A Supply Chain Vulnerability Map for the Automotive and Electronic Industries in Brazil

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ABSTRACT

This paper aims to explore various perspectives of the Supply Chain Risk Management (SCRM) as they relate to the automotive and electronic industries in Brazil based on the historical data from 2010 to 2016. The methodological approach was based on the Supply Chain Vulnerability Map (SCVM). The SCVM was tested in its totaliness and two more risks were added to the hazard vulnerability category to form the SCVM II. The exploratory surveys were used to better understand the impacts on the automotive and electronic industries in Brazil during the study period. An interesting finding was that most of the major automotive and electronic industries are concerned with integrating risk management, governance and compliance in the supply chain. The findings of the empirical investigation and SCRM historical data indicate that managers must integrate risk management, governance and compliance in the supply chain and use the proposed SCVM II. This research revealed the risks that surrounded the supply chain during the time period covered. In the study, the researchers added two more risks to the hazard vulnerability category: item 10, deficient rainfall (as seen in Manaus and São Paulo) and number 13, viral epidemics (to reflect the Zika virus around Brazil), it was named as SCVMII. Among the limitations of the research was that the study applied real data which might vary drastically due to economic downturn of the country. This might affect the performance of the investigated industries.

Keywords: *supply chain risk management; supply chain vulnerability map; automotive and electronics; sustainability; Brazil*

INTRODUCTION

With the advent of global and digital world, the number of geographically dispersed firms throughout the world has increased and the problem of Supply Chain (SC) disruption appeared as a main concern to many industries. The supply chain disruptions are the result of the unexpected events that might affect the flow of materials or operations. The unexpected events can be late deliveries, natural disasters or declining economy. In this note, the economic problem in Brazil was investigated from 2010 to 2016. Furthermore, it was noted that from 2000 to 2012, Brazil was one of the fastest-growing major economies in the world, with an average annual GDP growth rate of over 5%. Its economy in 2012 surpassed that of the United Kingdom, temporarily making it the world's sixth largest economy. However, this prosperity was short lived because Brazil's economic growth had stalled in 2013 and the country entered an ongoing recession in 2014.

According to the World Economic Forum, Brazil was the most economically competitive country in 2009, exceeding Russia for the first time, and narrowing the gap with India and China. Critical steps have been taken since the 1990s to help ensure her fiscal sustainability and to liberalize her economy, which have significantly boosted the country's competitiveness and provided more opportunity for development.

In 2012, Forbes reported that Brazil had the 5th largest number of billionaires in the world, a number much larger than other Latin American countries, and more than the United Kingdom and Japan. Brazil is a member of diverse economic organizations, such as Mercosur, Unasul, G8+5, G20, WTO, BRICS and the Cairns Group, which is conducive to its economic growth. However, Brazil has undergone economic recession that has continued for three years (2014 inflation = 6.41, 2015 inflation = 10.67 and 2016 inflation = 6.29). It has also suffered from a major political crisis that resulted in the impeachment of President Dilma Rousseff and widespread mistrust with the current political system. By the end of 2015, the economy diminished by approximately 4.5%, according to the Financial Times (dollar exchange rate for 2014 = 2.35 and 2015 = 3.33). During this time, Brazil's GDP plummeted 3.9 % due to a drop in salary levels, restrictions on credit and a rise in the basic interest rate. In 2016, Brazil's GDP fell again by 3.6 % due to a drop in all sectors. As a

consequence, gasoline prices became unstable, which directly affected the supply chain of the automotive and electronic industries. For example, the average prices of gasoline per litre during the worst part of the recession from 2010 to 2016 (Figure 1) were R$2,75, R$2,70, R$2,86, R$3,01, R$3,00, R$3,27 and R$3,75.

This fluctuation of gasoline price affected directly the transportation of the goods from the ports and airports to the factories. It also affected directly the price of the automotives and electronic devices sold in Brazil, making these two important markets to shrink in Brazil. Many automotive industries in São Paulo and Paraná (e.g. Toyota, Nissan, etc.) suffered a direct impact and had to retrench their employees. The Free Trade Zone located in Manaus also suffered a direct impact and some of the main electronic companies (e.g. SONY, Panasonic, Samsung, etc.) had to reduce the number of employees from different departments.

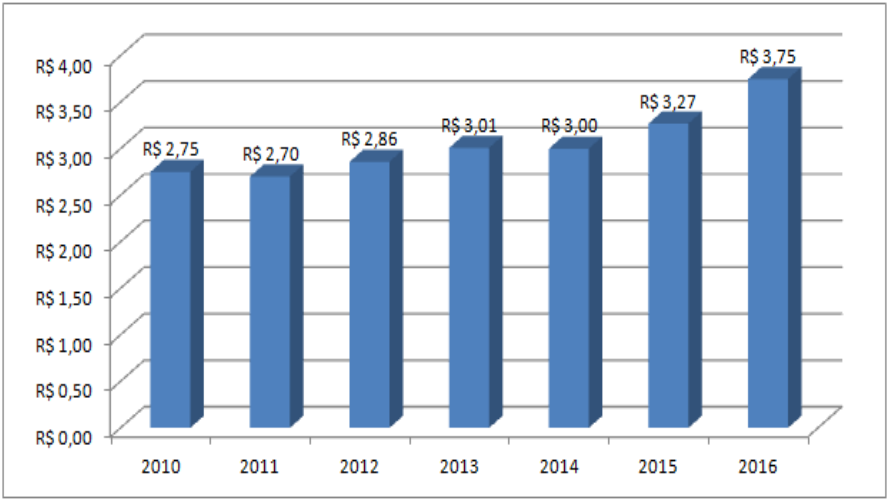

Figure 1: Fluctuation of gasoline price (R$/litre)

It must be noted that, in addition to the previously mentioned upheavals, natural disasters contributed to the disruption in the supply chain for both investigated industries during 2010 to 2016. There were heavy rains, floods, droughts and an accident at the Samarco Mining Company which took many lives. According to Morengo and Espinoza (2016), in 2010 in the Amazon Free Trade Zone located in Manaus, home

of some electronic industries, dangerously low river levels impeded the passage of ships carrying loads of containers. From 2012 to 2015, the flood in this region had significantly affected production. According to Siegler, Ravara, Pereira and Flynn (2016), Brazil in 2015 faced its worst environmental disaster as a result of the collapse of two mining dams owned by the Samarco facility that destroyed cities and blocked rivers for thousands of kilometres, impacting several supply chains and entire industries. Furthermore, several major supply chain risks were identified, such as operational, financial, and reputational. From 2010 to 2012, heavy rains and floods turned Rio de Janeiro into a disaster zone. In 2014, the water supply in Brazil's largest city of São Paulo was at risk, as the reservoir dropped 5%. In 2015 and 2016, the Zika virus caused worldwide panic as Rio de Janeiro prepared to host the Olympic Games. During the seven years of investigation, negative impacts occur in many manufacturing supply chains due to the existence of risk events which caused unanticipated changes in material flows along the supply chain. Therefore, those risk events were plotted on the vulnerability map, which represents a major impact on the SC vulnerability map model. Furthermore, this modification also brought a wide analysis on the possible risk events that will compose the SC vulnerability map.

LITERATURE REVIEW

Tang (2006a) reviewed the literature dealing with quantitative models and strategies to manage the risks. Vanany, Zailani and Pujawan (2009) studied the SCRM literature based on risk management processes. Rao and Goldsy (2009) elaborated the taxonomy of risk sources and a categorization scheme. They identified the key enablers and inhibiters of risk management practices. Tang and Musa (2010) employed the bibliometric method of citation and co-citation to assess the potential sources of risk and enhance the understanding of the SCRM. Dailun (2004) provided the basic framework of risk management focusing on financial risk management. Industrial trends and practices that cause risks and business turbulence are also considered without reviewing their empirical linkages (Narasimhan & Talliri, 2009; Trkman & McCormak, 2009). Singhal, Agarwal and Lal Mittal (2011) employed a multi-layered top town taxonomy to classify and codify the literature review on SCRM. According to Lavastre, Gunasekaran and Spalanzani (2012), SCRM refers

to the management of risks that may modify or stop the creation and efficient flow of information, materials and products within and among members in SC. Rouse (2016) defined SCRM as the coordinated efforts of an organization to help identify, monitor, detect and mitigate threats to supply chain continuity and profitability.

Wieland and Wallenburg (2012) defined SCRM as the implementation of strategies to manage both everyday and exceptional risks along the supply chain based on continuous risk assessment with the objective of reducing vulnerability and ensuring continuity. Blos, Hoeflich, Dias and Wee (2015) completed the work of Rangel, Olivera and Leite (2014) by classifying SCRM with the use of some ISO norms. The SCRM classification facilitates the understanding and management of risk in a supply chain by simplifying the identification process while also indicating the process in which the risk can occur. Since supply chain disruptions are generally uncertain events happening randomly during the operation of supply chain, it is really important to adopt a methodology to describe the current SCRM situation. Moreover, uncertainty prediction and supply chain restoration or reconfiguration are two common research topics in supply chain disruption risk management that aim at mitigating the adverse effects of disruptions on supply chain financial and operational performance (Blackhurst, Craighead, Elkins & Handfield, 2005; Tang, 2006a; Craighead, Blackhurst, Rungtusanatham & Handfield, 2007; Handfield and McCormack, 2008; Blackhurst, Dunn & Craighead, 2011; Gurnani, Mehrota & Ray, 2012; Sodhi & Tang, 2012; Tang & Musa, 2011; Habermann, Blackhurst & Metcalf, 2015; Yildiz, Yoon, Talluri & Ho, 2016; Heckmann ,2016; Khojasteh, 2018; Ivanov, 2018b).

RESEARCH METHODOLOGY

This research paper replicated the work of Blos, Quaddus, Wee & Watanabe (2009) based on a supply chain vulnerability map I (figure 2) to demonstrate the current SCRM situation for the automotive and electronic industries in Brazil and to test the completeness of the proposed supply chain vulnerability map I. Furthermore, the supply chain vulnerability map I shows the four quadrants: financial, strategic, hazard and operations. We tested and found out the necessity to add two more risks to the Hazard Vulnerability category: they are Deficient Rainfall and Virus Epidemic

(Figure 3), as seen in the next section. Furthermore, due to some risk constraints (e.g. economic recession, unemployment, budget deficit, credit rating and inflation), the number of returned questionnaires fluctuated year by year. However, the range of the automotive industry that was examined had increased significantly because we extended our area of research by adding two states, Bahia (at the northwest state) and Curitiba (at the south state), in order to make the survey more complete according to the implantation of new factories in these states. We utilized the same number of questionnaires and the same questions (72 questionnaires for the automotive industry and 30 questionnaires for the electronic industry) as found in Blos et al. (2009). We sent the questionnaires via e-mail to the targeted respondents, and some were interviewed face-to-face. The obtained data were added in twenty Excel spreadsheets, where the analysis and results are discussed in the next section.

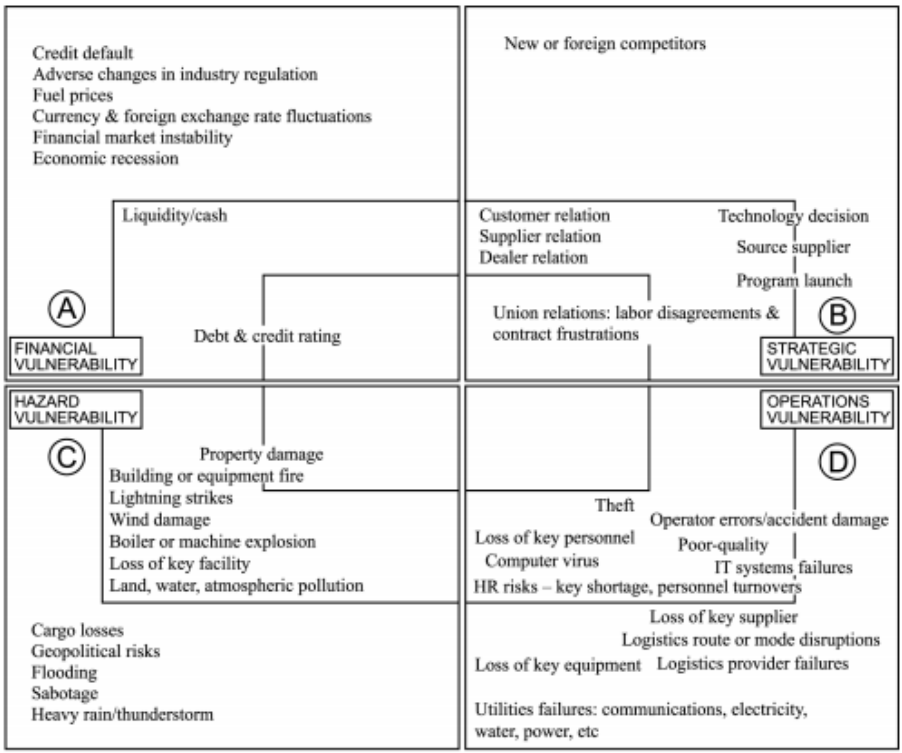

Figure 2: Supply Chain Vulnerability Map I (Source: Blos et al., 2009)

RESULTS AND ANALYSIS

From the collected data in twenty Excel spreadsheets, we plotted the SC vulnerability map, where several significant risks that could severely disrupt supply chain operations were identified. Those data were analyzed, tested and used to generate Table 1. We were able to use the supply chain vulnerability map to integrate the business-process model with a diagnostic model that revealed four categories of vulnerability (Elkins, 2003): financial vulnerability, strategic, hazard and operational vulnerability (Table 1). Each of the categories has a mechanism for locating, quantifying and minimizing supply chain risk. Using a series of questions and predefined rules that were built into the model, we identified and flagged all vulnerabilities from inside and outside the companies at each level.

Our sample of 253 returned/completed questionnaires during the seven-year study period yielded some very interesting information. Twenty five percent of those surveyed had a high level of knowledge regarding SCRM issues, 30 percent were unaware of these issues, and 45 percent had only a superficial knowledge of them. Table 1 shows the vulnerability impact rate for the Brazilian automotive and electronic industries from 2010 to 2016.

According to Table 1, there are some important results that are quite similar to both investigated industries. The top three financial vulnerability risks of the automotive/electronic industries (AI/EI) during the period of investigation are: debt and credit rating (AI/EI average = 26%), liquidity /cash (AI/EI average = 21%), and economic recession (AI/EI average = 15%). The top three strategic vulnerability risks of the automotive/electronics industries (AI/EI) during the period of investigation are: union regulations (AI/EI average = 22%), dealer relation (AI/EI average = 19%), and supplier relation (AI/EI average = 18%). The top three hazard vulnerability risks of the automotive/electronics industries (AI/EI) during the period of investigation are: property damage (AI/EI average = 15%), lightning strikes (AI average = 12%, EI average = 13%), wind damage (AI/EI average =12%). The top three operations on vulnerability risks of the automotive/electronic industries (AI/EI) during the period of investigation are: theft (AI/EI average =17%), operator errors (AI/EI average = 15%), and loss of key personnel (AI/EI average = 14%).

Table1: Vulnerability Impact Rate for the Automotive and Electrical Industries (2010-2016)

VULNERABILITY IMPACT RATE	2010		2011		2012		2013		2014		2015		2016	
1 Debt and Credit Rating	34	32	33	32	34	32	25	25	22	22	18	18	18	18
2 Liquidity/Cash	19	20	19	19	19	20	25	25	25	25	20	20	20	20
3 Economic Recession	15	15	15	15	15	15	15	15	15	15	17	17	16	16
4 Financial Market Instability	10	10	10	10	10	10	10	10	14	14	17	17	16	16
5 Currency and Foreign Exchange Rate Fluctuations	10	10	10	10	10	10	11	11	11	11	14	14	15	15
6 Fuel Prices	9	9	10	10	9	9	11	11	11	11	12	12	13	13
7 Adverse Changes in Industry Regulation	2	2	2	2	2	2	2	2	1	1	1	1	1	1
8 Credit Default	1	2	1	2	1	2	1	1	1	1	1	1	1	1
1 Union Regulations	25	25	19	19	22	22	23	23	24	24	19	19	23	23
2 Dealer Relation	18	18	20	20	16	16	18	18	20	20	22	22	20	20
3 Supplier Relation	17	17	19	19	15	16	19	19	19	19	18	18	18	18
4 Customer Relation	13	13	15	15	11	11	13	13	15	15	18	18	18	18
5 Program Launch	11	11	11	11	15	13	11	11	10	10	9	9	8	8
6 Source Supplier	8	8	8	8	10	9	8	8	4	4	6	6	5	5
7 Technology Decision	6	6	6	6	9	11	6	6	6	6	6	6	6	6
8 New or Foreign Competitors	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1 Property Damage	15	15	15	15	15	15	15	15	15	15	15	15	15	15
2 Building or Equipment Fire	10	10	10	10	10	10	10	10	13	10	10	10	10	10
3 Lightning Strikes	14	14	14	14	14	14	13	14	10	13	10	10	10	10
4 Wind Damage	14	14	15	15	14	14	10	12	12	12	10	10	10	10
5 Boiler or Machine Explosion	5	5	4	4	5	5	5	5	5	5	5	5	5	5
6 Loss of Key Facility	3	3	4	4	3	4	5	4	5	5	2	2	5	5
7 Land, Water, Atmospheric Pollution	7	7	7	7	7	7	8	7	8	8	17	17	15	15
8 Cargo Losses	4	4	4	4	4	3	5	4	5	5	2	2	3	3
9 Geopolitical Risks	6	6	5	5	6	6	8	7	10	10	8	8	5	5
10 Flooding/Deficient Rainfall	5	5	5	5	5	5	6	8	9	9	9	9	3	3
11 Sabotage	2	2	2	2	2	2	3	3	3	3	2	2	2	2
12 Heavy Rain/Thunderstorm	15	15	15	15	15	15	12	11	5	5	3	3	5	5
13 Virus Epidemic	0	0	0	0	0	0	0	0	0	0	7	7	12	12
1 Theft	18	18	17	17	17	18	18	19	15	14	18	18	15	15
2 Operator Errors/Accident Damage	14	16	15	15	15	16	15	15	15	16	15	10	16	16
3 Loss of Key Personnel	14	13	14	14	11	13	14	14	15	16	16	17	15	14
4 Computer Vírus	9	9	9	9	9	10	9	9	9	9	7	7	9	9
5 Poor-Quality	11	11	11	11	9	10	10	10	11	11	11	11	11	11
6 IT Systems Failures	9	9	9	9	9	8	9	9	9	9	8	9	9	9
7 HR Risks	10	10	10	10	9	8	10	10	10	10	11	12	10	10
8 Loss of Key Supplier	4	4	5	5	5	4	5	4	5	5	6	7	5	5
9 Logistics Route or Mode Disruptions	4	3	3	3	4	4	3	3	3	3	3	3	3	3
10 Loss of Key Equipment	3	3	3	3	4	3	3	3	3	3	2	3	3	3
11 Logistics Provider Failures	3	3	3	3	4	3	3	3	3	3	2	2	3	3
12 Utilities Failures	1	1	1	1	4	3	1	1	2	1	1	1	1	2

Notes: [a] AI = Automotive Industry; [b] EI = Electronic Industry.

Figure 3 "Supply Chain Vulnerability Map II" shows how the two new risk categories (in bold type) that we added corresponded with the major vulnerabilities from the last seven years. Moreover, the Financial Vulnerability (Economic Recession, Financial Market Instability, Currency & Foreign Exchange Rate Fluctuations, Fuel Prices, Debt & Credit Rating, Credit Default, and Liquidity/Cash) and Hazard Vulnerability, with Geopolitical Risks, Flooding/Deficient Rainfall and Virus Epidemic completely changed the SCM Vulnerability Map over the study period (2010-2016).

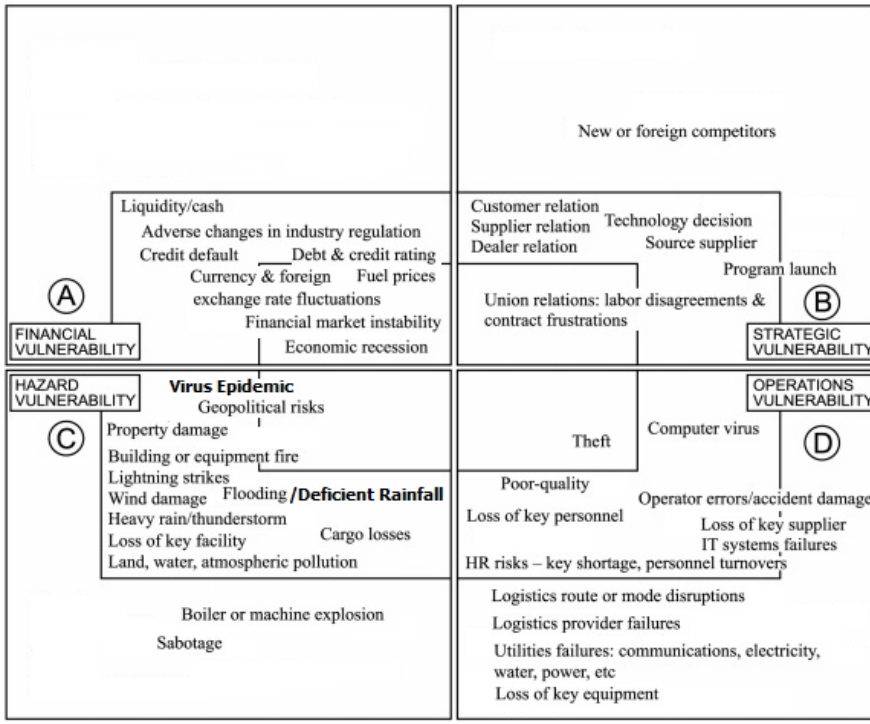

Figure 3: Supply Chain Vulnerability Map II
Source: Adapted from Blos et al. (2009)

Furthermore, Strategic Vulnerability and Operational Vulnerability were only slightly changed during this time. Although the World Cup (2014) and the Olympic Games (2016) contributed to the increased sale of TVs and mobile phones, many electronic industries decreased production

and fired many employees. According to the surveys and personal interviews, many managers reported that the recession forced them to take these drastic measures. In addition, many investigated managers informed that the current economic situation forced them to integrate risk management, governance and compliance in one department only and not separately.

CONCLUSION

We analyzed the SCRM in relation to the automotive and electronic industries in Brazil from 2010 to 2016, as well as 253 completed questionnaires, where the results are displayed in Table 1 and Figure 3. We added two more risks to the Hazard Vulnerability category: item 10, Deficient Rainfall (as seen in Manaus and São Paulo) and number 13, Viral Epidemics (to reflect the Zika virus around Brazil). Furthermore, our findings showed that the downturn of the Brazilian economy had a direct impact on the SCRM for these two industries, making the supply chain vulnerability map II with a complete list of supply chain vulnerability variables. While many of these sources of uncertainty persist, it is important to recognize that new, long-term shifts in the global economy will continue to pressure supply chains. A good finding is that most of the major automotive and electronic industries are integrating RM, governance and compliance in the department of supply chain only. The departments of purchasing, logistics and supply chain play an important role in supply risk management, as they are responsible for the procurement of parts, equipment, jigs, etc. Although the economic downturn during the study period directly impacted the SCRM in Brazil, many automotive and electronic industries have matured the knowledge in RM, making the RM part of their lives. However, many employees without the knowledge of RM are without job or have moved to different companies with low salary. Those findings are extremely important for the practitioners and also represent a new research mode for the academicians.

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