Environmental Risks in Supply Chain: A Multiple Case Study

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Abstract. Companies currently face other risk factors in addition to traditional economic risks. Environmental issues in supply chains have been seen as a topic of contemporary concern to scholars and practitioners. Chemical spills, inefficient water and energy consumption, and greenhouse gas emissions are examples of environmental risks companies must deal with. This paper aims to compare the literature findings on environmental risks, consequences, and strategies with business reality through multiple case studies. We identify which environmental risks, consequences, and strategies gathered from the literature are considered in companies' supply chains. This study is an initial step toward endorsing environmental risk factors in supply chain risk management. We offer academics an empirical approach to better elucidate the environmental vulnerabilities and consequences that companies need to be aware of.

Keywords: Environmental Risk, Supply Chain Management, Multiple Case.

1 Introduction

The currently globalized and highly competitive business environment has exposed organizations to several supply chain risks. Firms are no longer restricted only to economic risk factors but are also exposed to various other types of risks such as quality, safety, leadership, labor, and environmental factors [1]. Stricter legislation and pressure from numerous stakeholders regarding environmental and social aspects have caused concern for these issues to grow [2, 3]. In this way, as sustainability concerns are gaining more attention in society [4, 5], organizations must consider environmental and social risks together with conventional economic risks [3].

Hofmann et al. [6] define environmental supply chain risks as events that may occur within a focal firm's supply chain that can intensify harmful stakeholder reactions. Well-known cases of such adverse events include reputational losses to BP company

due to one of the largest offshore oil spills worldwide [2] and charges and boycotts against Volkswagen due to emission standard violations [7].

This current scenario offers significant opportunities for research in supply chain risk management once the academic literature also reveals some gaps in this field, including the need for more empirical research in supply chain risk management [8, 9, 10]. Within the context of supply chain risk management, this paper focuses on environmental risks. We aim to compare the literature findings on environmental risks, consequences, and strategies presented in Oliveira et al. [11] with business reality. For this purpose, we conduct a multiple case in three companies with factories located in Brazil. Thus, the question posed in this study is:

RQ: Do the literature's environmental supply chain risks, consequences, and strategies correspond with business reality?

In conducting a multiple case study, this paper contributes to filling a gap regarding the need to address environmental risks in supply chain risk management, providing more empirical research on this subject. Additionally, this paper can help practitioners better comprehend the environmental vulnerabilities their organizations need to be aware of. The present research is in coherence with several studies addressing the importance of empirical studies in furthering the field, validating results, and adding new evidence to past studies, developing, therefore, a basis for comparison between academia and practice [12, 13].

The remainder of the paper is structured as follows. We begin by reviewing the supply chain risk management literature and directing our attention to how environmental issues are integrated therein. Section 3 describes the research methodology adopted in the study. Section 4 presents the results, and Section 5 discusses the topic. Finally, Section 6 summarizes the conclusions and raises some future research in the field.

2 Literature foundation

Supply chain risk management (SCRM) is usually concerned with risks arising from interrelated materials, information, and asset flows in supply chains [9]. Different risks can disturb supply chains [14, 10], and the disruptions and impacts triggered by these risks first affect the focal company and consequently will have adverse effects throughout the supply chain [15]. These impacts are not only restricted to financial impacts but also involve reputational and legal consequences.

Within the context of supply chain risk management, we can highlight the environmental issues that have been seen as a topic of contemporary concern to scholars and practitioners [16, 17, 11]. Environmental misconduct may damage the company's brand, leading to boycotts by customers, and hitting billions of the value of a company. Companies that do not address environmental thinking in their corporate risk management strategy may lose opportunities in markets that lately are being shaped by environmental aspects. To avoid these adverse effects, companies need to identify the potential environmental risks, their probability of occurrence, and impact and then find their significance level. In this way, Ceryno et al. [18] point out three steps for the SCRM: risk identification, risk assessment, and risk strategies. The first step describes

risks; the second identifies the probability, impact and significance of risks; and the third defines strategies to prevent and mitigate the impacts of risks [18].

According to Hofmann et al. [6], companies can experience severe losses from environmental issues presented in their supply chains. Lee and Vachon [19] affirm that companies are pressed by stakeholders to address environmental issues upstream in their supply chains, and thus co-responsibility is receiving special attention from stakeholders. For example, when large corporations do not consider environmental damages caused by their first-tier suppliers, they may be boycotted by consumers, leading to injuries in the form of reputational losses [6]. Carter and Jennings [20] also stress that irresponsible supplier behavior may create negative publicity, reputational damage, and costly legal obligations for organizations. Thus, especially large and brand-oriented focal companies are held responsible for their suppliers' environmental performance [4].

3 Research Methodology

The paper follows the systematic case study approach proposed by Yin [21], which involves six steps: (i) planning, (ii) project development, (iii) preparation, (iv) data collection, (v) data analysis, and (vi) sharing. According to Yin [21], the case study method is used when there is a need for a deeper understanding and investigation of a phenomenon and its variables of interest in its real-life context.

The planning step involves evaluating the suitability of the case study method in contrast to other research methods. The present work explores adherence of environmental risks, consequences, and strategies raised in Oliveira et al. [11] with business practice. This is achieved through three real cases involving three companies where it is possible to analyze, validate or contrast the literature findings. The project step formalizes the research questions and defines the case study project (single or multiple) and criteria for interpreting results [21]. In the preparation step, we develop a case study protocol, provide an overview of our case studies (research questions and objectives), and explain our data collection procedure. For the data collection step, Yin [21] recommends using multiple sources of evidence, as using several sources allows for more detailed data collection. Data collection occurred over three phases and drew from the following sources of data: (i) answers to an online questionnaire by the interviewees; (ii) individual interviews; and (iii) a detailed study of documents sourced from corporate websites. Initially, a questionnaire was developed based on the taxonomy of environmental risks, consequences, and strategies developed by Oliveira et al. [11]. The questionnaire was sent to the companies through a web-based platform to collect background information on the scope of their environmental supply chain risks. Semi-structured interviews complemented the questionnaire responses to provide more robustness to the empirical dataset. Our semi-structured interviews made it possible to collect data using a pre-established script, also giving interviewees the freedom to discuss other pertinent subjects, making it possible to gather information not previously discussed.

Professionals who completed the questionnaire and took part in interviews have vast experience. These professionals are specialized in managing environmental risks and include the companies' Environmental, Health, and Safety department. Finally, the

third data collection stage analyzes and compiles documents made available by the respondents and also sustainability reports sourced from their corporate websites. Again, the information was compiled into an Excel spreadsheet for analysis. The data analysis stage is concerned with examining, categorizing, tabulating, testing, or recombining evidence to produce discoveries based on empiricism [21]. In this study, we use the pattern matching technique [21], whereby theoretical references from the systematic literature review conducted by Oliveira et al. [11] are used as a prognosis and compared to the results of the present empirical study. Finally, the sharing stage involved transmitting relevant information from the study through presenting results [21]. This stage is further illustrated in the following section.

4 Results

In this section, we present the results gathered from the case studies. As explained, we conducted our case study with three companies with factories located in Brazil. The characteristics of the companies are presented in Table 1.

Table 1. Companies characteristics

Company		**Activity**
A	Global petrochemical company focused on producing thermoplastic resins and primary chemical inputs	Chemistry Petrochemical
B	Brazilian manufacturer company focused on producing air compressors	Air compressors manufacturer
C	Multinational company focused on developing seeds, vegetables, biotechnology, and herbicides	Agriculture Biotechnology

We focused on analyzing and validating the environmental risks, consequences, and strategies raised by Oliveira et al. [11]. The environmental risks and consequences are listed in Tables 2 and 3, respectively:

Table 2. Environmental Risks

Environmental Risk	**Description**
Risk #1	*Greenhouse gas emissions and ozone-depleting substances*
Risk #2	*Other significantly harmful air emissions (persistent organic pollutants, volatile organic compounds, hazardous air pollutants)*
Risk #3	*Chemicals and toxic effluents released into water or groundwater*
Risk #4	*Chemicals and toxic effluents released into the soil*
Risk #5	*Inefficient use of raw materials*

Environmental Risk	Description
Risk #6	*Inefficient use of water*
Risk #7	*Inefficient use of energy*
Risk #8	*Excessive generation of hazardous or non-hazardous product waste*
Risk #9	*Intensive use of chemicals*
Risk #10	*Lack of health and safety management*
Risk #11	*Inadequate warehouse areas for hazardous materials and waste storage*
Risk #12	*Non-compliance with sustainable laws and regulations*
Risk #13	*Explosions, fires, chemical accidents*
Risk #14	*Natural and man-made disasters*

Table 3. Consequences

Consequence	Description
Reputational	*Damages to the company's reputation*
Financial	*Increased costs/reduced profits/financial consequences*
Legal	*Government penalties and legal actions*

For each environmental risk, interviewees analyzed in low, moderate, or high the following aspects:

- Probability of occurrence
- Impact of the risk

The probability is most often associated with the frequency of the risk, while the impact is related to the consequences suffered when the risk materializes. For each environmental risk, interviewees also pointed out the risks' main consequences. Table 4 summarizes the results of the three companies.

Table 4. Responses of Company A, B, and C

Company	Company A									Company B									Company C								
Environmental Risk	Probability			Impact			Consequence			Probability			Impact			Consequence			Probability			Impact			Consequence		
	Low	Moderate	High	Low	Moderate	High	Reputational	Financial	Legal	Low	Moderate	High	Low	Moderate	High	Reputational	Financial	Legal	Low	Moderate	High	Low	Moderate	High	Reputational	Financial	Legal
Risk #1			✓		✓		✓		✓	✓				✓		✓		✓			✓		✓		✓		✓
Risk #2			✓		✓		✓		✓			✓			✓	✓		✓	✓				✓		✓	✓	
Risk #3	✓					✓	✓		✓	✓					✓	✓		✓		✓				✓		✓	✓
Risk #4	✓					✓	✓		✓	✓				✓		✓		✓		✓				✓		✓	✓
Risk #5			✓	✓				✓			✓			✓			✓		✓			✓			✓	✓	
Risk #6	✓			✓				✓			✓				✓		✓			✓			✓		✓	✓	
Risk #7	✓			✓				✓			✓				✓		✓			✓			✓		✓	✓	
Risk #8			✓	✓				✓			✓			✓		✓	✓		✓			✓			✓	✓	
Risk #9											✓		✓				✓		✓			✓			✓	✓	
Risk #10											✓				✓	✓		✓		✓			✓		✓		✓
Risk #11											✓			✓		✓				✓			✓			✓	✓

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Company	Company A									Company B									Company C								
Environmental Risk	**Probability**			**Impact**			**Consequence**			**Probability**			**Impact**			**Consequence**			**Probability**			**Impact**			**Consequence**		
	Low	**Moderate**	**High**	**Low**	**Moderate**	**High**	**Reputational**	**Financial**	**Legal**	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**	**Reputational**	**Financial**	**Legal**	**Low**	**Moderate**	**High**	**Low**	**Moderate**	**High**	**Reputational**	**Financial**	**Legal**
Risk #12	✓					✓	✓		✓	✓					✓		✓			✓		✓				✓	✓
Risk #13	✓					✓	✓		✓	✓					✓	✓	✓		✓					✓	✓	✓	
Risk #14										✓					✓		✓		✓				✓			✓	
TOTAL	6	0	4	4	2	4	6	4	6	6	7	1	1	5	8	8	8	5	6	7	1	4	7	3	9	12	6

Of the fourteen risks, four are not considered by Company A (risks #9, #10, #11, and #14) and therefore are presented in Table 4 without probabilities or impacts. The interviewee did not consider these risks once their likelihood of occurrence was insignificant. Six environmental risks have a low probability of occurrence, and four are highly probable. Concerning impacts, four environmental risks are classified as having low impacts, two having moderate impacts, and four having strong impacts. The most cited consequences for Company A are reputational and legal. Company B has considered all fourteen environmental risks. Regarding probabilities of occurrence, six environmental risks are classified as having a low chance of occurrence, seven are considered moderate, and one is classified as highly probable. Concerning impacts of these risks, one is deemed to have low impacts, five are viewed as having moderate impacts, and eight are considered to have strong impacts. The most cited consequences are financial and reputational. Company C has also considered all fourteen environmental risks. Regarding probabilities of occurrence, six environmental risks are classified as having a low chance, seven are considered moderately probable, and one is highly probable. Concerning impacts, four environmental risks are considered to have low impacts, seven are viewed as having moderate effects, and three are believed to have strong impacts. Company C cites financial consequences most frequently followed by reputational consequences.

5 Discussions

By combining the probabilities and impacts, it is possible to evaluate the significance levels of each environmental supply chain risk. Table 5 shows the levels of each environmental risk for the Companies. Company A does not take risks #9, #10, #11, and #14 into account, and therefore 20% of environmental risks are considered low, 60% moderate, and only 20% high. For Company B, only 14% of environmental risks are considered low, 57% moderate, and 29% high. Finally, for Company C, 35% of environmental risks are considered low, 30% moderate, and 35% high.

Table 5. Significance levels of environmental risks

Company	Risk #1	Risk #2	Risk #3	Risk #4	Risk #5	Risk #6	Risk #7	Risk #8	Risk #9	Risk #10	Risk #11	Risk #12	Risk #13	Risk #14
A	●	●	●	●	●	●	●	●	✖	✖	✖	●	●	✖
B	●	●	●	●	●	●	●	●	●	●	●	●	●	●
C	●	●	●	●	●	●	●	●	●	●	●	●	●	●

● High risk
● Medium risk
● Low risk
× Risk not considered

The results mentioned above imply that risks with moderate and high significance levels are more likely to be managed and receive attention from companies. According to the interviewees, companies tend to develop strategies to deal with the most significant risks, that is, those that are more likely to occur and those whose impacts are more significant. Thus, the strategies identified in the literature were also validated by companies once most of them were considered in the risk management portfolio of companies.

Table 6. Strategies considered by each company

Strategy	**Description**	**A**	**B**	**C**
Strategy #1	*Wastewater and solid waste management*	✓	✓	✓
Strategy #2	*Introduction of eco-designed and environmentally friendly products*		✓	
Strategy #3	*Introduction of lean management practices*	✓	✓	✓
Strategy #4	*Carbon and water footprint monitoring*	✓	✓	✓
Strategy #5	*Efficient natural resource consumption (reduction programs, use of energy efficient and green technologies)*	✓	✓	✓
Strategy #6	*Substitution, precautions, and reduction in the consumption of chemicals and toxic waste*	✓	✓	✓
Strategy #7	*Eco-labelling of chemicals*	✓	✓	✓
Strategy #8	*Accomplishing a precise inventory of chemical consumption*	✓	✓	✓
Strategy #9	*Introduction of carbon emission reduction initiatives and practices (e.g., use of renewable energy/alternative fuels, filters, freight consolidation, driver efficiency, reduced fuel consumption)*	✓	✓	✓
Strategy #10	*Auditing and monitoring suppliers and use of sustainable criteria for supplier selection*	✓	✓	✓
Strategy #11	*Encouraging suppliers and partners to promote sound environmental policies*	✓	✓	✓
Strategy #12	*Employing local suppliers for reverse logistics*		✓	✓
Strategy #13	*Encouraging customers to make green and sustainable consumption choices*	✓	✓	✓
Strategy #14	*Compliance with sustainability regulations and certifications*	✓	✓	✓
Strategy #15	*Internal auditing programs*	✓	✓	✓
Strategy #16	*Programs and training focused on sustainability, health, and safety*	✓	✓	✓
Strategy #17	*Developing emergency and contingency plans*	✓	✓	✓
Strategy #18	*Developing a flexible supply chain*		✓	✓
Strategy #19	*Insuring against disasters*		✓	

Companies seek not only to look at their internal risks but also to map risks along their supply chains, as they know that the consequences of neglecting risks along the supply chain can be felt throughout the entire chain and its stakeholders. Company A has recently incorporated the Carbon Disclosure Project (CDP) and Water Supply Chain Program, which requires suppliers to report their greenhouse gas emissions and water consumption issues. In 2017, the company had reached its best levels of engagement, with 66% of its partners involved in climate change initiatives and 76% of its entire supply chain worldwide in water management issues. Along its upstream supply chain, the company also audits and evaluates service providers for the transport and disposal of its chemicals and toxic effluents, as the company understands the significant impact of such risks in cases of occurrence. Hence, co-responsibility regarding the transport, disposal, and treatment of these substances is a concern for the company. To better manage how its chemical waste is transported and discharged into water or soil, the company holds an audit process that periodically evaluates service providers through on-site visits.

Company B also adopts actions and procedures to monitor the supplier's competence regarding environmental risks. The assessment of its suppliers' environmental management systems is carried out through a questionnaire. This questionnaire is distributed to the company's suppliers every 2 years and includes a checklist addressing various environmental issues such as: (i) staff training and awareness of environmental and security issues; (ii) handling and storage of chemicals; (iii) the treatment, disposal and monitoring of effluents; (iv) the control and monitoring of atmospheric emissions; (v) the control, treatment and inventory of solid waste; (vi) emergency accidents; (vii) preventive maintenance; (viii) facilities; and (ix) the storage of chemical waste. The company grades the suppliers regarding each form of environmental risk and generates a final score for each supplier, classifying each as exhibiting excellent, good, adequate, or low levels of commitment. Suppliers classified with low commitment are reproved, and the company begins a process of replacing these suppliers.

Company C only audits and evaluates service providers related to the transport and disposal of its chemicals effluents. The company did not mention specific tools used to audit and manage its suppliers, but the interviewees understand that auditing suppliers contribute to an efficient strategy to prevent potential environmental issues and reputational losses.

6 Conclusion

This paper addresses a research-practice gap in empirical studies on supply chain risk management focusing on environmental risks. In response to the research question, we find that environmental risks in supply chains, consequences, and strategies found in the literature have adherence to companies' business realities. Besides, companies also comprehend and consider reputational and legal losses along with financial consequences. In this work, reputational consequences are associated with damage to a company's reputation that can spread throughout the supply chain. Thus, we follow a trend in the academic literature, as we emphasize the effects of stakeholders on companies,

including stakeholder reactions such as boycotts and litigation from customers and government penalties. The list of strategies derived from the literature is well-aligned with organizational realities, as companies identify most strategies in their risk management portfolios.

As with all studies, this work presents limitations. First, this study focuses on companies located in Brazil. The work does not consider managerial perspectives adopted in other countries, which may reflect different views of environmental supply chain risk management. The present study can help scholars and practitioners better understand the role of environmental supply chain risks and better comprehend their environmental vulnerabilities.

Future research should focus on other methods such as validation with experts and surveys. Moreover, case studies should be conducted across different countries to yield different perspectives and insights from other organizational contexts, which may result in different perceptions and effects of environmental supply chain risk management. The region in which a company is located, the intensity of stakeholder pressure, and regional legal requirements will certainly influence environmental factors and strategies. Future studies may also focus on conducting multi-criteria analyses to prioritize risks considered most important among experts. Finally, it is also important to address risks that may arise on the downstream side of the chain, i.e., on the demand side. For example, Company A maintains a department responsible for customer relationship, to track, for example, how they dispose the products that the company produces. Company C also develop guidance on the proper use and disposal of its products, thus minimizing their products' inappropriate disposal or use.

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