derived from events that can not be predicted or controlled by the decision makers, such as nature hazards or accidents (Wiboonratr and Kosavisutte, 2009 [36]). In a global economy, with supply chains’ crossing several countries and continents several times, from raw material to final product, those events, even if they happen in a remote place, can create large-scale disruptions. These disruptions are propagated throughout the supply chain, affecting the ability of the organizations to meet previously made commitments. Those events can cause se-

vere negative effects in supply chain leading to unfulfilled orders. In actual competitive market, it is necessary that supply chain becomes more resilient to those events.

This paper primary objective is to investigate the empirical links between disturbances and resilience strategies in a supply chain context. Several contributions on this subject can be found in literature Wong and Arlbjom (2008) [37] identified several supply chain uncertainties and related them to potential mitigation strategies. This paper fills a void in the literature (Oke and Gopalakrishnan, 2009 [21]; Simangunsong et al., 2010 [11]) by providing researchers and practitioner’s the links between supply chain disturbances and resilience strategies

## 2 State of the art

### 2.1 Supply chain disturbances

Rupture conditions in supply chain are observed when organizations are subject to disruptions, caused by sudden and unforeseen events (Ponomarov and Holcomb, 2009 [23]). An example of catastrophic event is September 11, 2001, where the terrorist attacks destroyed New York’s World Trade Center Towers. Automakers like Ford and Toyota had to stop their production lines in US facilities due the delays in the delivery of parts coming from foreign countries (Sheffi, 2001 [28]). However, others types of disruptions less catastrophic, but highly severe could occur; like the Robert Bosch GmbH example where in 2005 a quality defect in a small component supplied by another company resulted in the recall of several thousands of cars (Wagner and Bode, 2008 [35]).

In supply chain literature the terms uncertainty and risk are frequently used interchangeably (Ritchie et al., 2008 [10]). Tang (2006) [32] classified the supply chain risks in two categories: (i) supply chain operational risks, defined as “the inherent uncertainties such as uncertain customer demand, uncertain supply, and uncertain cost”; and (ii) disruption risks, defined as “the major disruptions caused by natural and man-made disasters such as earthquakes, floods, hurricanes, terrorist attacks, etc., or economic crises such as currency evaluation or strikes”. Jüttner (2005) [17] defined supply chain vulnerability as “an exposure to serious disturbance arising from supply chain risks and affecting the supply chain’s ability to effectively serve the end customer market”. To Azevedo et al. (2008) [1] supply chain vulnerability “is the incapacity of the supply chain, at a moment, to react to the disturbances and consequently to attain its objectives”. The term supply chain disturbance is been used to describe all the negative events that can

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<sup>†</sup> Correspondence to: Tel.: +351-212 948 542. E-mail address: hmlc@fct.unl.pt.

affect the supply chain in a broad context. To Barroso, Machado, and Cruz-Machado [3] disturbance is defined as “an unforeseeable event, which affects usual operation and stability of an organization or a supply chain”. It is possible to conclude that there are different types of events affecting negatively the supply chain behaviour. In this paper all these events, regardless of their nature, are denominated as supply chain disturbances.

## 2.2 Supply chain resilience strategies

To minimize the negative impact of supply chain disturbances, it is necessary to identify which are the system characteristics that can be used to manage the supply chain behaviour when disturbance occurs. Traditional production systems practices try to anticipate and resist to perturbations; however, new approaches are needed to assure a high level of responsiveness and to seek for efficient behaviours to react to disturbances. However a new type of system can be developed, the resilient systems with the ability to return to its original state or to a new one, more desirable, after experiencing a disturbance (Peck, 2005 [22]; Tang, 2006a [31]).

According to the supply chain failure chain managers will opt for different strategies to overcome the supply chain failures and return to the normal behaviour. For example in the event of the West Coast Port Lockout in 2002, the joint venture between Toyota and GM experienced a significant parts shortage to assemble its car. So, to be able to continue with production the company used air transport to ship some parts from Asia which increased the cost of each car by 300 to 600 (Sheffi and Rice, 2005 [29]). Tomlin (2006) [33] proposes mitigation and contingency tactics to overcome the negative effects of disturbances. Mitigation tactics are those in which the firm takes some action in advance of disruptions and so incurs the cost of the action regardless of whether a disruption occurs. The more efficient the mitigation strategies, the less severe are the negative effects. After the event occurrence, supply chain managers should implement some policies to return to the initial state. These policies are related with the contingency strategies: those in which a firm takes an action only in the event a disruption occurs (Peck, 2005 [22]). The ability to recover from a disturbance occurrence is related to development of responsiveness capabilities through flexibility and redundancy (Rice and Caniato, 2003 [24]). The more efficient contingency strategies, the smaller will be the recovery time.

In literature several authors prescribe strategies to increase supply chain resilience namely. Tang (Azevedo et al., 2008 [1]) proposes strategies based on: (1) postponement; (2) strategic stock; (3) flexible supply base; (4) make-and-buy trade-off; (5) economic supply incentives; (6) flexible transportation; (7) revenue management; (8) dynamic assortment planning; and (9) silent product rollover. Christopher and Peck (2004) [6] state that resilience in supply chains should be designed according to the following principles: (1) selecting supply chain strategies that keep several options open; (2) re-examining the ‘efficiency vs. redundancy’ trade off; (3) developing collaborative working across supply chains to help mitigating risk; (4) developing visibility to a clear view of upstream and downstream inventories, demand and supply conditions, and production and purchasing schedules; (5) improving supply chain velocity through streamlined processes, reduced inbound lead-times and non-value added time reduction. Besides, Iakovou et al. (2005) [9] refers to resilience interventions as: (1) flexible sourcing; (2) demand-based management; (3) strategic safety stock; (4) total supply chain visibility; and (5) process and knowledge back-up.

## 3 Research methodology

The primary objective is to establish empirical links between disturbances, problems and resilience strategies in a supply chain context. An inductive research approach was used; where theory emerges from empirical observations (Spens and Kovács, 2006 [30]; Golicic et al., 2005 [26]). This approach was selected to identify the main variables describing the supply chain resilience phenomenon and relationships among them. According to Golicic et al. (2004) [6] the qualitative path begins with the data collection; next the phenomenon is described from the point of view of informants; and finally ends with building a substantive theory from the descriptive data, identifying the main variables and relationships among them. Therefore in the first stage it is necessary to understand the effect of disturbances on supply chains and how companies overcome its negative effects. A case study approach was chosen for investigation of the research questions. This approach is adequate when the boundaries of a phenomenon are not only still unclear, but there is also no control over behavioural events (Rowley, 2002 [25]).

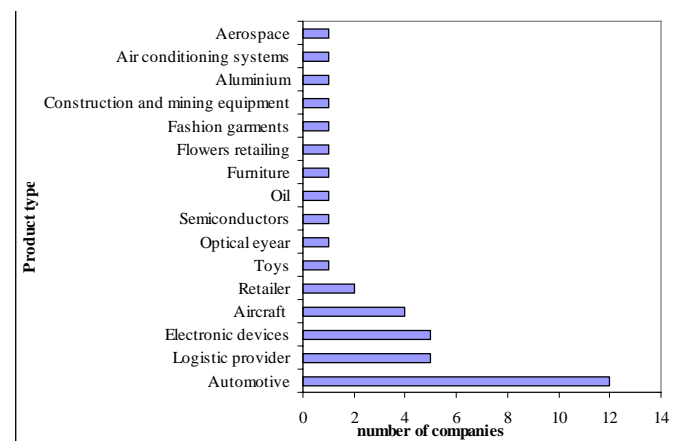
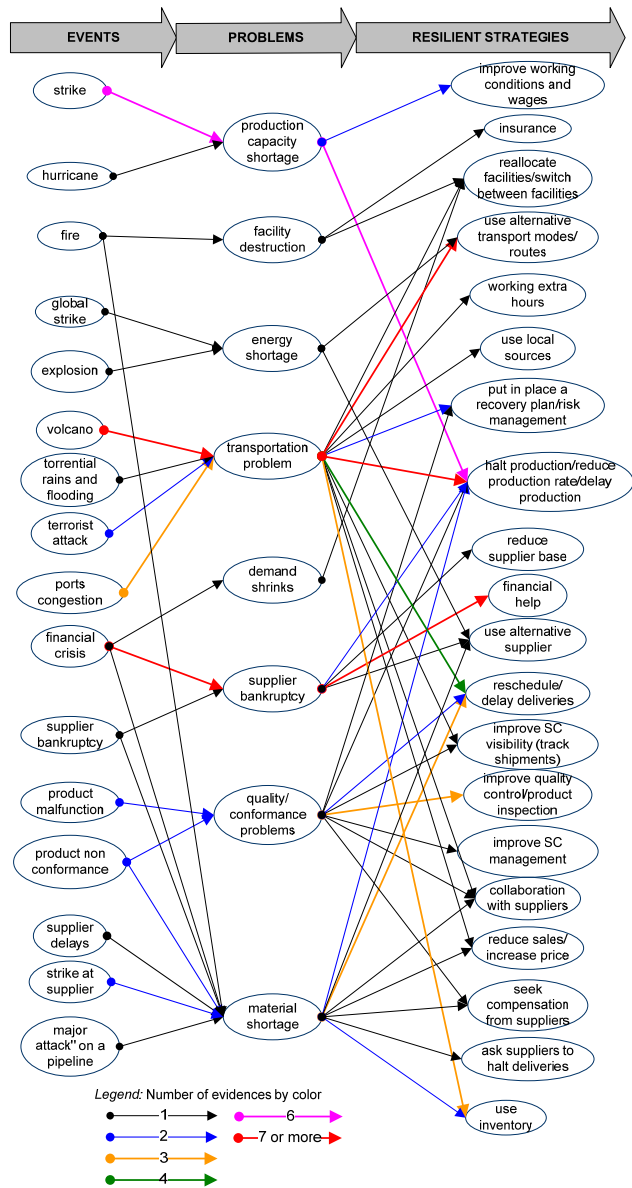


Fig. 1 Sample characterization

To attain the paper objective a sample with case studies was elaborated from grey literature were selected and analysed in detail. Despite, the study is limited to the selected case studies and to the available data in external sources, this research design helps to define issues specifically before undertaking a primary study like an in-depth case study.

Using a methodology similar to Visich et al. (2009) [34], Hendricks et al. (2009) [16], Mckinnon (2006) [19] and Finch (2004) [14] the secondary data for this research was gathered from the analysis of news published in grey literature. It was used a broad range of sources, namely specialized news magazines (e.g. Industry Week, Supply Chain Standard, Logistic Manager, and Logistic Week), and the Reuters global news agency. Electronic searches were undertaken using the combination of the terms: “supply chain”, “material shortage”, “part shortage”, “component shortage”, “stop production”, “down day”, “halt plant”, “production halt”, “production stoppage”, “disruption, failure, interruption, stoppage. The time line was from 2005 to 2010. In total 452 news and articles were obtained and analysed in detail. The selection criterion to a company be part of the study was that the references should describe a real situation where a company has subject to a supply chain disturbance being identified the failure a strategy to overcome. From the 452 news, 47 references were select to be part of this research (Appendix A). The final sample is constituted by 38 companies. Fig. 2 summarizes the sample profiles according to the product type.



**Fig. 2** Graph with links between supply chain disturbances, problems and resilient strategies

From these case study data base, it was collected secondary data related to the supply chain disturbance (which was the event), problems and strategies (which was the response). In what is concerned to the sample analysis, it is important to have in attention that only the information contained in the selected news has been used. Therefore the results are biased by the available information. This means that this study does not cover all the possibilities of disturbances and resilience strategies. It covers only the events and strategies reported in the sample. However, the aim of the research was to be comprehensive not exhaustive. The objective is not to offer further insight into the single cases, but to bring them together to get a wider picture and learn from the cross-case analyses (Seuring, 2004 [27]).

#### 4 Empirical findings

Examples of empirical evidences of events found in the sample include the natural events (like cloud of ash from Iceland’s Eyjafjallaj?kull, hurricanes, and floods), man made events (like strikes and terrorist attacks), accidents (like fire and explosion), events external to the supply chain (like financial) or internal to the supply chain (like supplier delays, product non conformance), among oth-

ers. The most referred event is the volcano ash cloud that leads to the closure of most of Europe’s airspace from 15 until 23 April 2010. In next weeks, airspace was closed intermittently in different geographic zones of Europe. The high number of references to this event in sample is justified due to the recent occurrence of this event and to the huge impact in the global economy. Another relevant event is the financial crisis which leads to the collapsing of sales, putting in danger the financial health of companies. The global effect of this event is illustrated in this citation: “PricewaterhouseCoopers estimates 670,000 small firms have already closed across China in the wake of the global crisis” (Fenton, 2009 [12]). Other event with negative effect is related product non conformance. The Boeing example provides some indications about this disturbance: “(Boeing) It did not anticipate how hard it would be to ensure that high-quality work from a vast array of suppliers arrived on time at its Everett, Washington, plant.” (McCormick and Grenon, 2009 [18]).

The sample also provides evidences that the events will derived in 8 main supply chain problems namely: “transportation problem”, “material shortage”, “supplier bankruptcy”, “production capacity shortage”, “quality/conformance problems”, “energy shortage”, “facility destruction” and “demand shrinks”. The most referred problem in sample is “transportation problem”. In fact the recent trends to extend globally supply chains, in addition to the deployment of lean practices to improve productivity, make the supply chains highly dependent on timely transportation. One citation reflecting this aspect is: “With an increasing number of companies operating just-in-time supply chains, it is vital that logistics firms keep cargo moving even when the services offered by airlines, trucking firms, ports or shipping lines grind to a halt (. . .) Having the ability to continue operations can help to avoid the hefty penalties associated with production delays. In the automotive sector, these can amount to 1million per hour” (NewDesk, 2010[20]).

To overcome these problems, a set of 20 supply chain strategies were identified in the sample. One of most referred in sample is the use of alternative transport modes/routes. In Land Rover case study this strategy deployment is explained with detail: “Jaguar Land Rover activated its contingency planning process to secure its supply chain from outside Europe. This included the chartering of an Ilyushin 76 aircraft to bring in more urgent supplies. Significant rescheduling of part availability from various suppliers was required, new shipping documentation prepared, consignments assembled and, within 20 hours, the aircraft was ready to take-off” (Austin, 2010 [2]). In worst case situation, the companies can be forced to halt, delay or reduce their production: “BMW is partially halting production at several sites because of spare parts not arriving due to the turmoil in European air traffic.” (France-Press, 2010 [15]).

Using the empirical evidences collected in sample a graph was develop to represent the links between disturbances and resilience strategies in a supply chain context (Fig. 2). In the graph the nodes represent events, problems and strategies. The arcs uses a colour code was used to identify the number of empirical evidences that supports the link between the nodes.

The graph in Fig. 2 enclosures the main relationships between supply chain disturbances that could happen and supply chain failures derived from them. And also contains the relationships between resilience strategies and supply chain problems. It makes possible the identification of relationships between the different elements. For example, if a “strike at the supplier” occurs, then it will probably lead to a “material shortage”. To overcome this problem, the model provides the 8 different strategies that can be used

to avoid or minimized this problem. The graph also supports visualizing the complexities in supply chain, since sometimes the same events can provoke different types of problems. For example, if the “product non-conformance occurs”, two possible problems could occur: “material shortage”, “quality/conformance problems”. To overcome these failures, a total of 9 strategies are derived from the graph; some of these strategies are common to the two problems (e.g. halt production and reschedule deliveries) others are just related to one problem (e.g. “use inventory” to overcome the “material shortage”).

The graph can be used by supply chain decision makers to: (1) identify the most likely problems which may endanger their supply chain (2) a variety of resilience strategies to encounter problems. Additionally it offers a holistic perspective towards supply chain resilience improvement, which decision makers could consider in the design and implementation of resilient strategies.

## 5 Conclusions

The identification of links between supply chain disturbances and resilience strategies was the base of this study. Secondary data was collected from a sample with 38 case studies derived from news media. In the sample contains evidences of 16 different disturbances, which will lead to 8 supply chain problems. These problems are the final consequence of the negative effects of disturbances in supply chain. The sample also provides empirical evidences of 20 resilience practices that can be deployed in the supply chain context.

Using the empirical evidences collected from the sample, a graph with the links between supply chain disturbances and resilience strategies was developed. The graph is proposed with two main objectives. The first one is to identify the links between disturbances and problems; this is to response to research question how the occurrence of a particular event can affect the supply chain. The second objective is to identify the most appropriate set of strategies to overcome a particular problem; this is to response to research question on how companies overcome the disturbance negative consequence.

The proposed model make intends to contribute to the research on supply chain resilience modelling by providing links between supply chain disturbances, supply chain failures and resilience strategies. From the managerial point of view the proposed model provides to managers a deeper knowledge of how disturbances could affect the supply chain behaviour and which strategies are more appropriated to reduce the occurrence of failure modes.

Despite the paper achievements some limitations to the study remain. Since the model was developed with secondary data its validity is limited to the studied sample. Additionally, the case studies are based in grey literature; the model is biased by the available information in news media. Future researches should include the model validation by performing in-depth case studies to identify disturbances, failures and strategies that maybe are not referred in the sample. Another issue in the proposed model is that the disturbance impact is not considered, as well as the failure severity it is not considered. Which can originate a narrow view of the problem may result: for example, a capacity shortage may derive from unavailability of a single machine (e.g. because of lack of maintenance) or could be related to machinery destruction (e.g., caused by a fire). A future study on disturbance severity assessment and respective impact on the proposed model should be carried out.

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**Appendix A**

Table 1: Companies in the selected sample

Company	Reference
Airbus	Hepher (2010). Airbus misses A380 goal, presses on A350. Obtained through the Internet: <a href="http://www.reuters.com/article/idUSTRE6BE3X420101215">http://www.reuters.com/article/idUSTRE6BE3X420101215</a> , [accessed 02/01/2011].
Alcoa of Australia	Reuters (2008). Alcoa declares ‘force majeure’. Obtained through the Internet: <a href="http://www.news.com.au/business/breaking-news/alcoa-declares-force-majeure/story-e6frfkur-1111116599740">http://www.news.com.au/business/breaking-news/alcoa-declares-force-majeure/story-e6frfkur-1111116599740</a> , [accessed 02/01/2011].
AMI	Anonymous (2010a). Air cargo counts the cost of disruption. Obtained through the Internet: <a href="http://www.logisticsmanager.com/Articles/13560/Air+cargo+counts+the+cost+of+disruption.html">http://www.logisticsmanager.com/Articles/13560/Air+cargo+counts+the+cost+of+disruption.html</a> , [accessed 02/01/2011].
Apple	Chang R. (2008). iPhone shortage: supply woes or new model? Obtained through the Internet: <a href="http://www.reuters.com/article/idUSN0240646420080402">http://www.reuters.com/article/idUSN0240646420080402</a> , [accessed 02/01/2011].
BMW	Matlack, C. (2010). How Munich Re Assesses Risk. Obtained through the Internet: <a href="http://www.businessweek.com/managing/content/dec2010/ca2010121_766041.htm?chan=careers_special+report+--+focus+on+risk+management+december+2010_special+report+--+focus+on+risk+management+december+2010">http://www.businessweek.com/managing/content/dec2010/ca2010121_766041.htm?chan=careers_special+report+--+focus+on+risk+management+december+2010_special+report+--+focus+on+risk+management+december+2010</a> , [accessed 02/01/2011].
	Agence France-Presse (2010). BMW Says Ash Disruption Hitting Production. Obtained through the Internet: <a href="http://www.industryweek.com/articles/bmw_says_ash_disruption_hitting_production_21627.aspx">http://www.industryweek.com/articles/bmw_says_ash_disruption_hitting_production_21627.aspx</a> , [accessed 02/01/2011].
Boeing	Rigby, B. and Hepher, T. (2008). Boeing strike impact to be felt globally. Obtained through the Internet: <a href="http://www.reuters.com/article/idUSN0529451820080908">http://www.reuters.com/article/idUSN0529451820080908</a> , [accessed 02/01/2011].
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	McCormick, G. E. and Grenon, A. (20089). Boeing delays 787 again. Obtained through the Internet: <a href="http://www.reuters.com/article/idUSTRE4BA3LH20081211">http://www.reuters.com/article/idUSTRE4BA3LH20081211</a> , [accessed 02/01/2011].
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Caterpillar Inc’s	Kelleher, J. B. (2009). “Zombie suppliers” haunt manufacturing sector. Obtained through the Internet: <a href="http://www.reuters.com/article/idUSTRE57O5AA20090825">http://www.reuters.com/article/idUSTRE57O5AA20090825</a> , [accessed 02/01/2011].
Chrysler	Sheffi, Y. (2006). Resilience Reduces Risk. Obtained through the Internet: <a href="http://www.logisticsquarterly.com/issues/12-1/article2.html">http://www.logisticsquarterly.com/issues/12-1/article2.html</a> , [accessed 02/01/2011].
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Dalrymple Bay Coal Terminal	Kebede, R. (2010). Rains halt coal supply to Australia’s Gladstone export terminal. Obtained through the Internet: <a href="http://af.reuters.com/article/energyOilNews/idAFL3E6NV03320101231">http://af.reuters.com/article/energyOilNews/idAFL3E6NV03320101231</a> , [accessed 02/01/2011].
Dana Corp.’s Stockton	Bartholomew, D. (2005). Cargo Crunch Obtained through the Internet: <a href="http://www.industryweek.com/articles/cargo_crunch_9980.aspx">http://www.industryweek.com/articles/cargo_crunch_9980.aspx</a> , [accessed 02/01/2011].

Table 1: Continued

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