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Doctorado en Logística y Dirección de la Cadena de Suministro

Valoración y evaluación del riesgo en Cadenas de Suministro

Supply Chain Risk Assessment and Evaluation

Tesis para obtener el Grado de Doctor
en Logística y Dirección de la Cadena de Suministro

Presenta

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Resumen

En general, se denomina riesgo a la probabilidad de que ocurra una situación disruptiva. Aplicando este concepto a la cadena de suministro, dichas interrupciones causan un efecto negativo en el flujo de materiales o servicios. El estudio de estos riesgos, originados en los procesos logísticos, permanece como un tema relevante en las organizaciones. Las empresas saben que existen situaciones de esta índole que se pueden presentar, pero la mayoría no se prepara para ello. Esto puede mermar su competitividad debido a la baja en la eficiencia de sus operaciones por alteraciones derivadas de la ocurrencia de un evento disruptivo. El enfoque en muchos casos es reactivo porque no se conocen riesgos, sus tipos, el grado de exposición al mismo, su probabilidad de ocurrencia y la severidad del impacto que puedan tener en las operaciones de la organización. Esta es la problemática abordada en este estudio.

En el Capítulo 2, estos tres últimos elementos se toman el método Fine-Kinney para la evaluación de riesgos personales y se propone como método de evaluación de riesgos en cadenas de suministros. El método se prueba en una empresa real para valorar el riesgo presente en su propia cadena. Esta adaptación del método incluye un ajuste en las escalas de exposición al riesgo, probabilidad de ocurrencia y severidad del impacto producido de acuerdo a los parámetros establecidos por la empresa en donde se aplica. Finalmente, se elabora un mapa de riesgos para conocer aquellas áreas y riesgos que requieren mayor atención y/o prevención.

A raíz de la aplicación de este modelo, se observó que muchas empresas aun no cuentan con una metodología de valoración de riesgos en cadenas de suministro. Es necesario partir de una base existente para no esperar a generar las bases de datos requeridas para tener conocimiento del perfil de riesgos en una empresa. A partir de esta premisa, en el Capítulo 3 se muestra qué tanto se puede avanzar con bases de datos ya existentes, como aquellas generadas por los temas de calidad de una compañía. Los resultados de un análisis realizado a la base de datos de no conformidades se cruzan con la información generada de la aplicación de la metodología de valoración de riesgos en cadenas de suministro propuesto en el Capítulo 2. Esto resulta en una similitud en las áreas de riesgo detectadas, aunque los valores normalizados presentan diferencias por el enfoque de ambos estudios, por lo que se propone como un estudio inicial para usar la información disponible sobre no conformidades en las empresas para la reducción de riesgos logísticos.

Una vez valorado el riesgo, el siguiente paso es evaluarlo para tomar decisiones en la estrategia táctica y operacional de las empresas. En el capítulo 4, se propone un modelo de producción-distribución que evalúa el riesgo como una penalización en el costo. Los parámetros para medir el riesgo, consideran los principios de la metodología de valoración de riesgos en la cadena de suministros propuestos anteriormente. Este modelo se evalúa en una empresa para observar el efecto del riesgo en una cadena de suministro multinivel y a partir de sus resultados se pueden tomar decisiones de distribución que optimicen el

uso de las plantas actualmente disponibles.

Al final, se plantean líneas de investigación y trabajos futuros necesarios para fortalecer la parte del estudio del riesgo en cadenas de suministro. Con ello, las empresas podrían implementar estos modelos y metodologías para tener beneficios por la reducción de eventos disruptivos, logrando un aumento de su competitividad al estar mejor preparados para los riesgos que pueden presentarse durante su operación.

Palabras Clave: riesgos en cadena de suministros, riesgos logísticos, valoración del riesgo en cadenas de suministro, administración del riesgo en cadenas de suministro, evaluación del riesgo.

Abstract

Risk is known as the probability that a disruptive situation will happen. Applying this concept to the supply chain, these disruptions have a negative effect on the flow of materials or services. The study of these risks, originated in logistics processes, remains a relevant topic in organizations. Companies know that there are situations of this nature that might occur, but most of them do not prepare for it. This can reduce its competitiveness due to the decrease in the efficiency of its operations because of alterations derived from the occurrence of a disruptive event. The approach in many cases is reactive because companies do not know the risks, their types, the degree of exposure to it, their probability of occurrence and the severity of the impact they may have on the operations of the organization. This is the problem addressed in this study.

In Chapter 2, these three last elements are taken from the Fine-Kinney method for personal risk assessment and is proposed as a method for supply chain risk assessment. The method is tested in a real company to assess the risk present in its own chain. This adaptation of the method includes an adjustment in the risk exposure scales, probability of occurrence and severity of the impact produced according to the parameters established by the company where it is applied. Finally, a risk map is prepared to prioritize those areas and risks that require greater attention and / or prevention.

Following the application of this model, it was observed that many companies do not apply a methodology for supply chain risk assessment. It is necessary to start from an existing database to avoid waiting to generate the databases required to have knowledge of the risk profile in a company. Considering this premise, Chapter 3 shows how much progress can be made with existing databases, such as those generated by a company for its quality issues. The result of an analysis carried out in the database of nonconformities is compared to the information generated from the application of the supply chain risk assessment methodology proposed in Chapter 2. This results on a similarity in the risk areas detected, although the normalized values present differences explained by the approach of both studies, so it is proposed as an initial study to use the available information on nonconformities in companies for the reduction of logistic risks.

Once the risk is assessed, the next step is to evaluate it to make decisions in the tactical and operational strategy of the companies. In Chapter 4, a production-distribution model that assesses risk as a cost penalty is proposed. The parameters for measuring risk consider the principles of the supply chain risk assessment proposed above. This model is evaluated in a company to observe the effect of risk in a multi-echelon supply chain and from its results distribution decisions that optimize the use of currently available plants can be made.

At the end, research lines and future work needed to strengthen the part of the study of risk in supply chains are proposed. With this, companies could implement these models and methodologies to have benefits from reducing disruptive events, achieving an increase in

their competitiveness by being better prepared for the risks that may arise during their operation.

Keywords: supply chain risks, logistics risks, supply chain risk assessment, supply chain risk management, risk evaluation.

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Chapter 1. Introduction

There is no doubt about the challenge it represents to try to have a strict control of a supply chain because of its inherent characteristic of collaboration. Each partner has its own processes and each process has its own established way to be done. A number of situations that can delay the product flow across the chain might happen, resulting in losses and delays. The more participants there are, the more complex the operation is. Enterprises know that disruption events can happen, but what they might not realize is that these can somehow predicted or even be prevented.

The desire of the companies on lowering disruptive events derived from risks is not enough. A general risk management strategy has to be adopted and correctly implemented. In this strategy, it is important not only to know the risk, but also to know its impact in case of occurrence (and furthermore, the capacity of an entity of recovering of it). Whatever the reason of disruption, it causes losses that spread to the rest of the supply chain during the time it takes for it to recover. Part of risk management, apart from preventing it, is to reduce its impact as much as possible, as well as speeding up the recovery of the chain. This is only possible when a standardized process to identify, measure, asses, and evaluate a supply chain risk is developed in a company. The risk identification, measurement, and assessment will provide the enterprise with the input information of the risk profile of the company: type of risks, origin of the risk, and even the relative importance that each risk represents. The evaluation of the previously identified risks will allow the companies to see the how events derived from these risks are happening during the real operation and if the contingency plans are working as they should.

The first part of this study, in addition to establishing the general parameters of what risk involves, looks for the development of a methodology to assess these risks, identifying risk sources to know how to prioritize efforts to lower them. A next step includes the development of risk mitigation plans based on previous findings.

The second part emerges from the need of beginning to work proactively on strategies to lower supply chain risk. As a very low proportion of the enterprises have solid developed supply chain risks and/or incidents databases, a way of starting from something that they already have was pursued. On Chapter 3, some similarities on Quality databases allowed them to be analyzed and compared with the results obtained from the supply chain risk assessment methodology proposed. This was made to establish if the resulting analysis was suitable to propose general measures to mitigate logistics risk in advance before the development of a proper supply chain risk assessment methodology.

Once the risk is known and assessed, the focus of the project leaned toward the evaluation of risk for decision-making on supply chain networks, specifically on the production-distribution part. It is important to establish a way to model risk as a penalization on cost so it could be considered on an optimization model. It is also relevant to prove the model under real conditions to observe the way the variables interact.

1.1 Justification

All the delays, the losses on cost, the affectation on customer perception, and the extra time required to overcome a disruptive event can be somehow foreseen. Although they cannot always be prevented, strategies to lower their occurrence or mitigation plans on how to handle those events can be developed in advance. This can be considered also as a decision-making driver on how to perform our strategic, tactical, and/or operational activities.

Although there are some methodologies proposed to develop supply chain risk assessment, low application on real world companies was perceived on the literature. It is important for this research to develop something very applicable that represents a practical contribution. The methodology presented generates a prioritization of risks considering the characteristics of a company to develop mitigation strategies to those who represent more threat. This would reduce disruptive events derived from that risk. A continuous application of the methodology allows the company to always have an updated knowledge on the risk they should work to minimize.

The analysis of Quality databases for logistics risk reduction has its justification on the level of dissemination of the first one. Most enterprises look for Quality assurance of their products and processes. This focus is more spread than risk reduction on a logistics level.

Talking about the production-distribution model, there are very few proposals that include risk. There is no consensus on which risks should be considered and how. This represents an opportunity to propose ways to quantify risk to aid decision making.

1.2 General and Specific Objectives

1.2.1 General Objective

Design and apply a methodology that allows the identification, measurement, assessment and evaluation of existing risk in supply chains.

1.2.2 Specific Objectives

- Review and analyze the literature of supply chain risk for the selection of methods and variables to consider.
- Design and / or adapt a methodology and instruments required to identify, measure, and assess risk in a company.
- Design and / or adapt a methodology that analyses previously existing Quality databases, such as nonconformance reports, to detect supply chain risks.
- Design and / or adapt a production-distribution model that integrates risk to evaluate its effect on the network design.
- Implement the methods in a company to validate their functionality.

1.3 Research Questions

- How can a methodology for supply chain risk assessment be developed considering identification, measurement, and assessment?
- How can a methodology for Quality database analysis be developed to detect supply chain risks?
- How can a production-distribution model include risk evaluation?

1.4 Scopes and Limitations

1.4.1 Scopes

Regarding the scope of the study, an alternative methodology based on the Fine-Kinney method will be presented for phase one and two of the Supply Chain Risk Management Process (SCRMP) proposed by Tummala & Schoenherr in 2011, which is shown on Figure 1.1.

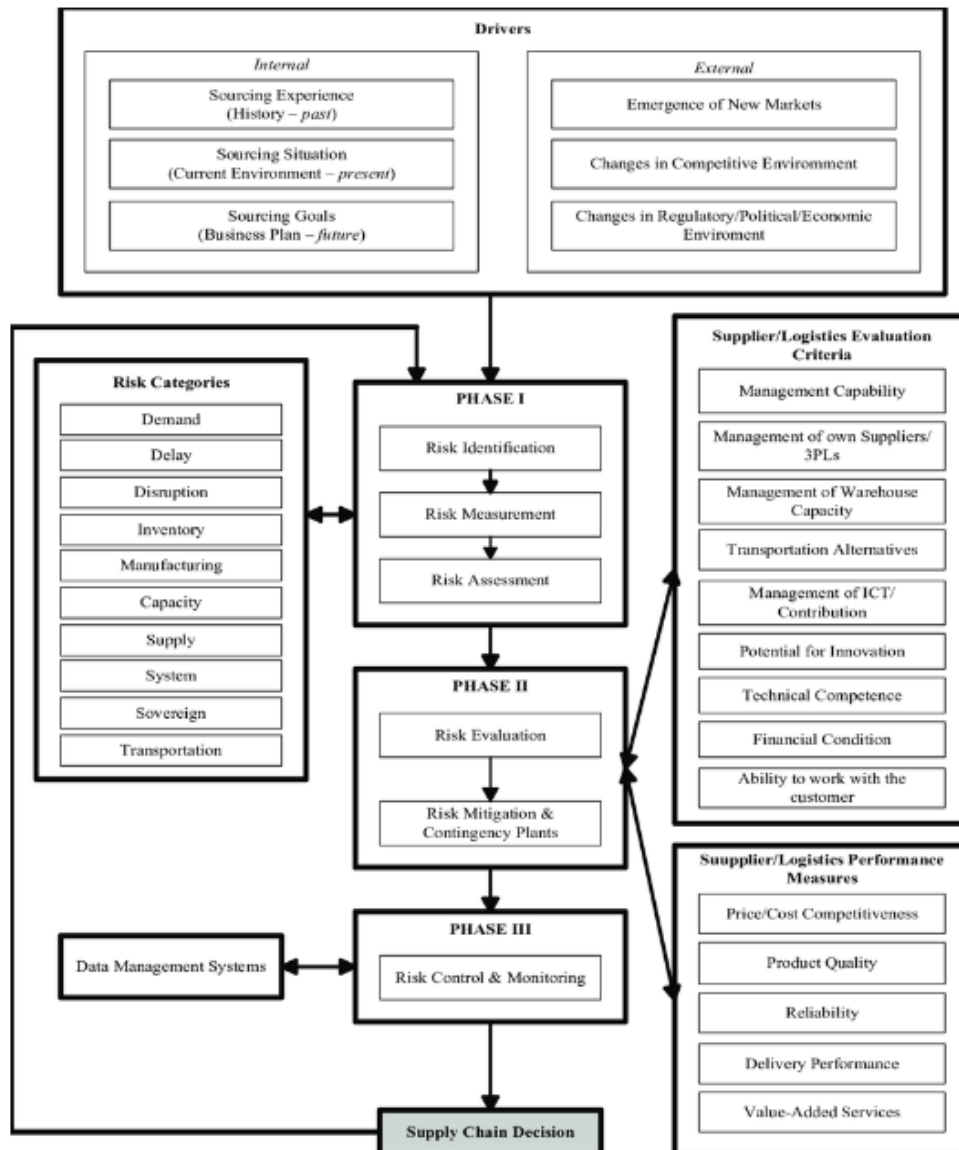


Figure 1.1: Supply Chain Risk Management Process (complete). Source: Tummala & Schoenherr, 2011.

Phase one of the SCRMP, presented on Chapter 2, consists of the identification, measurement and valuation of risks through the analysis of the supply chain within a company, determining its occurrence and the potential impact of the risks for a subsequent

evaluation. This study will be applied to a chemical company to observe the prioritization of risks due to their type of product and their own processes.

On the same company, the Quality database analysis will be done to verify the differences between this and the method presented before, to evaluate the suitability of using one or the other methodology. This is presented on Chapter 3.

Phase two of the SCRMP, presented on Chapter 4, consisting on the evaluation of the risk will be done by modelling risk as a penalization cost of a production-distribution model. The study takes place in a different company, with current operations in Mexico and Europe, but looking to extend globally.

1.4.2 Limitations

- There is a generalized lack of hard data on risk on the enterprises. Both the supply chain risk assessment and the determination of variables for the production-distribution model, involve a fair level of interpretation by the personnel involved in providing the information.
- Being a dynamic activity, the risks and their valuation may change as time passes. This is why the process should be continuous, but in the research, only the information on a specific period might be presented.

1.5 Structure

This research work construct the knowledge in phases, looking to reinforce it from the basis to the application on each chapter as follows:

- Chapter 2. Adaptation of the Fine-Kinney Method in Supply Chain Risk Assessment
- Chapter 3. Quality Analysis as a foretaste for Supply Chain Risk Assessment: A Case Study
- Chapter 4. Effect of risk on a production-distribution model. Case Study on a Global Industry
- Chapter 5: Conclusions and future work.

Chapter 2. Adaptation of the Fine-Kinney Method in Supply Chain Risk Assessment

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2.1 Abstract

Competitiveness based on the efficient operation of global supply chains requires a reduction of total logistic costs while maintaining them flexible to market changes and unforeseen events. Therefore, the focus on safety remains a key issue within the study of supply chains. Safety (or lack thereof) has an impact on operating costs, delivery time, inventory volume and the value of insurance rates, which can lead to a decrease of international competitiveness. This makes supply chain safety a competitive advantage, source of added value. The present study aims to expose risk factors assessment using an adaptation of the Fine-Kinney method, in which risks are analyzed based on their risk exposure, likelihood and impact severity. This adaptation includes an adjustment on the occurrence scale to consider the general degree of incidence, as well as on the severity scale to consider the number of impacts that each risk involves. A risk map for the processes associated with the chain using the scales considered is also proposed. Risks associated to the supply chain of a chemical company located in Mexico are assessed using this methodology, in order to establish the degree of vulnerability of each process involved, as well as to document the existing processes in the mitigation of risks. In the scope of the analysis, a total of 118 risks were found and classified, spotting 14 with a high-risk level. 18.6% of documented risk mitigation plans were detected, as well as 38.98% of undocumented plans. This is a first effort on identifying the sources of risk and thus, can be useful to prioritize the mitigation approach towards each one, in order to develop over the long term a risk management process at a corporate level.

2.1.1 Keywords

Fine-Kinney method; supply chain risk management; risk assessment.

2.2 Introduction

Globalized markets and outsourcing of activities minimize the control that companies can exert on the supply chain, since these make them more complex and extensive. Adding difficulties to normal variations on supply and demand, there are also some other issues that, although not directly related to the performance of the chain, can improve or hinder the flow of resources that transit through it. While the focus on risk is not new, the approach to safety remains a significant issue within a supply chain study. Both security and safety have repercussions on operating costs and therefore in its international competitiveness.

There is a growing awareness among companies to minimize the impact of the occurrence that the risks to which they are exposed could have. The first part to achieve a culture in risk management in supply chains, following the determination of the company work on this topic, is to identify the different sources of risk [1] in order to develop strategies to overcome them. It is imperative to find a balance between safety/security and competitiveness, investing resources in safety/security-related issues, affecting the least possible to logistic costs but reducing the vulnerability of supply chains.

2.3 Theoretical Framework

2.3.1 Risk

Risk is the probability that a given event (generally negative and undesirable) occurs within a certain time [2]. It focuses mainly on the consequences of the occurrence of such events, which may be failures, accidents, and injuries, among others. It is considered as the function of the probability that an event occurs and the magnitude of its consequences in case of occurrence [3], as show on eqn (2.1).

$$\text{Risk Level} = \text{Probability of Occurrence} * \text{Consequence of Occurrence} \quad (2.1)$$

There are two different approaches to risk that complement each other. One of them focuses on ensuring the correct functioning of a specific product / process / procedure, which leads to operating under appropriate conditions to avoid accidents and their consequences. The other approach has to do with the prevention, detection and response to illegal events such as theft, sabotage and unauthorized access, among others. These concepts are safety and security respectively. In other words, safety refers to protection against unintended random incidents, resulting from one or more coincidences, while security is the protection against deliberate incidents resulting from planned acts [4].

2.3.2 Risk Analysis

A risk analysis can be defined as the study of the possibility and consequences of each risk factor, once identified and classified [5]. It will help determine which factors have to be managed in order to minimize the overall risk impact on the chain. Three approaches (qualitative, quantitative, semi-quantitative) can be used to determine the level of risk, depending on the detail desired and/or the historical information about previous risk events

available. Some of these methods are summarized in the following tables.

Table 2.1: Methodologies for risk analysis. (Source: Adapted from Cruz et.al [6] and Romero [7]).

Considered factors in different approaches					
Qualitative		Quantitative		Semi-quantitative	
What if...?	development of scenarios	Quantitative Fault Tree Analysis (FTA)	Existing preventive measures for hypothetical accidents	Simple valuation	Review of damages
Matrix of risk factors	Detailed identification			Binary Method	Probability and severity of occurrence
Historical risk analysis	Information about incidents and accidents			Fine-Kinney Method	Exposure, likelihood, scale of risk
Checklists	Compliance of relevant safety aspects	Quantitative Decision Tree Analysis	Events to which the sequential processes of hypothetical accidents lead	Steel Method	Frequency, probability of occurrence, maximum probable loss, number of people exposed
Job safety analysis	Description of a specific process to detect potential risks				
Failure Mode and Effect Analysis (FMEA)	Severity rate, occurrence rate, detection rate	Quantitative Analysis of Causes and Consequences	Causes of an accident and its evolution	Strohm & Opheim Method	Frequency, probability of occurrence, maximum probable loss, number of people exposed, company's difficulty of survival
Hazard and operability analysis (HAZOP)	Process risks, potential operating issues				

Of particular note is the use of the Fine-Kinney method, which is widely used for professional risk assessment. It implies that risks can be somehow pondered considering the likelihood, the exposure to the risk and the possible consequences that the incidence of the risk might bring (Kinney [8]). The risk score is a function of the product of the three factors, as presented on eqn (2.2).

$$\text{Risk level} = \text{risk exposure} * \text{likelihood} * \text{impact severity} \quad (2.2)$$

The Scales used by the Fine-Kinney's method are the ones shown on Table 2.2.

Table 2.2: Scales proposed on the Fine-Kinney method. (Source: Berezutskyi & Berezutskaya [9]).

Exposure		Likelihood		Consequences	
10	Permanent	10	Expectations that happens	100	Catastrophe, many victims
6	Regular (daily)	6	Very likely	40	Alarm few victims
3	Occasionally	3	Unusual, but possible	15	Very heavy, 1 deceased
2	Sometimes (monthly)	1	Unbelievable	7	Heavy, disability
1	Sometimes (annually)	0.5	One can imagine but incredibly	3	Serious injury and absenteeism
0.5	Very rare	0.2	Almost impossible	1	Minimum, enough first aid
0	Never	0.1	Unable		
		0	Absolutely impossible		

Table 2.3: Risk score interpretation, Fine-Kinney method. (Source: Berezutskyi & Berezutskaya [9]).

Risk score	Risk situation
> 400	Very high risk; consider discontinuing operation
200-400	High risk; immediate correction required
70-200	Substantial risk; correction needed
20-70	Possible risk; attention indicated
< 20	Risk; perhaps acceptable

Once obtained information about risks and their impacts, a risk map can be carried out. This is an instrument that allows locating harmful factors in a given work space [10]. The purpose of risk maps is to implement prevention plans and programs as a priority for those risks with greater impact, to monitor risk management evaluating the effectiveness of the preventive actions implemented and to improve working conditions regarding safety/security.

2.3.3 Supply Chain Risk

The supply chain is the combination of organizations and service providers that manage the supply and manufacture of raw materials, as well as the delivery of finished products from the origin to the final customers [11]. In order to achieve an efficient coordination of all the operations required to ensure the supply, manufacture and delivery to the customer fulfilling their requirements, the supply chain management is carried out.

Risk is the result of uncertainty about future events. In a supply chain, this uncertainty has to do with the occurrence of events that may interrupt the flow of materials in the way it was conceived. The more complex the chain is, the more likely it is that events will be affected. Outsourcing operations increase risk within a supply chain, especially if companies providing the outsourced service have not verified their security requirements [12].

Different authors designate different concepts to risk triggers, such as risk types [13], supply chain risk threats [14], or supply chain risk vulnerability constructs (sources, drivers, consequences and mitigating strategies) [15], with their respective proposes of prevention and mitigation. Identification of potential sources of risk and implementation of actions to contain vulnerability are considered supply chain risk management. For mitigating supply chain risk, robustness [16], resilience [17] or a combination of both [18] within supply chain processes is consistently proposed.

To identify supply chain risk, qualitative methods of risk analysis using qualitative [19] or quantitative methods [20] can be applied. Although safety analysis on supply chains has been considered previously, since 9/11 events focus on security had increased its relative importance. Closs and McGarrell [11], for example, elaborate on security by enumerating critical dimensions and requirements for secure supply chains and proposing a tool to evaluate the level of security on companies.

Some other studies focus on the generation of informs that include the situational description of the risk for supply chains, either on a safety or a security point of view as to a country like Mexico in general [21] or a wider zone like Latin America regarding risk on inland supply chains [22]. Organisms as APICS fosters and presents findings on a supply chain risk management survey and compares them with the evolution since 2014 [23]. As an incentive for considering supply chain risk management, Peleg-Gillai [24] shows the inherent benefits of investing on supply chain security that innovative companies report.

2.3.4 Supply Chain Risk Management

Supply chain risk management consist on the identification and handling of the different types of risks through a coordinated approach among the stakeholders within it, in order to reduce the total vulnerability of all the processes involved. Khan [25] also says that it is a matter of avoiding the loss of customer trust and the erosion of shareholders' equity as a result of supply chain disruptions.

Focused on security supply chains, the C-TPAT program, part of the U.S. Customs and Border Protection's (CBP) cargo enforcement strategy, developed a risk analysis process [12] focused on terrorism, smuggling of illicit materials and people, organized crime, and conditions that can increase the risk of such threats. Closs and McGarrell [11] propose a methodology for establishing the level of security of a supply chain. For safety on supply chains, Kleindorfer and Saad [20] propose a management system to deal with risk that derive on supply chain disruptions based on statistical analysis of accidents on a chemical industry.

Tummala & Mak, Ellegaard, Finch, Manuj & Mentzer, Schoenherr et al. [1] developed the Supply Chain Risk Management Process (SCRMP) that provides a conceptual framework for efficiently and effectively managing the risks (on safety and/or security) existent throughout the chain. The complete model is shown on Figure 2.1.

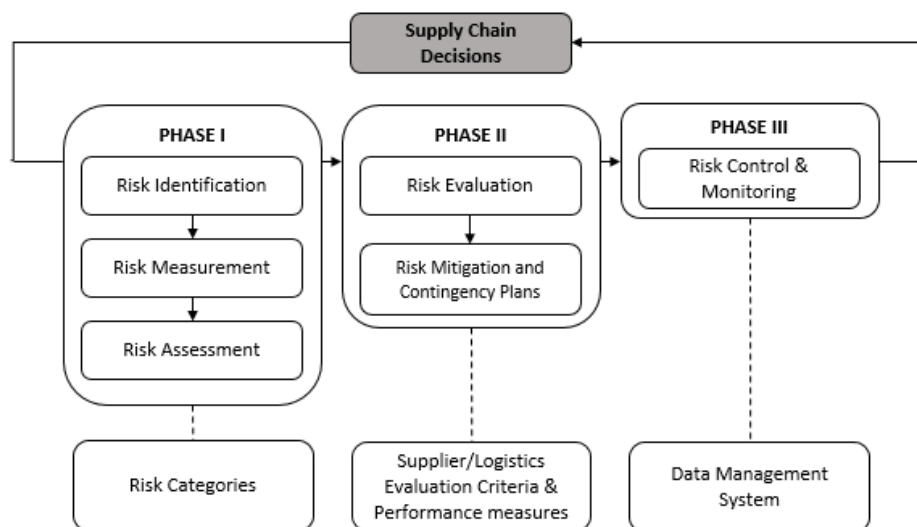


Figure 2.1: Supply Chain Risk Management Process. (Source: Adapted from Tummala & Schoenherr [1]).

2.4 Methodology

2.4.1 General method

This paper presents an alternative methodology based on the Fine-Kinney approach for the phase one of the SCRMP [1]. This phase consists on the risk identification, which will be performed by analysing the company's logistics chain, measuring and assessing them, determining their occurrence and the potential impact of the risks for later evaluation.

The process is established as follows:

1. First, key supply chain are identified in the organization that will conduct the study, by mapping the relationships among key areas to understand resource flows through them. In this step, it is important to identify the key personnel involved, since they would be participating on step three of this process.
2. Then, the general instrument proposed is adapted to the organization that will conduct the study. This instrument has been designed to obtain relevant information regarding the risks detected, their impact, recurrence and current process of mitigation.

The instrument designed aimed at knowing the different risks of the company. In order to analyse the risk more deeply, besides the base elements of risk exposure, likelihood and impact severity, two other aspects were taken into account.

3. Next, a series of interviews to those involved in controlling the process of the relevant areas detected are applied.

An open interview format is suggested. In this, the interviewed person is allowed to delve into the occasional and recurrent detected risks and what has been done to recover from the events occurred, as well as the mitigation plan (if any). The interviews should be of audience by area of study so the key personnel involved could jointly analyse the situations presented. It is an aimed interview that seeks to cover the elements embodied in the instruments described on step 2.

The obtained information is processed in order to perform a risk analysis and a risk map, evaluating the degree of vulnerability with which the organization's processes currently count. The analysis is based on the Fine-Kinney method, considering that subjective scales for each aspect have to be adjusted to the specific organization studied. All the aspects considered in the methodology are explained below.

2.4.2 Subjective scales and other considered aspects

2.4.2.1 Risk exposure

Exposure to risk is expressed as the relation between the existing risk situations and the time during which, one is vulnerable to it [32], as summarized on eqn (2.3).

$$Risk\ Exposure = \frac{risk\ situation}{time\ of\ exposure} \quad (2.3)$$

2.4.2.2 Likelihood

It is the frequency with which a risk derives on a disruptive event in a process, as shown on eqn (2.4). The likelihood is determined taking into account the available historical information. In case of not having it, a subjective criterion of occurrence is applied, to which a scale of probability was assigned. This scale must consider the degree of incidence of all the risk detected.

$$Likelihood = \frac{disruptive\ event\ due\ to\ a\ risk}{risk\ of\ exposure} \quad (2.4)$$

To calculate the scale, subjective criterion for all the risks, even for those with historical information available, has to be obtained in qualitative terms (such as: very frequently, frequently, normal, rare, very rare, never/almost never, for example.). There would be some data with both qualitative and historical data. From these, average quantitative values can be inferred in order to meet qualitative description. Once obtained the ranges, the probability average is assigned to those risk that lack of historical information. These last values should be validated by experts in the area where risks are detected.

2.4.2.3 Impact severity

It determines the subjective impact of the occurrence of the risk. In this methodology, severity impact level is considered as an incremental scale of the possible impacts a risk can have, as shown on eqn (2.5). The occurrence of a risk may have consequences for the organization in one or more of them. Impacts should also be pondered by the relative importance each organization might have.

$$Impact\ severity = \frac{\sum_{i=1}^n relative\ weight_i * impact_i}{risk\ of\ exposure} \quad (2.5)$$

2.5 Case Study: Chemical Company

2.5.1 Background

The proposed methodology was implemented in a chemical company located in Mexico. Since 2008, it manufactures and distributes emulsions, materials for opacifiers, dispersants, biological modifiers, coatings, adhesives and biocides in a mostly local market with an approximate 40% of export operations to Caribbean and Latin American countries mainly. This enterprise intends to know the most important risks within its supply chain with the purpose of subsequently suggest specific risk management programs for those that represent greater vulnerability according to the impact of the disruptive event triggered by that risk.

The functional supply chain mapping, which includes the identified scope areas, is shown on Figure 2.2. A more detailed flow mapping of the logistics of the company's resources was also elaborated.

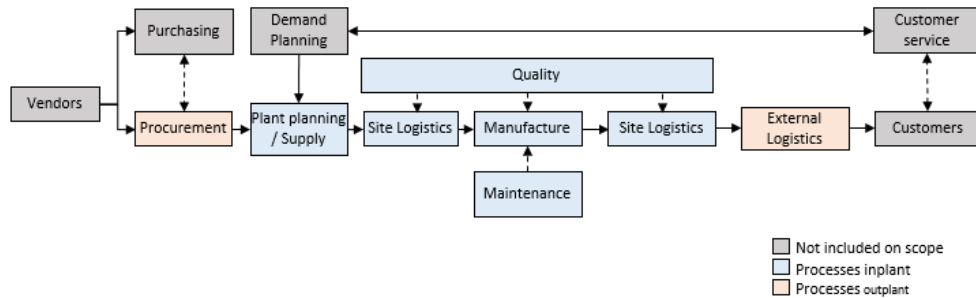


Figure 2.2: Study scope of the company's supply chain. (Source: own elaboration).

After instrument adaptation, its application was conducted. A safety analysis was carried out at the workplace where, on the basis of the specific process performed by each area, the potential risk of disruption in the product flow was obtained. Conducting interviews with decision makers introducing What if? technique made it possible to obtain information both from the supply chain process and from the risks detected. The realization of process maps also allowed to glimpse points vulnerable to a disruption. The approach towards a scenario of risk factors allowed a deeply description of the effects of previously detected risks.

When obtaining the information of the instruments, a semi-qualitative analysis was carried out. Risk factors assessment is done using the formulation proposed and its results enable the creation of the risk map of the processes involved. The degree of vulnerability of each process is established by plotting its impact and recurrence. The results are presented in the following section.

2.5.2 Subjective scales

2.5.2.1 Risk exposure

In this particular case, although time of exposition for each risk detected might be calculable, it was presumed that every process has the same time exposure to every risk detected. This first assumption was done considering that the processes are exposed to any risk at any time.

2.5.2.2 Likelihood

The subjective criterion applied for occurrence was calculated as explained on the methodology, assigning subjective probability of the risk occurrence as shown on Table 2.4. While collecting the information, it was detected that from the risks identified 30.51% have not derivate in a disruption event and 29.66% have solid information about occurrence. It was necessary to assign subjective probability to 39.83% of the risk detected.

Table 2.4: *Subjective probability of the risk occurrence. (Source: Own elaboration).*

Occurrence	Assigned probability
Very frequently	28.57%
Frequently	22.86%
Normal	17.14%
Rare	6.86%
Very rare	3.43%
Never/almost never	0.01%

2.5.2.3 Impact severity

The risk is evaluated considering aspects which derive in consequences for the organization. Having revised the literature, these aspects have been grouped in four: economical, when the impact has a repercussion on costs; personnel, when the damages extend to the integrity of human resources; operational, when it origins a variation of the normal process of product flow; and in the image of the company itself, which represents the perception of disruption by the client, society or other direct or indirect participants in the business. When considering these four types of impact, the impact severity of the consequences of a risk is measured according to the following scale, considering that the same importance has been given to all of them.

Table 2.5: *Subjective impact of the risk. (Source: Own elaboration).*

Severity	Number of impacts of each risk
Very low impact	1
Low impact	2
High impact	3
Very high impact	4

2.5.3 Results

The number of risks detected were 118, mainly in External Logistics (25.42%), Site Logistics (17.8%), Manufacturing (16.1%) and Quality (15.25%). Their occurrence impact mostly on the process operation (45%) and costs (29%). The most controlled issue is personnel safety (6%). Of the risks detected, 69.49% have developed into some disruptive event on average. The proportion by area is shown on Figure 2.3.

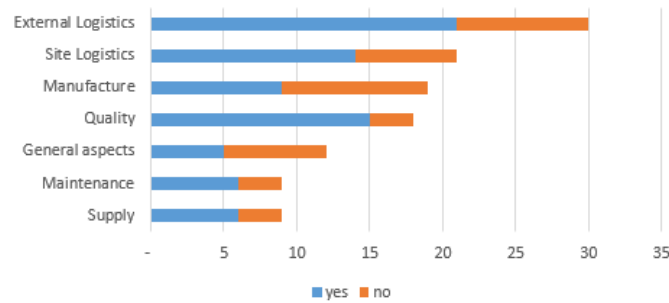


Figure 2.3: *Disruptive events originated by the risk detected. (Source: own elaboration).*

The above information only includes exposure to risks. The likelihood and severity previously calculated complements it. Considering the three aspects, it can be observed that the area where the risk can affect the company more by its combination of likelihood /severity of impact is Site Logistics (31.01%), followed by External Logistics (26.75%), Quality (18.61%), and Supply (9.99%). Manufacture (5.34%) and Maintenance (2.64%), despite presenting several risks, their periodicity and impact place them at the last places. This may be due to greater attention to the control of the production process, which reduces the likelihood. All areas have a proportional participation in the potential operational disruption, while External Logistics can have greater economic and image impact, as shown on Figure 2.4. This is because External Logistics represents the last link towards the customer and has direct a contact with him in the delivery of the finished goods.

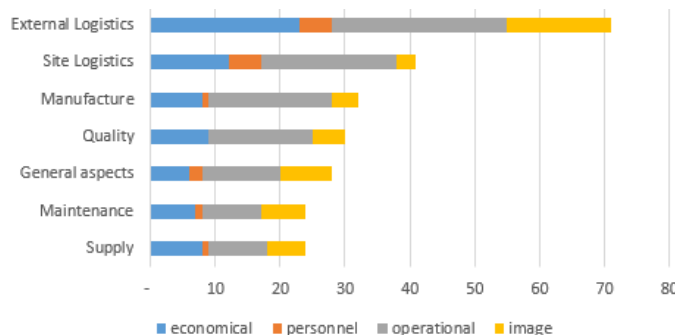


Figure 2.4: *Impact of risks by area. (Source: own elaboration).*

Once information was analyzed, the general risk mapping obtained is as follows, where the detected risks can be identified by degree of vulnerability. The limits established for the risk map are obtained considering the previously calculated subjective scale.

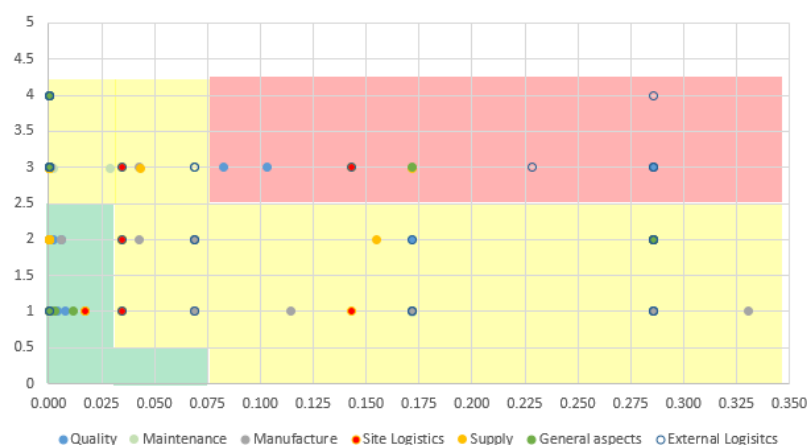


Figure 2.5: General Risk Map. (Source: own elaboration).

Table 2.6 shows the areas by vulnerability in terms of the potential risks of disruption of the chain. Some control is observed in the Manufacturing process and General Aspects. Supply and Maintenance remain as the least risk level. The areas with the greatest potential for disruption are Site Logistics, Quality and External Logistics, either because of the periodic occurrence of events and/or the direct impact they have on the customers they serve.

Table 2.6: Risk level by area. (Source: Own elaboration).

	Number of risks	Risk level**	Number of risks with the highest risk level
Site Logistics	21	6.1010	3
External Logistics	30	3.6184	4
Quality	18	3.6071	5
Supply	9	2.1696	1
Manufacturing	19	1.3722	0
General aspects	12	0.7581	1
Maintenance	9	0.3743	0

**Considering exposure, likelihood and impact severity

2.5.3.1 Findings on risk mitigation

Although 69.49% of the risks detected have resulted in some kind of disruptive event, it is noteworthy that only 18.64% have some type of documented mitigation plan. However, informal actions are applied for a considerable percentage (38.98% for a total of 57.62% risk with mitigation plans). There is no plan for 42.37% of the risks detected. Those areas with the most documented mitigation procedures are Manufacturing, Quality and Site Logistics. Logistics and General Processes stand out like those with the least mitigation plans either documented or undocumented.

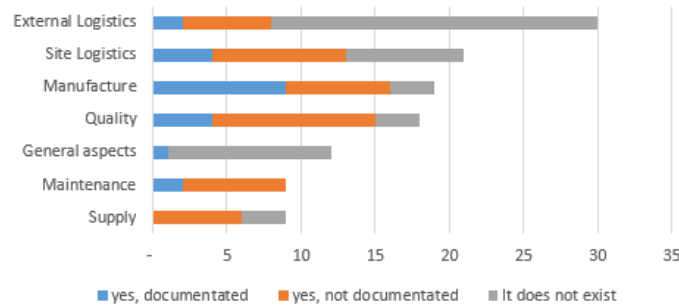


Figure 2.6: Findings on mitigation plans. (Source: own elaboration.)

2.6 Conclusions

Companies can begin to focus on improving safety in the supply chain by applying their own methodologies or by aligning them with existing methods or regulations, as the proposed adaptation of the Fine-Kinney method did in this case. Knowing the sources of risks and classifying them will allow to prioritize the actions that must be implemented to reduce their consequences, remembering that the logistics chain is as secure as its weakest link.

The first action is to assess the current process by looking at the main actors in the chain and the common sources of risks in the environment in which the business is carried out. This assessment will allow the creation of a map of risks and determine their level of vulnerability. This should not be a one-time process, but the first step to institutionalize an integral risk management program that re-evaluates risks and their consequences on a regular basis.

In the case of study presented, the findings are significant. The areas of Manufacturing and Maintenance are perceived as the most controlled, probably because of the corporate approach to optimizing the key business process. Site Logistics and External Logistics are seen as the most vulnerable to disruption. This may be due to the proximity of the External Logistics area to the customers, which increases the impact towards them or the direct and frequent involvement of Site Logistics in the process. It is not surprising then that four risks detected on External Logistics and three of Site Logistics are categorised as most vulnerable. Regarding mitigation plans, it was detected that the company has 18.6% documented mitigation plans (most of them for the areas of Manufacturing, Quality and Site Logistics), 38.98% of undocumented plans and 42.4% without any plans for the risks detected (mainly in the areas of External Logistics and General Processes).

The next step following the identification of the sources and the prioritization of these sources, should be the development of risk management plans and their implementation. These strategies for planning, mitigation, detection, response and recovery must focus on the awareness of the participating actors throughout the chain on developing a culture of prevention and action management of risk. This represents the future work to be developed at each area and at the whole company, then, best practices could be also replicated in an intercompany implementation.

It is important to establish a solid basis for supply chain risk detection and assessment. From these first approaches it will depend that future endeavour to mitigate them will accomplish expectations. One of the actions that has proven to work for identification and prevention of impact of risks is to maintain a collaborative supply chain. Good supplier-customer relationships facilitate communication and joint work to deal with disruptive situations. Coordinated actions between all the actors within the supply chain turn out to be the most effective and sustainable over time.

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Chapter 3. Quality Analysis as a foretaste for Supply Chain Risk Assessment: A Case Study

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3.1 Abstract

Supply chain disruptions lead to a loss of effectiveness. These can be analyzed to be reduced by applying a Supply Chain Risk Assessment (SCRA), but its application is not so widespread. Since Quality Analysis (QA) aims to reduce process variations, existing quality databases can be considered to increase logistics performance by reducing supply chain risk. This study applies SCRA and QA to a company to observe the suitability of the second method when detecting supply chain risks. For SCRA, a study based on Fine-Kinney methodology was considered. For QA, non-conformity databases were analyzed considering risk types, sources, origins and impacts. Finally, both normalized risks are compared. Ranking of risks by area is almost the same, despite of significant differences between normalized results, explained by a more exhaustive focus of SCRA. QA is not proposed to substitute a SCRA, but as an early complement to use databases available for logistics feedback.

3.1.1 Keywords

Supply chain; logistics, supply chain risks; logistics risks; supply chain risk assessment; quality analysis; quality databases; supply chain disruptions; logistics performance; Fine-Kinney method.

3.2 Introduction

There are a few similarities between Quality and Logistics areas. Both Quality and Logistics share the assignment of meeting customers' specifications and therefore increase their satisfaction. Both can represent a distinctive element of value that increases competitiveness on organizations.

These similarities might help companies that want to start focusing on reducing their supply chain risks in order to strengthen their logistics performance since there is a lack of empirical studies for supply chain risk management (Ferreira et al., 2018). Currently, few enterprises generate information on logistics compliance in order to develop strategies to upgrade their achievement.

With an early focus of companies on offering better products and services to their customers, Quality Management has been part of the enterprise strategy since long ago. Therefore, its probability of being certified (or looking to be certified) on ISO 9000 is high. In addition, since this ISO requires the registration of any deviation on the quality product/process, it is easier to count with this type of information when looking for potential areas of opportunity on the logistics issues.

Trying to optimize the time for implementing actions to improve Logistics through the mitigation of supply chain risks, Quality databases might help to detect problems, while generating the specific information that might focus on logistics and/or supply chain. At the end, both processes search the continuous improvement that will lead to a growth on the value that the organization can provide to its customers.

3.3 Literature Review

3.3.1 Supply chain risk

Materials and components flow through a series of processes in different companies in order to make their way as products to the final customer. Supply chains include all these companies as well as their relationships of information, material and money exchange. The continuous flow within the supply chain derives into efficiency as well as compliance of the customers' requirements such as delivery time, quality of the product and a fair price. Consequently, disruptions in the conceived process might diminish the total efficiency of the chain (Chen, et al., 2013). That is why risk for disruption on the supply chain should be assessed for its reduction in benefit of the stakeholders.

Jüttner et. al (2003) categorizes supply chain risk sources as environmental, network and organizational. A similar, more extended classification is suggested by Christopher and Peck (2004), who consider supply chain risks as supply, demand, process, control and environmental. Manuj and Mentzer (2008) group process and control as operational risk and focus environmental risk to security.

Other classification for supply (chain) risks (Zsidisin, et al., 2000) include business, supplier capacity constraints, quality, production technological changes, product design changes, and disasters risks. Cavinato (2004) categorizes supply chain risks on five networks: physical, financial, informational, relational, and innovation.

At an upstream level, risk constitutes an inevitable part of purchasing (Ellegaard, 2008). Failures on inbound goods or services can affect not only the firm that buys them, but their distribution channels and the final customer (Zsidisin and Ellram, 2003). Supply risk is constituted by the adverse events in inbound supply that affect the ability to meet customer demand (on quantity, quality, cost or time) or causes threats to customer security (Manuj and Mentzer, 2008; Zsidisin, 2003).

Operational risks are those that affect the internal ability to produce goods and services. Demand risks are those that affect the likelihood of customers placing orders as well as the possible variations on them. Security risk include the threats on human resources, operations integrity, and information systems (Manuj and Mentzer, 2008).

Logistics risks are consistently detected on supply chain management research and can be defined as the potential disturbance in the flow of goods, information and money (Ellegaard, 2008). Supply risk can be associated with (information) security, opportunistic behaviour, and corporate social responsibility (Spekman and Davis, 2004). This means, the vulnerability when sharing information, the reliance on suppliers that might act in their own interest and the interaction of suppliers with their stakeholders have an impact on the operation of the company.

The correct handle of information is widely studied as a source of competitiveness on the supply chain (Finch, 2004). Bandyopadhyay, et al. (1999) structured Information Systems risk on three levels: application, organizational and inter-organizational. Application level includes internal or external factors that detonate a failure of an application, such as natural disasters, accidents, deliberate acts, data information security risks and management issues. Organizational level refers to a generalized failure on IS implementation through all functional areas, such as: legal risk, strategic decision making, strategic and sustainability risks, and increased bargain power. Inter-organizational level include those risks that affect the whole organization networking, such as controls on suppliers/customers systems, policies and procedures.

Cousins, et al. (2004) detail the impact of environmental hazards (environmental impact exposures; economic, political and social exposures) on financial, performance, physical, social, psychological and time losses. Other sources of supply chain disruption can be labour strikes, natural disasters and pandemics, terrorism, process breakdowns, supplier disruptions, logistical failures, and political instability (Schoenherr, et al. 2008).

In a practitioner-oriented research, demand and process risks are found to be directly affecting supply chain performance, while supply and demand risk influence process risk (Chen et al., 2013). Other researches disaggregate these general risks according to the

industry studied. Principal risk events identified on fourteen in-depth qualitative interviews with senior supply chain executives across eight industrial companies (Manuj and Mentzer, 2008) were: currency, transit time variability, forecasts, quality, safety, business disruption, survival, inventory (and tools) ownership, culture, dependency and opportunism, oil price fluctuation, and risk events. A Participatory Action Research held on a manufacturer and distributor of commercial tools for contractors and residential customers resulted on the detection of 17 risk factors relevant for their supplier selection (Schoenherr et al., 2008). These risk factors by descending order of importance according to the research are product cost, product quality, order fulfilment risk, transportation risk, ANSI compliance, competitor cost, supplier fulfilment risk, on-time/on-budget delivery, logistics risk, sovereign risk, wrong partner risk, overseas risk, supplier risk, demand risk, supplier's supplier management, natural disasters/terrorism, engineering and innovation. Bak (2018) groups supply chain risk into four categories based on where the continuity is interrupted. These categories are design, relationship, process, and economic continuum.

3.3.1.1 Proposed terminology

Considering the previous research, and trying to bring all the observed concepts together, the following sources of risk and types of risk are proposed. In general, there are three sources of risk on supply chains as shown in Figure 3.1.

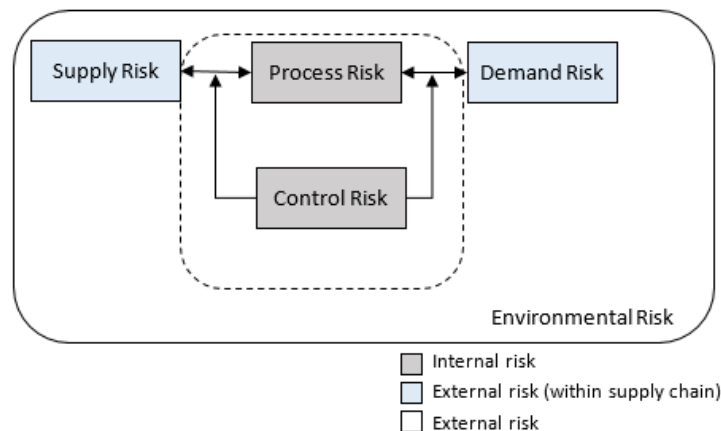


Figure 3.1: Risk sources within the supply chain. Source: Adapted from Christopher, M., and Peck, H. (2004), and Jüttner, U., Peck, H., and Christopher, M. (2003).

The internal risk is the one that can be controlled by the organization to which it affects. It is much more common and has a generally milder impact than external risk. External risk on the other hand does not depend on the company. It comes suddenly, as a result of its interaction with the environment. There is an intermediate part, the external risk to the company but internal to the supply chain. These risks are generated because of the changes in the upstream and downstream^A part of the network and which theoretically can

^A The supply chain consists of three general components: upstream, midstream, and downstream. Upstream includes those activities required for the sourcing of raw materials, such as procurement activities, supplier selection and development. Midstream deals with internal processes that transform the raw material into the final product.

be anticipated and controllable with internal measures. Each type of risk associated with each source of risk is shown in Figure 3.2 and explained below.

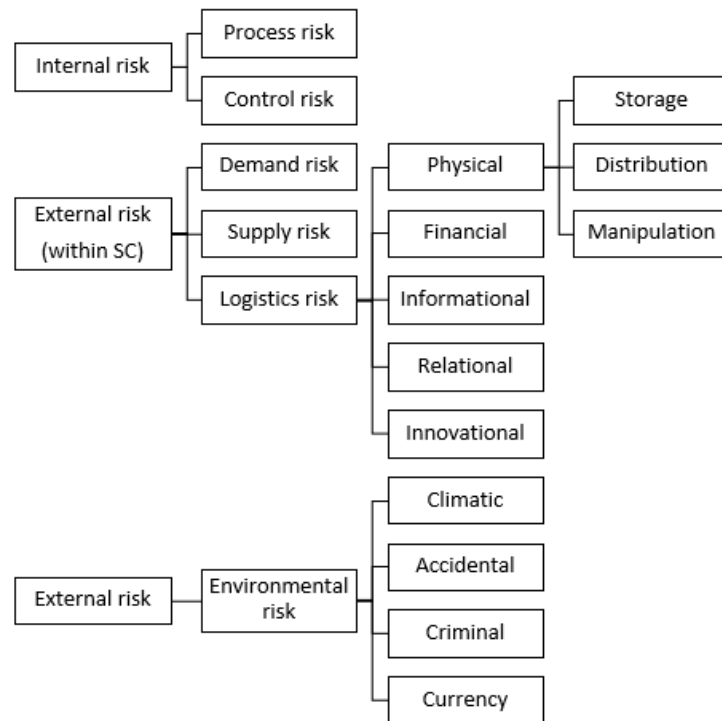


Figure 3.2: Risk sources within the supply chain (extended table). Source: Own elaboration.

Process risk refers to the correct functioning of the infrastructure and the operation, while control risk refers to the correct setting and compliance of norms and procedures.

Demand risk aims to guarantee the correct levelling between the company's inventory level of finished goods and the market requirements. Supply risk looks to guaranty the correct level of inputs that the process requires to meet the demand. The logistics risk can apply to the different flows, for example, material delivery (distribution), material management (manipulation), and/or material stock keeping (storage). Other examples include cash flow (financial) and data generation, movement, access and use (informational). A good relationship among stakeholders as well as the innovative opportunities between all the supply chain participants is also considered.

For environmental risk, events such as climatological elements, not intentional incidents, illegal activities, and exchange rate fluctuation are taken into account.

3.3.2 Supply chain risk management

Supply chain risk management looks for the reduction of the vulnerability of a supply chain

Downstream has to do with the activities involved on the delivery of the products to the final consumers, such as storage, distribution, transportation and after-sale services (Crandall, Crandall and Chen 2014).

caused by one or more of the risks presented before (Peck, 2006). Its function is to identify risks in order to find out the best way to handle them. Supply Chain Risk Management consists on acknowledging and dealing with risk concepts, risk sources and risk consequences within a specific supply chain in order to develop risk mitigation strategies (Jüttner et al., 2003). An appropriate Supply Chain Risk Management might mitigate the changing business environment and result on a better financial performance and a competitive advantage (Hauser, 2003). Some authors have proposed management systems to deal with supply chain disruption risk (Ellegaard, 2008; Finch, 2004; Manuj and Mentzer, 2008; Schoenherr et al., 2008). Tummala and Schoenherr (2011) proposed a Supply Chain Risk Management Process, in Figure 3.3.

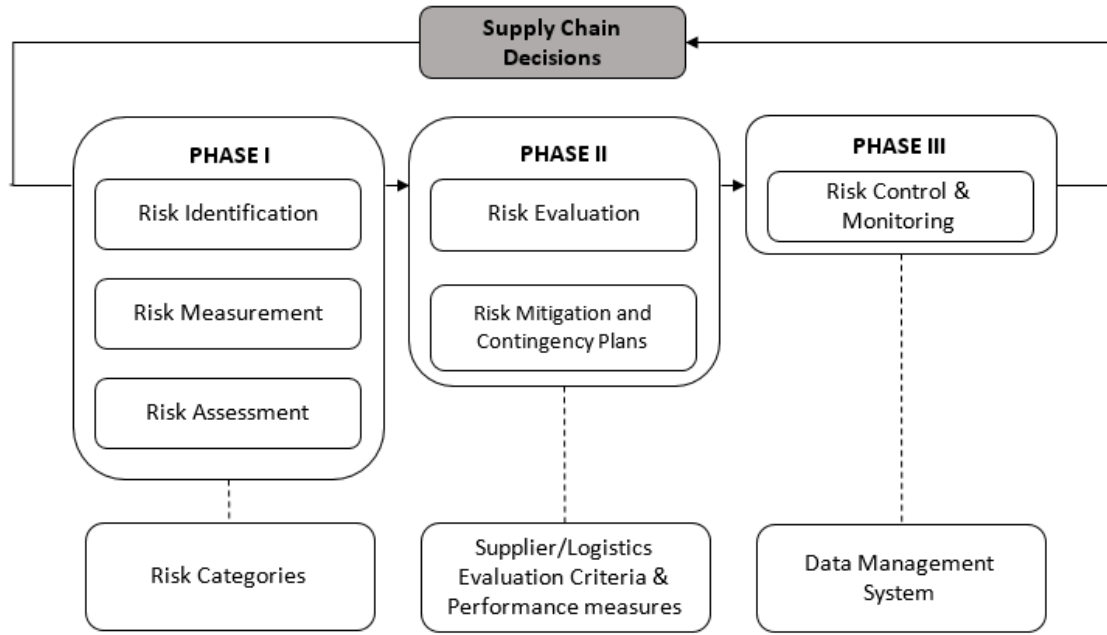


Figure 3.3: Supply Chain Risk Management Process. Source: Adapted from Tummala and Schoenherr (2011).

Based on them, other authors have adapted risk management methodologies to suit for supply chain. Phase 1 includes identification, measurement and assessment. For this step, Cruz, De la Torre, and Martinez (2018) proposed a detailed methodology based on the Fine-Kinney method in which elements such as risk exposure, likelihood and impact severity were measured in each supply chain related area using the Equation 3.1, 3.2 and 3.3.

$$Risk\ Exposure = \frac{risk\ situation}{time\ of\ exposure} \quad (3.1)$$

$$Likelihood = \frac{disruptive\ event\ due\ to\ a\ risk}{risk\ of\ exposure} \quad (3.2)$$

$$Impact\ severity = \frac{\sum_{i=1}^n relative\ weight_i * impact_i}{risk\ of\ exposure} \quad (3.3)$$

The identified risks are evaluated and ranked considering these three aspects in order to prioritize the focusing of limited resources in trying to minimize those risks that might reduce the total supply chain risk. Impacts were analysed and segmented in four: An impact on personnel is generated when a risk might damage in any way our labour force. An operational impact occurs when risks derive into a disruption on the conceptualized way a process should work. Economic impacts happen when a risk result on a direct implication on costs. When there is an impact on the image, there is also a negative connotation on stakeholders' trust since they perceive the disruption and its consequences.

3.3.3 Quality analysis

Every process is subject to diminish its variability by following a continuous improvement process (Gejdoš 2015). It is necessary to establish the variation parameter before looking for its root cause.

A Statistical Process Control can be carried out using a range of tools to determine variance in a system and its root causes. These tools can be Ishikawa diagram, diagrams of the relationship (cause-and-effect) (Czajkowskaa and Stasiak-Betlejewska, 2015); Pareto Analysis, check sheets, histograms, scatter grams; statistical process control charts and inspection plans (Gejdoš, 2015; Kahn et al., 1996).

ISO 9000 standards on Quality Management Systems (QMS) sees the result of the process as a way of describing the company's performance. Opportunity areas can be detected from failures in the quality product/process. According to this ISO standard, deviations on the quality product/process, known as non-conformities, should be documented. The rate of non-conformities is recognized as an important indicator for measuring the organization performance. Non-conformities should be enquired to its roots causes in order to establish corrective/preventive actions towards them.

This is achieved by a simple process, shown in Figure 3.4. It starts with the decision of turning a failure detected into a formal non-conformity. Then, the non-conformity report is fulfilled with information, which will establish the priority for its solution. In addition, a failure code will be assigned in order to direct the responsibility of its solution to a specific actor within the process. This responsible area will be in charge of determining the underlying causes and developing corrective/preventive actions to avoid its recurrence.

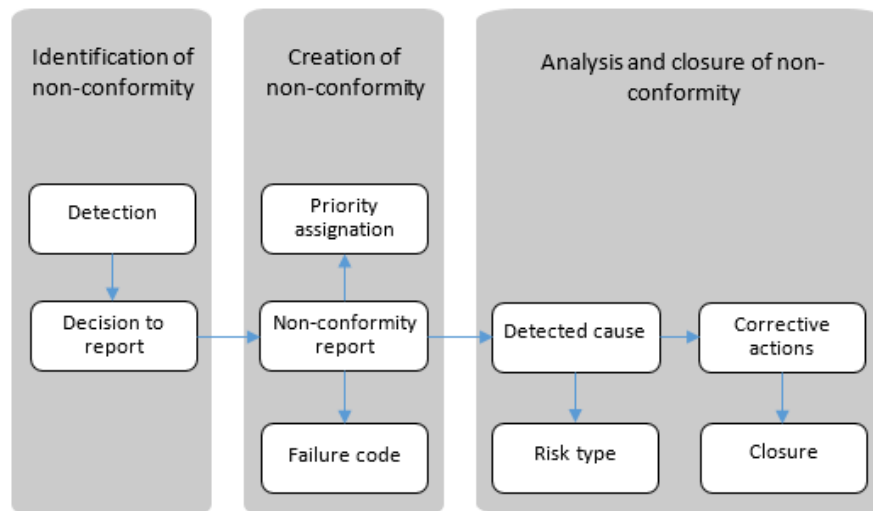


Figure 3.4: Non-conformity process. Source: Own elaboration based on Case Study.

Quality assurance systems are not one-process oriented. The correct compliance of the system will lead to prevent low quality in the whole organization, which includes the Logistics areas. Measurement of quality of the logistics service has been oriented to strengthen the 7R's (Czajkowskaa and Stasiak-Betlejewska, 2015; Zhang and Zhang, 2011):

- Relevant goods
- Right quantity
- Right timing
- Right place
- Right quality
- Relevant costs
- Right customer

A low level of logistics services is inferred to increase non-conformities occurrence because of the relationship with customers (Dowlatsahi, 2000; Czajkowskaa and Stasiak-Betlejewska, 2015). Techniques applied to influence quality of processes, such as stock sizing, responsiveness, communication between functions of supply and/or delivery, have to do with supply chain management. Therefore, some logistics deviations derive into non-conformities. High service quality processes have resulted to have greatest impact on logistics service quality (Zhang and Zhang, 2011). It makes sense then, that quality assurance on organization processes can provide a landscape of logistics processes performance.

3.3.4 ISO

The International Organization for Standardization (ISO for its Greek word isos, which means equal) is an international organization that aims to develop industrial standards since 1947. They assumed responsibility of the creation of documents that can be used as guideline to ensure the correct functioning of processes and products. Currently, ISO has

presence in 164 countries and works with 781 technical bodies for standards development. They have published 22996 International Standards (ISO, 2020a).

From all the standards, the following four have been identified as the most suitable to include elements seeking to reduce supply chain risks: ISO 28000:2007 Specification for security management systems for the supply chain, ISO 31000:2018 Risk management, ISO 22301:2019 Societal security and 39001:2012, Road Traffic Safety (RTS) management systems. The most known and widespread ISO might be ISO 9000 Quality management, according to ISO records (ISO, 2017). The five of them are explained in Table 3.1.

Table 3.1: *Supply chain/Quality related ISO Standards. Source: Own elaboration based on (ISO, 2020b), (ISO, 2020c), (ISO, 2020d) & (ISO, 2020e).*

Standard	Description
<i>ISO 28000:2007 Specification for security management systems for the supply chain</i>	It proposes guidelines to develop an accurate security management system, especially those relevant to the supply chain security assurance.
<i>ISO 31000:2018 Risk management</i>	It provides a general framework for risk management as well as a risk management process.
<i>ISO 22301:2019 Societal security</i>	It gives generic specifications to develop a documented management system in which disruptive events can be well handled reducing their impact.
<i>ISO 39001:2012 Road Traffic Safety (RTS) management systems</i>	It aims for the development of a RTS policy to reduce road traffic crashes and injuries.
<i>ISO 9001:2015 Quality Management</i>	As part of the ISO 9000, this ISO aims to ensure requirements' compliance based on quality improvement.

Supply chain risk management is so young on ISO perspective that just in 2016 the measurement of certifications based on both ISO 28000:2007 and ISO 39001:2012 Standards were included as Management System Standards on ISO reports (International Organization for Standardization, 2018). The reach of the certifications that might have to do with supply chain risk management is around 0.29% in 2016, around 0.34% in 2017, and around 0.21% in 2018. This means that it is much more probable to find a company certified on Quality Management than on a Supply Chain Risk Management aspects. The number of worldwide certifications on ISO Standards and its development from 2016 to 2018 are shown in Table 3.2.

Table 3.2: ISO Standards based certifications worldwide development. Source: Own elaboration based on (ISO, 2018) & (ISO, 2019).

STANDARD	2016		2017		2018***	
	Total	%	Total	%	Total	%
ISO 9001	1105937	70.15%	1058504	67.99%	878664	67.20%
ISO 14001	346147	21.96%	362610	23.29%	307059	23.48%
ISO 22301*	3853	0.24%	4281	0.27%	1506	0.12%
ISO 28000*	356	0.02%	494	0.03%	617	0.05%
ISO 39001*	478	0.03%	620	0.04%	547	0.04%
OTHER**	119767	7.60%	130249	8.37%	119210	9.12%

* ISO certifications related to supply chain issues

** Mostly ISO 50001, ISO 27001, ISO 22000 & ISO 13485

*** Calculation method changed, resulting on a reduction of valid certificates.

In Table 3.2 it is shown that the proportion of certification on Quality Management is around 67-70% while the number of supply chain related certifications is very low and growing slowly. This is the justification of the study. It is more suitable to find enterprises with developed quality management databases than companies with a specific supply chain risks database. A level of analysis applied on this quality databases might be helpful to start focusing on supply chain risk reduction without waiting until full Supply Chain Risk Management implementation. Using quality databases is not a substitute to supply chain risk databases but, well applied, it could represent a guideline that enterprises might consider while building the focused Supply Chain Risk Management strategy.

3.4 Case study: chemical company

The study was implemented in a chemical company located in Mexico, which manufactures and distributes emulsions, materials for opacifiers, dispersants, biological modifiers, coatings, adhesives and biocides worldwide.

The company aims to develop on the mid-term a Supply Chain Risk Management Program and want to know if their existing processes and/or databased might be helpful to start. The functional supply chain mapping, which includes the identified scope areas, is shown in Figure 3.5.

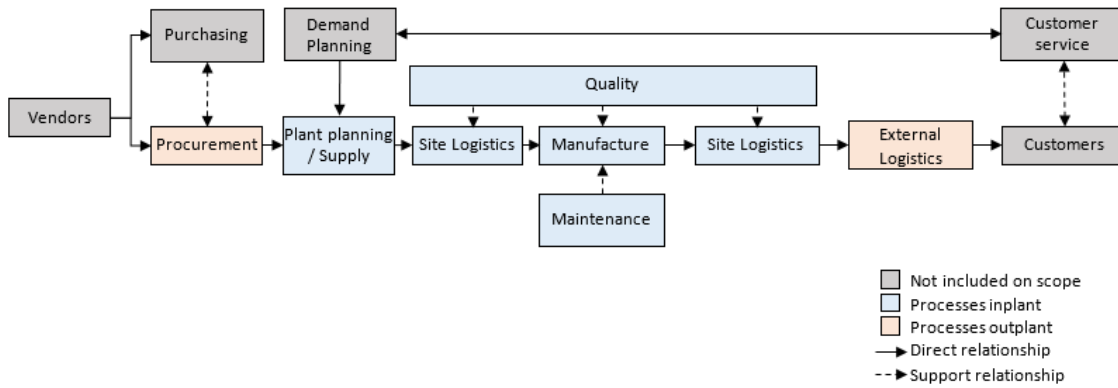


Figure 3.5: Study scope of the company's supply chain. Source: Cruz, De la Torre, and Martinez (2018).

3.4.1 Objective

This paper aims to find out the relation between the risk factors found applying a methodology focused on supply chain risk and those found analysing the Quality Management System of a company. This comparison should display the feasibility of analysing non-conformity reports as a first effort to minimize risks related to supply chain.

3.4.2 Scope and limitations

This study case considers the results obtained in the application of an adaptation of a widely used risk management methodology applied to supply chain risk assessment (Cruz, De la Torre, and Martinez 2018). The general findings are compared with those obtained by the analysis of the non-conformity reports generated between 2011 and 2016. Both methodologies are applied to the same company. The type of industry might influence the findings resulting on variances when applying the same methodology to other industries (Ferreira, et al 2018).

3.4.3 Methodology

The data collection method includes the review of existing literature regarding quality issues, process variability, and supply chain risk, as well as process control tools for logistics variability reduction. In addition, supply chain risk management processes were revised.

For the first part, the supply chain risk assessment consisted in the detection of key responsables on each part of the supply chain process were identified by mapping the relationships among key areas to understand resource. Then, after adapting an instrument designed to obtain information regarding risks detected, their impact and recurrence, a series of interviews to the previously detected responsables was conducted. The most important part consisted on the adaptation of the scales of risk exposure, likelihood and impact severity to the specific company where the study is being conducted. This was done applying Equations 1 to 3 to find the specific parameters to consider on the analysis. The information was processed to obtain results that lead to a prioritizing of the risk areas of the

enterprise from the logistics process flow of the material within it.

For the second part, the non-conformity database of the same company was analyzed using IBM SPSS Statistics. The database was revised to avoid duplicity. A “supply chain risk type” code was assigned to each risk associated by its impact to a logistics process, the risks correspond to those shown in Figure 3.2 “Risk sources within the supply chain (extended table)”. A more detailed evaluation to each of the 867 non-conformities was done in order to address each one to the corresponding origin of the risk. Even when Information risk is a part of logistics risk, it was handled separately because of its recurrence and importance. Supply risk is assumed to be contained by the Quality Department, the Supply Department, and the corresponding supplier. Since the analysis is to the non-conformity reports done to the final production there should not permeate until those steps of the process.

Furthermore, results were normalized using Equation 3.4, where z represents the normalized value, X is the individual result obtained in each scale, which is the value to be normalized; μ and σ represent the mean and the standard deviation of the total data set that is being normalized. This allowed a proper comparison considering some assumptions. Finally, findings are presented.

$$z = \frac{x - \mu}{\sigma} \quad (3.4)$$

3.5 Results

3.5.1 Supply chain risk assessment (Fine-Kinney based)

The application of the Fine-Kinney based method for supply chain risk management assessment brought the results shown in Figure 3.6, where it can be observed the distribution of the risk assigned to each area and by type of impact.

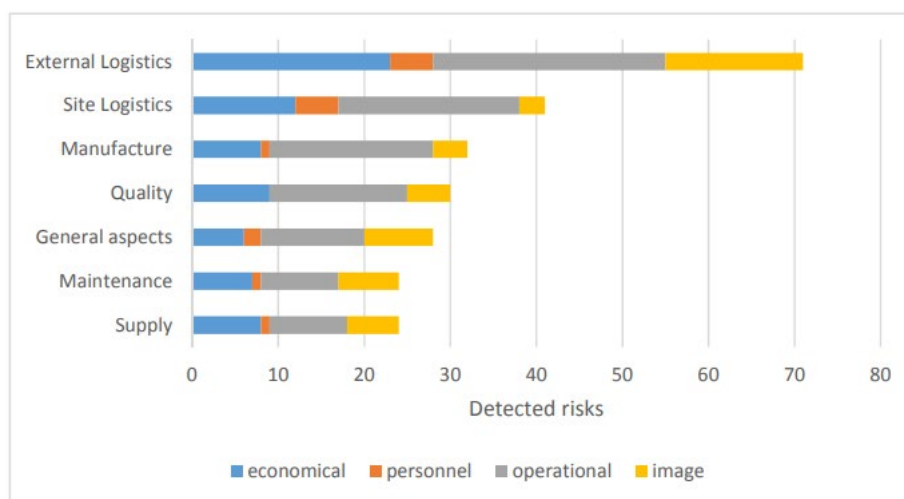


Figure 3.6: Impact of risks by area (Fine Kinney based). Case study. Source: Cruz, De la Torre, and Martinez (2018).

In each area, a risk level was identified and normalized to have a base for comparison. The risk level and its normalization using Equation 4 is shown in Table 3.3.

Table 3.3: Subjective impact of the risk and normalized values on a chemical Company. Case study. Source: Own elaboration based on Cruz, De la Torre, and Martinez (2018).

<i>Department assignment</i>	<i>Risk level**</i>	<i>Normalized risk Fine-Kinney based</i>
<i>Site Logistics</i>	6.101	1.8927
<i>External Logistics</i>	3.6184	0.5614
<i>Quality</i>	3.6071	0.5553
<i>Supply</i>	2.1696	-0.2155
<i>Manufacturing</i>	1.3722	-0.6431
<i>General aspects</i>	0.7581	-0.9725
<i>Maintenance</i>	0.3743	-1.1783

**Considering exposure, likelihood and impact severity

It was detected that the main affectation on the company due to the combination of exposure, likelihood and impact severity is Site Logistics, External Logistics and Quality. Other areas such as Manufacture and Maintenance are presented as “stable” since they are exposed to risk, but the importance of the company to production control had minimized their probability of occurrence. The potential impact of operational disruption is high and proportional in all areas. External Logistics risk occurrence can derive on a great economic and image impact since they represent the link of the company with the final customer.

3.5.2 Supply chain risk assessment (quality analysis based)

A total of 867 non-conformities were analyzed. The database analysis provided non-conformity profile information, which is considered to be useful for the continuous improvement of the organization.

In order to categorize risk according each part of the supply chain, a supply chain risk type code was assigned after an exhaustive analysis on each one of them. It was necessary to determine also the origin of the failure and the kind of disruption each event brought to the company. Risk sources and their distribution are shown in Figure 3.7.

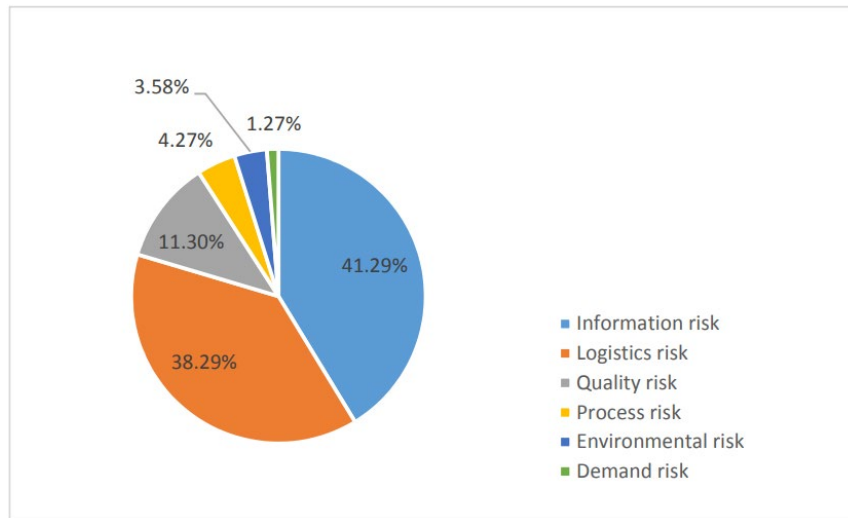


Figure 3.7: Distribution of non-conformity reports by risk. Case study. Source: Own elaboration.

Even when Information risk is part of the Logistics risk, it is presented as independent because of its recurrence since more than 41% of risks identified had to do with errors on information systems, miscommunication or incorrect data. Logistics risks represent 38.29% of the non-conformities of the organization. Wrong material, differences on quantities, damage on product during material handling, due dates and times not met are some examples. Quality issues on the product itself represent 11.30% of the non-conformities. Process risk, generated by variations on the production process are well controlled (4.27%) since the focus of the chemical company is to maintain their processes as stable as they can in order to avoid even safety risks.

The risk is evaluated considering aspects that derive in consequences for the organization. When the inspection to a certain issue is conducted because of customer's request, not only the regular process has been compromised, but also the level of reliability of the company to the client. For this particular case, the ratio of deviations by detection form is shown in Figure 3.8.

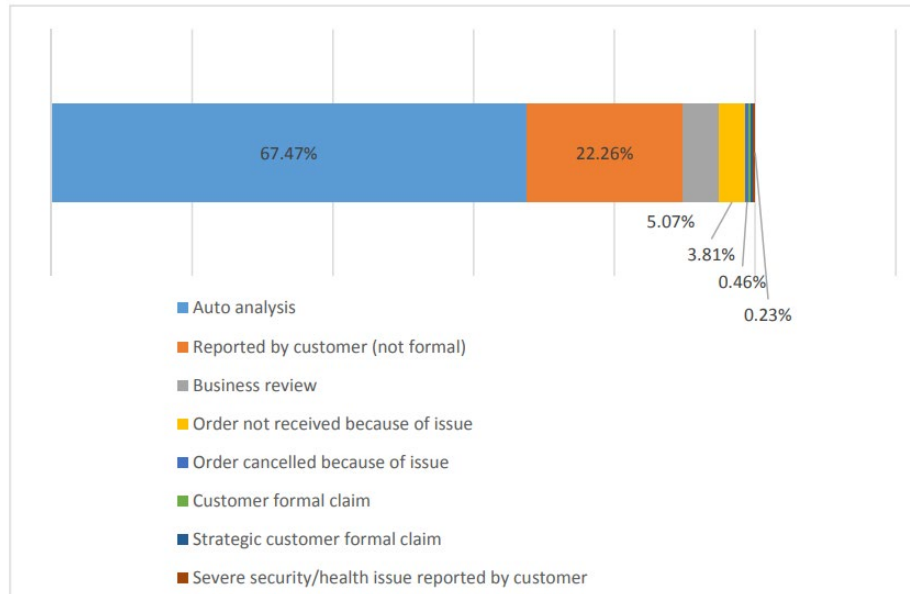


Figure 3.8: Ways failures are detected. Case study. Source: Own elaboration.

The 27.46% of failure analysis where based on recommendations of the customer, either formal or informal. In the other hand, 72.54% of detections where internal so at least, reliability of the company's process was not affected.

The way deviations are identified on the process has a lot to do with the impact of each failure. The relative importance given to each failure then, had to do with the quantity of issues affected as it was detected, so as shown in Table 3.4.

Table 3.4: Subjective impact assignation. Case study. Source: Own elaboration.

	Personal	Image	Operational	Economical
Business review			X	
Auto analysis			X	
Reported by customer (not formal)		X	X	
Customer formal claim		X	X	
Severe security/health issue reported by customer	X	X	X	X
Strategic customer formal claim		X*	X	X
Order cancelled because of issue		X	X	X
Order not received because of issue		X	X	X

*Affectation is greater because the customer affected is strategic

Every disruption leads to an operational break, therefore every non-conformity implies a change on the conceived process. When there is an involvement of the customer on the failure detection, there is an impact on the company's image, meaning that confidence from the customer might have been damaged due to disruption on the regular process. Strategic customers have a greater impact than regular ones, due to the volume of operations or the

quantity of revenue they represent. Direct economic impact (loss material, sale, i.e.) represent another type of impact, while the affectation of the disruption to personal integrity increases to the top the impact of the risks involved.

Determining the causes of risk might help to detect the opportunity areas that allow a substantial improvement of the process if they are handled correctly. The proportion of each cause is detailed in Figure 3.9. Causes where grouped considering if:

- There was a deviation to the existent procedures (internal process).
- The correct information does not exists (data)
- The conditions of the product do not meet the customers' requirements (quality).
- The product was damaged during its handling (material handling)
- The risk was perceived during the delivery process (transportation)
- The customers' changes affected the regular procedures (customer)
- The failure was a result of an information technology deviation (system)
- The deviation is a result of a miscommunication issue
- The risk is derived from not suitable/not existent infrastructure or equipment
- The risk was caused by safety and/or security issues
- Other unknown causes lead to the risk detected.

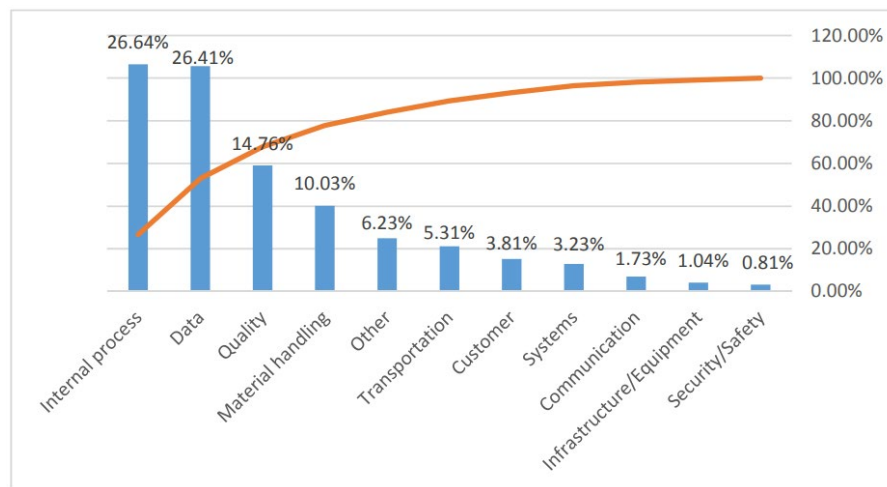


Figure 3.9: Pareto diagram for risk causes. Case study. Source: Own elaboration.

Deviations to established procedures and correct data available represent around 26% of the causes each. It is not a lack of formal processes, but a misunderstanding of what have to be done in specific cases. Deviations in data have to do with incomplete and/or wrong information uploaded on system. Being the non-conformity report a Quality based documentation it is expected that product quality issues are high on the list (14.76%). There is opportunity areas also on material handling (10%). The rest of the causes stand for less than 6% each, while there is a 6.23% of non-conformities that causes could not be specified.

By impact, the distribution of the risks according to a Department assigned is shown in Figure 3.10.

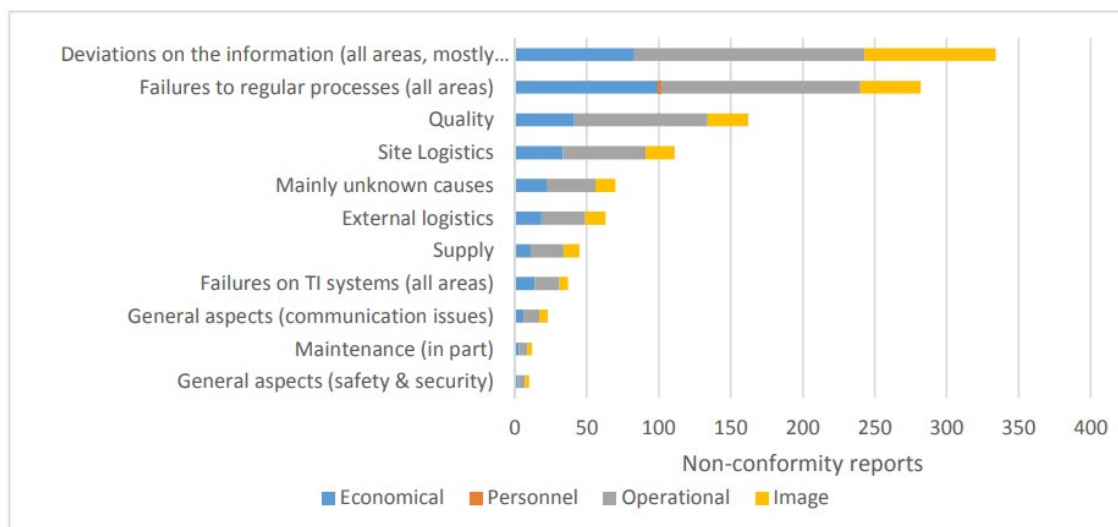


Figure 3.10: Impact of risks by area (quality analysis based). Case study. Source: Own elaboration.

In order to address each risk to a particular area to work with looking for variability reduction, causes were linked as shown in Table 3.5. Some causes are not just one area issue though. With the total information, a pondering method by impact factor using the criteria shown in Table 3.4 was applied in order to prioritize the company's department by degree of risk. Then, normalization using Equation 4 was also used.

Table 3.5: Department assignment considering risk causes and normalized risk. Case study. Source: Own elaboration

<i>Risk causes</i>	<i>Department assignment</i>	<i>Normalized risk Quality Analysis</i>
<i>Data</i>	Deviations on the information (all areas, mostly site logistics)	2.1669
<i>Internal process</i>	Failures to regular processes (all areas)	1.6849
<i>Quality</i>	Quality	0.5507
<i>Material handling</i>	Site Logistics	0.0687
<i>Other</i>	Mainly unknown causes	-0.3282
<i>Transportation</i>	External Logistics	-0.3944
<i>Customer</i>	Supply	-0.5645
<i>System</i>	Failures on TI systems (all areas)	-0.6401
<i>Communication</i>	(All areas)	-0.7724
<i>Infrastructure/equipment</i>	Maintenance (partially)	-0.8764
<i>Security/safety</i>	(All areas)	-0.8953

3.5.3 Comparison between both methodologies

Having obtained the results by different methodologies, normalization was applied to both sets of data in order to be subject for screening. Some areas were not considered in the comparison since they were not considered on both of the studies. This non-inclusion might affect the grade of variation of the results obtained. Comparison is shown in Table 3.6.

Table 3.6: Comparison of normalized risk for Quality Analysis and Fine-Kinney based method. Case study. Source: Own elaboration

Department assignment	Normalized risk Quality Analysis		Normalized risk Fine-Kinney based		Variation
<i>Site Logistics</i>		2.1653		1.8927	14.40%
<i>Quality</i>		0.1362		0.5614	-75.73%
<i>External Logistics</i>		-0.5808		0.5553	-204.58%
<i>General aspects</i>		-0.5306		-0.2155	146.16%
<i>Supply</i>		-0.7098		-0.9725	-27.01%
<i>Maintenance</i>		-0.9464		-1.1783	-19.68%
<i>Not considered</i>	All areas (unknown causes)	-0.5306	Manufacturing	-0.6431	
	All areas (errors on procedures)	0.9966			

Normalized results give a broad picture of the areas with logistics issues. In both sets of data it is observed that the sequence of areas match except for External Logistics, which is positioned after General Aspects in Quality Analysis. This is explained considering External Logistics as a department outside the organization, since it is run by a 3PL^B. Errors or deviations on the final processes addressed to the 3PL are not included on the company's non-conformance database but managed as opportunity areas for the transport vendor. Including these areas might rise the External Logistics issues to correspond the other method's case.

Although the order is quite the same on both studies, there are significant differences on the normalized risks obtained. Only two pairs of areas have less than $\pm 20\%$ variation (Site Logistics and Maintenance). Some variations might be generated either by the inability to address each failure to a specific area or those areas that were not considered on both studies. In both cases, data was excluded. The difference on Supply area may be explained by the containment of quality issues at raw material level (remembering that quality analysis was done to non-conformities of the customers to final products).

^B Sweeney and Evangelista (2005) define third-party logistics as activities carried out by a logistics service provider on behalf of a shipper and consisting of at least transportation. Other activities, such as warehousing and inventory management; information related activities, such as tracking and tracing; and value added supply chain activities, such as secondary assembly and installation of products, can be integrated into the service offering.

Considering the difference between the number of risks that could be detected on either the Fine Kinney-based or the quality analysis supply chain risk assessments, the proportion of the risk assigned by impact is obtained and shown in Figure 3.11 and Figure 3.12.

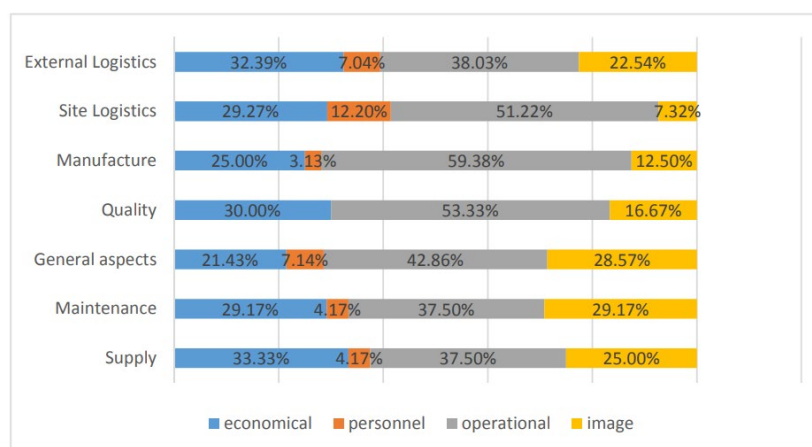


Figure 3.11: Impact proportion of risks by area (Fine Kinney based). Case study. Source: Own elaboration.

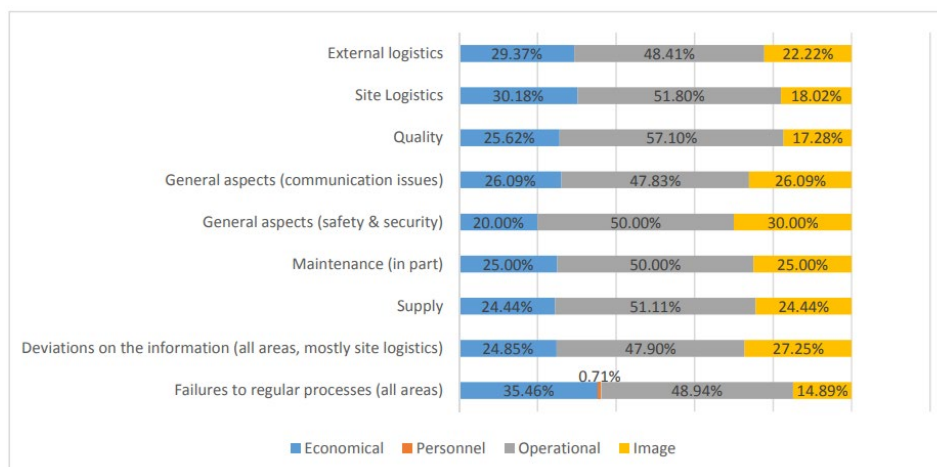


Figure 3.12: Impact proportion of risks by area (quality analysis based). Case study. Source: Own elaboration.

It is relevant the lack of personnel impact on the quality analysis based report. The non-conformity report does not show any implication for the personnel involved. Once again, the focus of the report on quality issues is perceived when revising the graphic as percentage values. Operational impact is recurrent on both graphics as the most important impact in every area. In the Quality analysis based, impacts on the image are slightly larger than on the Fine Kinney based, meaning that maybe there is more acknowledge from the customers than perceived by employees (remembering that the Fine Kinney based study considered empirical knowledge from the interviewed personnel).

In both cases, the areas that have a greater impact on image in the eyes of their customers

are general aspects (communication, safety and security), maintenance, supply and external logistics. In addition, on the quality analysis it is also observed the deviations on the information. Larger impacts on economic aspects generate as a result of failures on External Logistics, Site Logistics, Supply and Quality, being failures to regular processes incorporated also on the quality analysis.

3.6 Conclusions

It is necessary to develop supply chain risk assessment to find out the possible sources of disruption within a company and its trade partners. Since it is based on the correct definition of risk factors and sources to be able to handle the same terminology, the supply chain risk sources proposal presented on this study provides relevant information for this end. There are some specific methodologies that aim to rank these sources of disruption as individual risks and/or by area. Implementing these methodologies involve an investment of time and dedicated results to get to risk identification, measurement and assessment. This initial step can be strengthen with the analysis of existing databases in the company. As a great focus on continuous improvement, there is more probability that enterprises have keep records of deviations on the normal processes, known as non-conformities. The study presents that results using quality analysis are very similar to those obtained using a logistics-oriented method, with the advantage of less time and resources invested. The quality analysis based method does not substitutes it, but gives a wide landscape of what areas can be more problematic speaking about logistics.

In this particular case, logistics risk are the most common ones on the specific study case, detecting information risk as the most recurrent. Most failures are detected by the same personnel, which implies a lower impact when disruption is not perceived by the customer. Deviation to internal processes correspond to the most frequent cause of the risks. This means, procedures exist but they are not followed correctly on the usual basis. Incorrect and/or non-existing data is the second more frequent cause. Specific logistics issues, such as data, communication, material handling, and transportation, are display at important levels in the Pareto showing risk causes. It is important to understand though, that different industries might represent variations on the patterns of risk described (Jüttner et al., 2003).

The obtained information from the quality analysis is a solid base to start with the assessment of supply chain risks. For the case study, errors on procedures, communication and data can be considered in advance while designing a supply chain risk management process. It make sense that misperceptions between actors affect significantly because of the nature of a collaborative process. Teamwork among them might help in future issues, when there is a risk of disruption and it can be handled early to avoid severe affectations.

In further steps of its implementation, quality databases could be improved to consider more details (such as personnel implication of the risk developed) if they are found suitable to fulfil a requirement. As resources allow supply chain risks to be handled separately, results can still be obtained and compared to observe other opportunity areas. The idea is to make the most of the assets that already exist to manage processes more efficiently.

Chapter 4. Effect of Risk on a Production-Distribution Model. Case Study on a Global Industry.

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4.1 Abstract

The tactical and operational decisions of which vendor to source from, where to produce and how to distribute to the customer are related with factors such as transportation cost on sourcing and distribution, the material utilization while fabricating, and the operating cost of the plant. This paper considers also the risk involved in developing these activities, such as process and control risk, demand risk, supply risk, handling and distribution risk in order to evaluate risk as a penalization on the cost derived from the risk exposure, the likelihood, and the severity impact. Therefore, a production-distribution model in a multi-echelon supply chain, which considers risk, is proposed. The objective of this paper is to determine the effect of risk along the supply chain on the tactical decision of network design. Parameters to measure risk are also proposed. Finally, the model is applied in a global industry to observe how the variation of demand volume and location respond on the total operation. With the information provided from each scenario tested, some strategies of production-distribution on the evaluated zones were observed, finding out the best way to take advantage of the capacity of the two existing plants to develop a strategic policy to produce and distribute worldwide.

4.1.1 Keywords

Production-distribution model; risk; risk effect; risk evaluation; risk measurement.

4.2 Introduction

The multinational characteristic of organizations is increasing in the last years. In fact, globalization of the supply chain is considered one of the most important logistic challenges for this millennium (Skjoett-Larsen, 2000). This provides a wider range of options when making strategic decisions such as efficient planning of the supply chain network, which might impact corporations' competitiveness because of its enduring effect (Goetschalckx, Vidal, & Dogan, 2002) (Bustos Rosales, Herrera del Canto, & Zamora Dominguez, 2014). In supply (chain) network design, resolutions about suppliers, manufacturing plants, and distribution channels have to be considered. This includes (but is not limited to) volume, lot size, location, and BOM relationships; in fact, most planning aspects (Jang, Jang, Chang, & Park, 2002).

To get to a practical decision on supply chain network, some considerations about specific business case scenarios can be also taken into account. Some examples of these can be the deterioration cost of the load (Bustos Rosales, Herrera del Canto, & Zamora Dominguez, 2014), reverse logistics systems (El-Sayed, Afia, & El-Kharbotly, 2010), shortage costs (El-Sayed, Afia, & El-Kharbotly, 2010), transportation time (Bustos Rosales, Herrera del Canto, & Zamora Dominguez, 2014), on time delivery (Jansen, van Weert, Beulens, & Huirne, 2001), special type of materials (hazardous materials) (Xie, Lu, Wang, & Quadrifoglio, 2012) (Giglio, et. al, 2004) (Kawprasert & Barkan, 2008), among others. Vidal & Goetschalckx (1997) stated that research should focus on global interrelated networks, which can represent qualitative and uncertain factors that can develop disruption events. However, consideration of risk on supply chain literature remains relatively low. There are some proposals on how to manage risk, though. Iakovou (2001) includes risk in his study as a second objective aside cost minimization on a design network modelling.

This paper integrates some of the detected risks along the supply chain on a production distribution model, and evaluates the cost efficiency behaviour when varying risk conditions in order to provide a general outline that might help companies make decisions to take advantage of the global networking mentioned before.

The first part of the study describes risk on supply chains. Then, the proposed model is presented. Finally, the results of a study case where the model is tested with some parameter variations are presented in order to achieve general conclusions on how risk affect this type of models.

4.3 Previous literature

Logistics is a value-adding process that supports competitiveness by increasing customer service, price and quality competitiveness, and level of response to demand (Slats, Bhola, Evers, & Dijkhuizen, 1995). Some logistic actors that shape supply chains include procurement / purchasing, production planning / scheduling, inventory management / warehousing, and transportation/distribution. Linear Programming (LP), Integer Programming (IP) and Mixed Integer Programming (MIP) have been exhaustively used to

model interactions between these actors in order to find the optimal relationship between them (Agadaga & Akpan, 2017) (Klose & Drexler, 2005). Using any operation research technique such as modelling should be a decision support tool for a decision maker (Vidal & Goetschalckx, 1997) (Slats, Bhola, Evers, & Dijkhuizen, 1995). Previous literature on MIP for production-distribution modelling, for example, had considered the characteristics shown on Table 4.1.

Table 4.1. Main characteristics of selected MIP strategic production-distribution models. Source: (Vidal & Goetschalckx, 1997); (Bilgen & Ozkaran, 2004)

Capacity limitation	Inventory characteristics	Side constraints
Customer service features	Methods of solution applied	Single sourcing
Decision levels	Nonlinear costs considered	Status of facilities
Dynamic characteristics	Number of commodities	Stochastic features
Industrial application	Number of echelons	Variables
International features	Objective function	CPU time

The supply chain design can bring up some strategic decisions such as selection of locations for manufacturing plants and warehouses; assignation of suppliers and transportation channels, and; volumes of material to produce, hold, and ship (Vidal & Goetschalckx, 1997). Most previous research focuses on a single supply chain component (Vidal & Goetschalckx, 1997) as well as on a single objective function, mostly cost minimization or profit maximization (Bilgen & Ozkaran, 2004). Although it is common that this single supply chain component is distribution, some previous studies do consider sourcing strategy in the design of a supply chain network, along with production and distribution activities (Jayaraman & Pirkul, 2001).

There are quite of previous studies on strategic problems, therefore, more tactical/operational modelling have to be done for research and application. Even when mathematical modelling can help improving operations in companies, its application is not so widespread (Vidal & Goetschalckx, 1997). It is inferred that studies should be more focused to real conditions such as BOM constraints, considering other optimization aspects like flexibility, quality, or delivery performance in addition to cost minimization/profit maximization, taking into account globalization on the production/distribution dynamic, or allowing for uncertain environments. Moreover, even when probabilistic modelling is involved, it generally considers customer service levels or lead times (Bilgen & Ozkaran, 2004) (Vidal & Goetschalckx, 1997).

There are other “real-life” characteristics to include in modelling. It is important for the model to simulate also qualitative factors, being one of them the general infrastructure of a country. In addition, there should be a way to consider vendor and/or transportation channel reliability when deciding on them for a particular supply chain. (Vidal & Goetschalckx, 1997). Risk considers somehow this reliability and thus has been previously studied for specific industries like marine oil transportation (Iakovou, 2001) or hazardous material transportation

(Xie, Lu, Wang, & Quadrifoglio, 2012) (Jamroz, et. al, 2010).

The extension of the network and its strategy affects its dynamic. To build an agile supply chain, it is necessary to find out how to deal with demand variations, making it useful to consider other strategies to increase capacity (Bilgen & Ozkarahan, 2004). International supply chain models though, have to consider a more difficult setting due to variations on costs or time (taxes, duties, exchange rates, transfer prices, trade requirements, and coordination between network members).

A previous study on components determined by regression on intra-Latin American commerce transportation costs find out the importance of mode of transportation, cargo value, trading volume, and covered distance (Hoffmann, Pérez, & Wilmsmeier, 2002). Even when freight, insurance, and other transportation costs for international trade have been going down from 6.64% of the imports in 1980, 5.22% in 1990, 5.39% in 1999, to 3.46%^C in 2006, it remains an important consideration when developing global supply chains (Hoffmann, Pérez, & Wilmsmeier, 2002) (Dussel Peters, 2008). This is because global trade have significantly reduced custom duties. For example, tariffs accounted in 1999 for 1.86% on average from Latin America to United States. This numbers are considered as a total, since they are going to vary depending on the country and the transportation mode, as shown on Table 4.2.

Table 4.2 Transportation cost as a percentage of value of imports by transportation mode (1990-2006). Source: (Dussel Peters, 2008)

	Total		Air		Maritime		Inland	
	2006	1990-2006	2006	1990-2006	2006	1990-2006	2006	1990-2006
Total	3.46	3.59	2.6	2.95	4.93	5.01	1.24	1.51
Canada	1.45	1.8	1.32	1.1	3.18	4.68	1.36	1.69
China	6.26	6.67	4.2	6.17	7.12	6.93		
Mexico	1.14	1.34	2.27	2.23	1.88	3.42	0.92	0.95
Japan	2.8	2.81	2.7	3.07	2.9	2.78		
Germany	2.41	2.59	2.18	2.53	2.61	2.72		

All this previous information should also be considered when modelling global supply chains (Goetschalckx, et.al, 2002) (Vidal & Goetschalckx, 1997). The modelling issues that accommodate the global manufacturing characteristics have been emerging only recently (Jang, Jang, Chang, & Park, 2002).

What previous research indicates is that there is a need to model multi company network configurations to find out potential dynamics (Vidal & Goetschalckx, 1997). In this paper, risk would be considered as the variable that triggers changes on supply chain network tactical decisions.

^C Considering only transportation cost.

4.3.1 Risk

Risk has been identified as an opportunity for research in supply chain modelling (Iakovou, 2001). Being risk the outcome of uncertainty about future events, in a supply chain it might consider the consequences derived from those events that interrupt the flow of resources along it (Cruz Netro, De la Torre Romero, & Martinez Flores, 2018). These disruptions are triggered in a general way by three sources of risk, which are interrelated as shown on Figure 4.1, where internal risk is generated (and therefore can be controlled) within the company affected, and the external risk is generated by the interaction of the company with either its supply chain or only the environment.

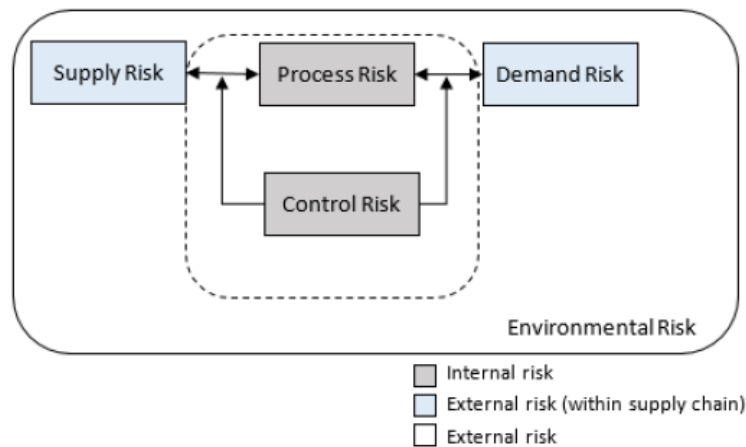


Figure 4.1: Risk sources within the supply chain. Source: Adapted from Christopher, M., and Peck, H. (2004), and Jüttner, U., Peck, H., & Christopher, M. (2003).

4.3.1.1 Process/control risk

Process and control risk have to do with the reliability of the operation and infrastructure in order to develop and maintain quality of both the finished products and the procedures to develop them (Cruz-Netro et.al, 2018). An adequate level of process/control performance assures the production of the required volume of the requested product, which reduces the risk of non-fulfilment of an order to the customers.

4.3.1.2 Supply/demand risk

Supply and demand risks seek to level production and inventory levels with market requirements on both ends of the supply chain. Supply performance refers to the compliance of the orders from our vendors due to causes that can be directly imputed to them. This can delay the programed production schedules because of the lack of raw material. Demand performance refers to the possibility of variations on the established demands when customers place their orders. This can affect the programed production schedules if more product needs to be fabricated, as well as incur in additional expediting costs of the unscheduled raw material/finished product.

4.3.1.3 Environmental risk

Environmental risk considers other intentional or non-intentional events not related with the company or its operation, but that can affect it directly or indirectly. During transportation, for example, some sources of risk are transportation mode, type of load (Iakovou, 2001), driver experience, load volume/weight, type of vehicle, driving conditions, season/shift, traffic, route and its condition, weather among others (Giglio, et. al, 2004) (De la Torre, Moreno, Moreno Quintero, Martinez, & Olivares Benitez, 2014).

To measure risk for a homogeneous road segment, Xie, et. al (2012) consider the product of the accident rate and the number of people affected by a potential HAZMAT accident, this is accident probability per shipment, population density, and length for the k-th segment of road link. This last element, length of the road, is relevant and considered as travel distance (Kawprasert & Barkan, 2008) (Giglio, et. al, 2004).

Risk increases when considering global scenarios. As stated previously, global supply chain configuration carries additional considerations, such as exchange rate fluctuation, uncertainty of market prices, taxes and duties, profit repatriation, duty drawback/relief, transfer prices, trade barriers, exchange rates, (Goetschalckx, Vidal, & Dogan, 2002). In addition, complexity to coordinate flow of cash and flow of information rises (Vidal & Goetschalckx, 1997). Other critical sources of risk involve qualitative factors such as government stability or political environment.

The different nature of the environmental risks makes it very complex to try to reduce risk in every existing source, so the proposal is to consider historical delays of 3PL's on transportation for obtaining a handling and distribution risk parameter. It is common for global companies to delegate transportation to a 3PL, mostly or even solely, based on cost and neglecting the effect of the transportation services on the whole supply chain efficiency (Bustos Rosales, Herrera del Canto, & Zamora Dominguez, 2014), so including this type of information will be useful for a better informed decision on transportation alternatives. Delays can then be translated to cost of no production due to a lack of raw material or penalization cost because of late delivery to customers.

The reality is that risk has an impact on efficiency, which differs depending on the industry, the stage on the supply chain, the operational activity performed, among others. To measure the expected risk cost, it is necessary to obtain the empiric probability distribution of past events, as well as the cost estimate of damage which each exact event triggered (Iakovou, 2001). Depending on the considered situation, it will be necessary to do a more precise risk analysis (Kawprasert & Barkan, 2008). According to the Fine-Kinney risk estimating method (Cruz Netro, De la Torre Romero, & Martinez Flores, 2018), the risk level is given by the product of risk exposure, likelihood and impact severity.

4.4 Description of the model

The paper focuses on the modelling of a production-distribution facility location-allocation problem, which is a mixed integer program (MIP) model (Jayaraman & Pirkul, 2001). Its design will consist basically on the tactical decisions of where to manufacture and from where to source for a specific customer (as a raw material or as a final product).

The proposed model aims for cost minimization considering risk level as a penalization to this cost, subject to capacity and utilization constraints on both vendor and manufacturing plant. To describe the model, the following assumptions, sets, parameters, and variables are defined.

4.4.1 Model assumptions

- This is a single period model. A decision on how to procure/manufacture/distribute a given demand will depend on both the demand location and volume. It is thought for a discrete manufacturing derived from a project system.
- This is a single product scheme.
- The location of the customers as well as their volume of demand vary from project to project.
- The quantity of material required for manufacturing operations varies depending on the manufacturing plant. Some plants have more efficient processes since they have longer time operating and personnel is more experienced.
- The location and capacity of both suppliers and facilities are known.
- The costs involved are known (raw material price, transportation costs, manufacturing costs, fixed operational costs, and indirect material utilization cost).
- Random events along the supply chain are assumed to reduce effectiveness by incurring into extra costs. Both issues, rates and costs, are known.
- Both vendors and customers have a unique 3PL for transportation; further models might include alternatives on mode and/or transportation vendor.

4.4.2 Sets, parameters, and variables

Sets		I: vendors J: facilities K: customers
Parameters	Supply	P_i : Price of raw material from vendor i TCV_{ij} : transportation cost from vendor i to facility j CS_i : supply capacity of vendor i SR_i : supply risk level
	Manufacturing	MC_j : manufacturing cost on facility j CM_j : manufacturing capacity of facility j F_j : fixed operational cost of facility j U_j : material utilization rate on facility j IC_j : indirect material cost on facility j PCR_j : process and control risk level
	Distribution	TCP_{jk} : transportation cost from facility j to customer k D_k : demand of customer k HDR_{ij} : handling and distribution risk level (in supply) HDR_{jk} : handling and distribution risk level (in distribution) DR_k : demand risk level
Decision variables		X_{ij} : quantity of raw material acquired from vendor i for facility j Y_{jk} : quantity of product manufactured on facility j for customer k L_j : binary variable; its value equals to 1 if the facility is in operation and 0 otherwise

4.4.3 Model

The total cost is given by the supply cost plus the fabrication cost plus the distribution cost, as shown on Equation 4.1.

$$TC = SC + FC + DC \quad (4.1)$$

Where the supply cost considers not only the purchase price of the raw material, but also the transportation costs from the vendor to the facility. The fabrication costs includes two fixed costs, the fixed cost of operation and the cost of indirect materials on each facility, as well as the variable manufacturing cost. On both supply and distribution, transportation costs include freight, custom clearance, insurance and handling charges.

The following model is established in order to minimize the total cost of finished product for the given demand, considering vendor and fabrication facility, in addition a cost penalization derived from the risk level for each process is included (Equation 4.2).

$$\begin{aligned} \min Z = & \sum_i^I \sum_j^J (P_i + SR_i + HDR_{ij} + TCV_i) X_{ij} + \sum_j^J (F_j + IC_j) L_j \\ & + \sum_j^J \sum_k^K (MC_j + TCP_{jk} + HDR_{jk} + DR_k) Y_{jk} \end{aligned} \quad (4.2)$$

s.t.

$$\sum_{j \in J} Y_{jk} = D_k \quad \forall (k \in K) \quad (4.3)$$

$$\sum_{k \in K} Y_{jk} \leq CM_j \quad \forall (j \in J) \quad (4.4)$$

$$\sum_{j \in J} X_{ij} \leq CS_i \quad \forall (i \in I) \quad (4.5)$$

$$\sum_{i \in I} U_j X_{ij} - \sum_{k \in K} Y_{jk} L_j = 0 \quad \forall (j \in J) \quad (4.6)$$

$$\sum_{j \in J} L_j \geq 1 \quad (4.7)$$

$$L_j = \{0, 1\} \quad \forall (j \in J) \quad (4.8)$$

$$X_{ij}, Y_{jk} \geq 0 \quad \forall (i \in I), (j \in J), (k \in K) \quad (4.9)$$

Where Equation (4.3) ensures the fulfilment of the demand for every customer. Equations (4.4) and (4.5) confirm that the capacity of either the suppliers or the manufacturing facilities are not exceeded. Equation (4.6) balances the quantity of finished product elaborated by

the manufacturing facilities with the quantity of raw material procured, considering the variable utilization material rate, which is in function of the process stability. It is assumed a degree of consolidation on every facility, which originates variation on the utilization material rate. Equation (4.7) makes sure that at least a manufacturing location is chosen. The sum of the chosen manufacturing locations, might equal a fixed value (the quantity of manufacturing locations to open on the network). Equations (4.8) and (4.9) establish the binary nature of the variables as well as their non-negativity condition.

4.4.4 Risk level

Even when Fine-Kinney method considers proposed scales for exposure, likelihood, impact severity, and risk level, it is inferred that the parameters can be adjusted to reflect what a specific case might consider risk (Cruz Netro, De la Torre Romero, & Martinez Flores, 2018). The general formula of risk level is expressed on equation 4.10.

$$\rho = E * L * S \quad (4.10)$$

Where: $E = \{0,1\}$ and $0 \leq L \leq 1$

Risk exposure (E). The risk is addressed only to the part of the supply chain in which it can be generated.

Likelihood (L). The probability of occurrence depends on the specific part of the supply chain in which the disruption of the conceived process is generated. This is, the process continuity. One big issue of supply chains is lack of supply chain performance metrics (Lee & Billington, 1992) in order to observe the exact proportion of the disruption. The most utilized metric with this scope is fill rate, which is the proportion of orders filled immediately from the available inventory (Beamon, 1999). This parameter can give a general idea of the inefficiency of the process due to unexpected events. For the distribution risk, it is necessary to get a proportion of risk per length using previous statistics for individual track segments or other segments determined to have similar characteristics (Kawprasert & Barkan, 2008) (Xie, Lu, Wang, & Quadrifoglio, 2012) (Giglio, et. al, 2004).

Impact severity (S). There is a specific cost related to the delay in the specific part of the supply chain depending on the processes affected by this delay. Stochastic delay is consider a function of probability and size of delay (Jansen, van Weert, Beulens, & Huirne, 2001). Then, the shortage cost depends on the shortage quantity and time (El-Sayed, Afia, & El-Kharbotly, 2010).

To obtain risk level, the aspects shown at Table 4.3 are evaluated along the supply chain by solving Equation 4.10 for each risk parameter.

Table 4.3. Parameters considered to obtain risk level. Source: own elaboration

Risk level		Risk Exposure	Likelihood	Impact Severity
PCR _j	Process and control risk	For Y _{jk} in fabrication cost	Manufacturing plant fill rate	Cost of expediting finished product. Cost of rescheduling manufacture
DR _k	Demand risk	For Y _{jk} in distribution cost	Variability on customer orders	Cost of expediting raw material/ finished product. Cost of rescheduling manufacture
SR _i	Supply risk	For X _{jk} in supply cost	Vendor fill rate	Cost of rescheduling manufacture/ cost of maintaining inventory.
HDR _{ij}	Handling and distribution risk	For X _{jk} in supply cost	3PL fill rate, distribution lenght	Cost of rescheduling manufacture
HDR _{jk}		For Y _{jk} in distribution cost		Cost of expediting finished product.

4.5 Case study

To observe the interaction between variables in order to develop information for decision-making, the proposed model was implemented on a company with an international supply chain. This company counts with two production plants in different countries and the idea is to evaluate in which way they can share capacity to fulfil customer requirements. Only the principal raw material is considered, which represents the 90% of the value of the final product. The requirement is done once as a result of a project system scheme. The decision on how to procure/manufacture/distribute according the given demand is relevant on the final cost of the project. In this case, fixed costs as well as indirect material costs are considered for both scenarios, since the two plants are on operation and even when there is no production scheduled, they should be paid. This eliminates the binary element of L_j , remaining as a linear programming model of a transshipment problem.

For this sensitivity analysis, it is crucial to count with relevant, accurate information. The collection of the data, as well as its review and validation was a very important part of this study, and its complexity had to do with the scope of the model. This information was obtained on a series of interviews to the mainstream personnel, which provided the required existing data from current vendors, processes and customers to create the baseline. The system is willing to be a referent for future decisions, so it was kept as general as possible to avoid too specific information that might result on bias. It has to be kept in mind that this model is intended to be adjusted to other industries as well.

4.5.1 Scenarios

Firstly, the model was tested with the current parameters to check its effectiveness. In addition, the delivery costs as a percentage of the sales were calculated to measure and compared with those on Table 4.2. The difference between them was an average of 0.826%, which validates the model as accurate enough for developing the upcoming scenarios and allows to project scenario costs using this table expecting low variation.

The current source of supply is going to be considered on the different scenarios. What is going to be evaluated are two important aspects: the location of the potential customers worldwide and the demand volume required for each customer, since the expected profit is directly affected by the demand mean for a given capacity of the network (El-Sayed, Afia, & El-Kharbotly, 2010). Changes in these two aspects represent variation on some of the risk parameters associated with demand (which are demand risk D_k and handling and distribution risk HDR_{jk}). The case study evaluates the duct fabrication mainly for offshore platform construction. The mainstream is located in two plants: one located in Mexico and the other, in Spain. Although the current market is in Mexico and some countries in Europe, potential demand spreads worldwide as shown on Figure 4.2. The complete list of companies/yards by country that build platforms is listed on Table 4.4.

Table 4.4. Companies/yards by country that build platforms. Source: (Cruz Netro, Medina Álvarez, Cartas Carrillo, & Garza Flores, 2016)

Australia	Australian Ship Repairs Group, Keppel Cairncross
Brazil	Estaleiro Promar, Eisa
Canada	Canadian Shipbuilding & Engineering
China	Hudong- Zhonghua
Korea	Ulsan Shipyard, Daewoo Shipbuilding & Marine Engineering
Denmark	Odense-Lindo, Orskov Christensens
United States	McDermott Shipbuilding NASSCO, Ocean Technical Services, Northwest Norfolk Shipbuilding & Drydock Corp.
England	Ailsa Troon, SLP Engineering & Construction Swanhunter Ltd.
India	I-maritime
Japan	Hitachi Zosen Corporation, Kawasaki Heavy, Industries Mitsui
Malaysia	Malaysia Shipyard & Engineering Yong Choo Kui
Norway	Aker Stord Kvaerner ASA, Ulstein Group
Panama	Braswell Shipyard
Singapore	Keppel Corp. Sembcorp Industries Jurong
Taiwan	Ching Fu Shipbuilding



Figure 4.2. Some of the major construction yards in the world. Source: Own elaboration based on case study and (Cruz Netro, Medina Álvarez, Cartas Carrillo, & Garza Flores, 2016)

To establish potential customers, the principal construction yards were grouped and classified in seven zones. For each zone, the gravity centre of the construction yards was obtained for distance calculations. Figure 4.3 shows the final location for each customer, which are analysed in this study.



Figure 4.3. Gravity center by zone. Source: Own elaboration in (Geomidpoint.com, 2020) & (Google Maps, 2020)

The location and distances to the plants are shown on Table 4.5. The distances are considered as a factor of risk due to the length between vendor and customer.

Table 4.5. Distance to facilities by zone. Source: Own elaboration on (Google Maps, 2020)

Zone		Latitude	Longitude	DISTANCE TO FACILITY (km)	
				1-Spain	2-Mexico
1	Mexico & Central America	20.1716	-97.9904	8843.95	241.18
2	US & Canada	36.8140	-83.9783	6722.92	2400.07
3	Europe	51.0914	0.0947	1698.43	8942.74
4	Asia	21.6724	119.4774	11410.13	13649.5
5	Australia	-27.3899	153.1617	17850.42	12633.08
6	Brazil	-8.3971	-35.0006	5830.91	7830.04
7	India	18.8957	72.9088	7837.52	15579.06

The scenarios evaluate three levels of demand for each current market location and considers low demand on potential markets. For risk considerations, a different cost of expediting and a penalization based on distance length was applied per zone. In addition, some scenarios consider only one entry market to evaluate on costs. With this information, it is intended to estimate the entry strategy on these markets. Apart from considering volume, scenarios consider also variations on demand risk according to the customer's location. All these information was introduced on the previous presented model and run on the optimization model software Lingo, in order to obtain the optimal solution and cost to each scenario. The scenarios considered are shown on Appendix A.

4.6 Results

After running the 33 scenarios considered, a number of results came out. First, for all the scenarios, the total capacity of the plant in Mexico should be considered even when it handles higher costs of maintaining inventory and the lower utilization rate on its plant. This can be explained, among other things, because of the low penalization on risk management (Mexico is very near two of the important markets), as well as the lower transportation costs that might be originated by the highest rates on wages and salaries in Europe. The market is sourcing for the material from the cheapest combination of conditions, although total demand is the same. The difference has to do with the customers soliciting the material. The total cost per kilogram for the processed finished product is between 2.15 and 2.18 USD, depending on the market it is sent to (further located customers represent higher transportation costs) . All the previous information can be observed on Figure 4.4.

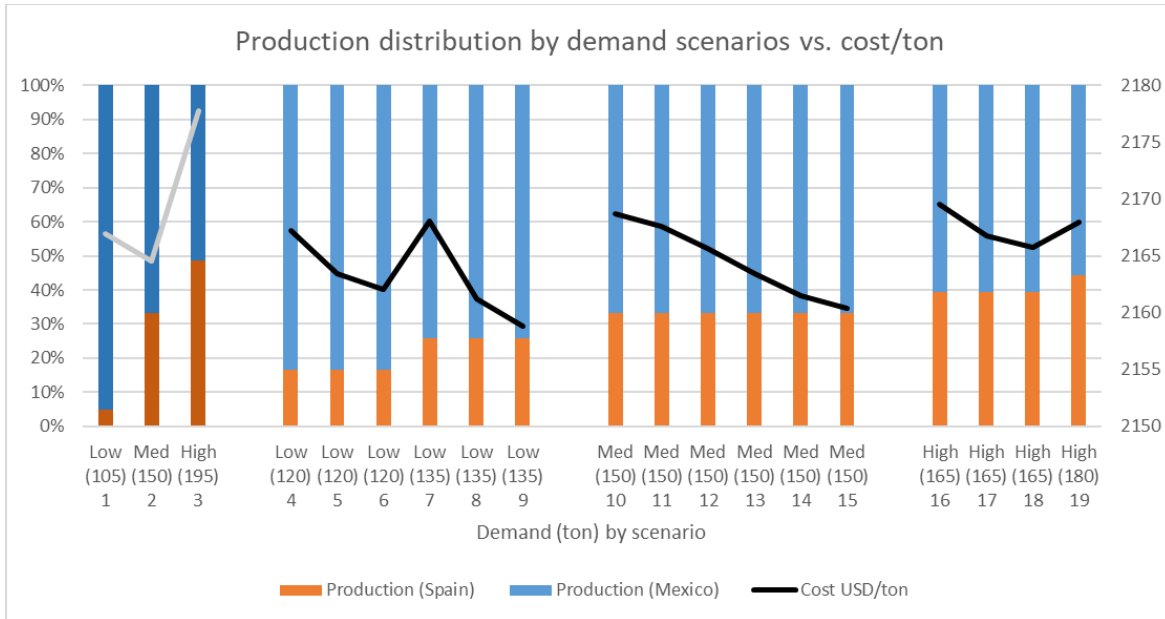


Figure 4.4. Production distribution by demand scenarios vs. cost/ton. Source: Own elaboration

Checking on the general results, it is clear that the origin of the demand determines where and how much is it necessary to produce to fulfil the demand. Risk variation is detonated by demand location as well. For example, on low demand (15 ton) for 6 customers and medium demand (30 ton) on one customer (scenarios 4, 5, 6), the highest cost is for the medium demand on Europe market (scenario 4), followed by the one where the medium demand is in US & Canada market (scenario 5). The lowest cost is when the medium demand is located on Mexico & Central America market (scenario 6). A similar pattern is shown along the graph presented.

In Figure 4.5, a general chart with information on where to produce depending on the demand and the location of the customer is presented. It combines the three level of demand tested: 105 ton equitably distributed on the seven customers representing a low demand of 15 ton; 150 ton equitably distributed on the three current markets (30 ton each) and 15 ton on the four potential markets; and 195 ton equitably distributed on the three current markets (45 ton each) and 15 ton on the four potential markets. On the x-axis, the seven customer zones are presented. It is shown how the distribution between plants on Mexico and Spain should be to minimize total costs.

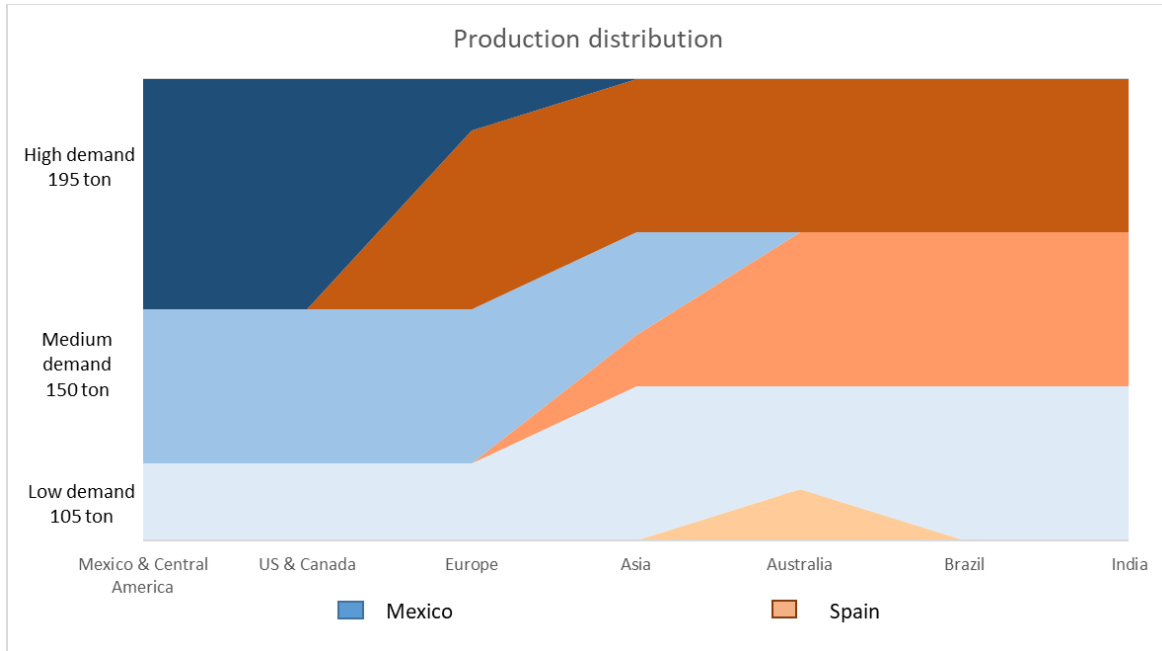


Figure 4.5. Production decisions based on demand and location. Source: Own elaboration

As stated earlier, production distribution considers to use the whole capacity of Mexico's plant due to lower costs. To have an idea of how to start the expanding strategy, the scenarios 22-33 were analysed on Table 4.6. On the three scenario groups (low, medium, high) the lowest costs are obtained for the entry market located on Asia, sourced by the plant in Mexico. The cost variation is minimal (less than 0.35%) and declining as the demand goes up, and even considered to be not significant when the demands are high (0.03%).

Table 4.6. Expanding strategy decision based on cost. Source: Own elaboration

Customer location		LOW (15 ton)		MED (30 ton)		HIGH (45 ton)	
		Production	Cost variation	Production	Cost variation	Production	Cost variation
1	Mexico & Central America	x		X		x	
2	US & Canada	x		X		x	
3	Europe	x		X		x	
4	Asia	Mexico		Mexico		Mexico	
5	Australia		0.34%		0.16%		0.03%
6	Brazil		0.33%		0.15%		0.03%
7	India		0.34%		0.16%		0.03%

4.7 Conclusion

It is undeniably that operation research tools are necessary to analyse alternatives for major logistic strategies (Slats, Bhola, Evers, & Dijkhuizen, 1995). Modelling can help to determine in advance the dynamic of a global system broadly speaking. In this case, the proposed model can determine the optimal configuration of the logistics system network when different vendors and manufacturing facilities are available at the same time that includes a penalization for risk factors.

The seven customers reviewed in this study considered risk factors such as distance, vendor/manufacture plant/3PL fill rates to calculate the best strategy to use effectively the capacity given by the two plants available. This can be relevant to use in advance to see how the costs are behaving and decide where to source from.

For the company where the case was analysed, these results represent relevant information for decision-making. At a first glance, it is visible where to source when expanding to other markets. In addition, they can check on the cost variation when increasing the production or sourcing elsewhere. An entry strategy on other markets can also be inferred. Finally, the database and configuration of the model might provide the decision maker to update any modifications on cost, volume, vendor, customer location or even risk event to have a broad overview of their supply chain dynamic.

To improve the risk factors considered it is imperative to generate and have available more information on disruption events. In this case study, for example, the company does not have this information documented, but the interviewed personnel do remember those events. Even information on near miss events could eventually lead to a better decision making. In addition, the type of product being manufactured and/or distributed has to be considered, since it will be strongly associated with the type and level of risk that may present.

Another important consideration is transportation providers. These partners carry a huge responsibility on both risk and cost. They decide on routes, have an impact on service time and share the handling/transportation risk on the last step of the supply chain. They also deal with information that can help to integrate risk management in the modes and levels of transportation, which would lead to a better control on methods and measures of risk management (Jamroz, et. al, 2010). On the other side, raw material vendors can also be developed locally to minimize detected risks and/or lower costs.

In spite of the different factors that have to be considered on real life, the modelling of scenarios provides the insight on how the dynamics might work. Currently, the processes are handled individually resulting on a less robust system and larger final total costs. In this study case, in order to take advantage on the available capacities and knowledge of both plants, a more integrated supply network design and production/distribution planning system is needed (Vidal & Goetschalckx, 1997).

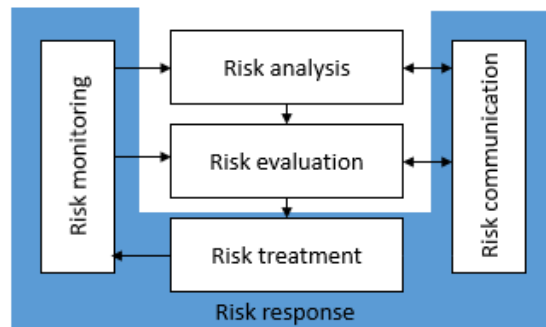
4.8 Future work

Network design modelling would reinforce by the addition of other important parameters such as in-transit and/or in-house inventory cost (Jang, Jang, Chang, & Park, 2002). It can also consider other distribution cost schemes rather than cost/kg to include the capacity of the truck/container where the product is delivered. Another way to go is to review how other industries behave when considering risk factors.

In the same way, the distribution link on the value chain can be disaggregated to include other elements by route such as: daily traffic average, number of thefts, proportion of stolen vehicles against average traffic, type of product transported, type of vehicle stolen, type of road (toll vs. toll-free), segment-specific accident rate, between others (Kawprasert & Barkan, 2008) (De la Torre, Moreno, Martinez & Olivares, 2014).

The application of this type of model combined with a general risk model allowed to integrate some concepts that otherwise would be left behind. As a future work, it might be useful to integrate elements from a transport-oriented risk management system, which combines risk analysis and evaluation, risk monitoring, risk treatment, and risk communication as shown on Figure 4.6 (Jamroz, et. al, 2010).

Figure 4.6. Diagram of the components of the phases of the integrated method for risk management in transport TRANS – RISK. Source: Adapted from (Jamroz, et. al, 2010)



Thinking in future research lines, with some hi-tech available tools it might be possible to combine historical data with real-time information (Giglio, et. al, 2004) for a more integral supply chain and/or transportation risk management that might be updating events as they happen, performing decision-making processes easier, faster, and more effective.

4.9 Appendix 1

Scenarios considered on the case study. Source: Own elaboration

Scenarios	Total production (ton)	Volume considered per customer's location*						
		1	2	3	4	5	6	7
		Mexico & CA	US & Canada	Europe	Asia	Australia	Brazil	India
1	105	LOW	LOW	LOW	LOW	LOW	LOW	LOW
2	150	MED	MED	MED	LOW	LOW	LOW	LOW
3	195	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW
4	120	LOW	LOW	MED	LOW	LOW	LOW	LOW
5	120	LOW	MED	LOW	LOW	LOW	LOW	LOW
6	120	MED	LOW	LOW	LOW	LOW	LOW	LOW
7	135	LOW	LOW	HIGH	LOW	LOW	LOW	LOW
8	135	LOW	HIGH	LOW	LOW	LOW	LOW	LOW
9	135	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
10	150	LOW	MED	HIGH	LOW	LOW	LOW	LOW
11	150	MED	LOW	HIGH	LOW	LOW	LOW	LOW
12	150	LOW	HIGH	MED	LOW	LOW	LOW	LOW
13	150	HIGH	LOW	MED	LOW	LOW	LOW	LOW
14	150	MED	HIGH	LOW	LOW	LOW	LOW	LOW
15	150	HIGH	MED	LOW	LOW	LOW	LOW	LOW
16	165	MED	MED	HIGH	LOW	LOW	LOW	LOW
17	165	MED	HIGH	MED	LOW	LOW	LOW	LOW
18	165	HIGH	MED	MED	LOW	LOW	LOW	LOW
19	180	HIGH	HIGH	MED	LOW	LOW	LOW	LOW
20	180	HIGH	MED	HIGH	LOW	LOW	LOW	LOW
21	180	MED	HIGH	HIGH	LOW	LOW	LOW	LOW
22	60	LOW	LOW	LOW	LOW			
23	60	LOW	LOW	LOW		LOW		
24	60	LOW	LOW	LOW			LOW	
25	60	LOW	LOW	LOW				LOW
26	105	MED	MED	MED	LOW			
27	105	MED	MED	MED		LOW		
28	105	MED	MED	MED			LOW	
29	105	MED	MED	MED				LOW
30	150	HIGH	HIGH	HIGH	LOW			
31	150	HIGH	HIGH	HIGH		LOW		
32	150	HIGH	HIGH	HIGH			LOW	
33	150	HIGH	HIGH	HIGH				LOW

*where LOW=15 ton; MED=30 ton; HIGH=45 ton

Chapter 5. Conclusions and Future Work

This research is about finding ways for companies to start considering some types of risk to make their operations more efficient. The first part consists on deciding to take a step into risk management and prevention. It is possible to develop a practical methodology to assess supply chain risk in a company to make the process more systematic. In this case, the methodology was based on the Fine-Kinney principles of exposure to risk, likelihood, and impact severity. Through the research, it was evident that each company has its own parameters to consider these principles and that is why personalized information is necessary to represent the reality of risk on each company. Chapter 2 was about finding out risk and how to assess its consequences, in order to prioritize the establishment of mitigation plans and reduction-risk actions.

As important as these actions are, they are not as scattered as needed yet. Chapter 3 presented a way in which Quality databases could be analysed to detect some logistics risks from there, anticipating the creation of supply chain risk specific databases. The idea is to have a foundation to start working on the implementation of actions for logistics risk reduction in parallel of developing a focused supply chain risk management. The comparison between the methods showed a certain pattern with some expected limitations that might not affect on the prioritization of risks.

With the basis on which supply chain risks to observe, Chapter 4 aims to focus on using these findings for decision-making. Risk assessment was evaluated on a production-distribution model, meaning that the fundamentals of risk previously studied can be expanded to different focuses and settings. The results showed the impact of the risk considering some scenarios in a global company. Once again, the necessity of having a database with the disruption events information pops up. There is little documentation on risk, disruption events, or near-disruption events, although people in the companies remember them.

Another general finding is that collaboration between all the partners involved in the supply chain results imperative to have coordinated actions when there is a disruption. Since disruptive events can be generated in any part of the supply chain, coordination between the actors involved can derive in the joint development of rapid response plans for the main detected risks. Risk management culture is necessary to be implemented from the strategy down to make sure that operative measurements can be taken to reduce risk.

5.1 Future Work

To observe how the variables interact in the proposed supply chain risk assessment methodology, it is necessary to evaluate other companies in the same industry, as well as in other industries. In addition, it is essential to fully implement the methodology for a long term to measure the effectiveness of the mitigation plans proposed. Although the results obtained from the different parts of the study allow the companies to consider risk mitigation strategies for the risk detected in that moment, this is not a single time action. It should be a continuous evaluation of the risks that were already identified and of the mitigation plans that were already implemented.

For the production-distribution model, other parameters such as inventory levels and truck capacity might be integrated. The way of calculating the cost penalty of the risk can be reinforced with current information on real disruptive events that can start being documented for this matter. This is only the first two phases of the supply chain risk management: assessment and evaluation. The third phase, consisting on risk control and monitoring, is the next step to fully develop the methodology. This information can be generated automatically if some sort of hi-tech gadget can be incorporated to gather this data for real-time monitoring and control. That is a potential research line. From there, regression methods that consider some other relevant variables might be run and used to predict risk events when evaluating real-data parameters. Also, visualization through the supply chain would allow the different actors to act proactively in case of a disruption. As a result, collaboration schemes with vendors and 3PL's can be developed to strengthen the whole supply chain.

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Appendix A

Evidence of publication on Safety and Security Engineering VII

ADAPTATION OF THE FINE-KINNEY METHOD IN SUPPLY CHAIN RISK ASSESSMENT

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ABSTRACT

Competitiveness based on the efficient operation of global supply chains requires a reduction of total logistic costs while maintaining them flexible to market changes and unforeseen events. Therefore, the focus on safety remains a key issue within the study of supply chains. Safety (or lack thereof) has an impact on operating costs, delivery time, inventory volume and the value of insurance rates, which can lead to a decrease of international competitiveness. This makes supply chain safety a competitive advantage, source of added value. The present study aims to expose risk factors assessment using an adaptation of the Fine-Kinney method, in which risks are analysed based on their risk exposure, likelihood and impact severity. This adaptation includes an adjustment on the occurrence scale to consider the general degree of incidence, as well as on the severity scale to consider the number of impacts that each risk involves. A risk map for the processes associated with the chain using the scales considered is also proposed. Risks associated to the supply chain of a chemical company located in Mexico are assessed using this methodology, in order to establish the degree of vulnerability of each process involved, as well as to document the existing processes in the mitigation of risks. In the scope of the analysis, a total of 118 risks were found and classified, spotting 14 with a high-risk level. 18.6% of documented risk mitigation plans were detected, as well as 38.98% of undocumented plans. This is a first effort on identifying the sources of risk and thus, can be useful to prioritize the mitigation approach towards each one, in order to develop over the long term a risk management process at a corporate level.

Keywords: Fine-Kinney method, supply chain risk management, risk assessment.

1 INTRODUCTION

Globalized markets and outsourcing of activities minimize the control that companies can exert on the supply chain, since these make them more complex and extensive. Adding difficulties to normal variations on supply and demand, there are also some other issues that, although not directly related to the performance of the chain, can improve or hinder the flow of resources that transit through it. While the focus on risk is not new, the approach to safety remains a significant issue within a supply chain study. Both security and safety have repercussions on operating costs and therefore in its international competitiveness.

There is a growing awareness among companies to minimize the impact of the occurrence that the risks to which they are exposed could have. The first part to achieve a culture in risk management in supply chains, following the determination of the company work on this topic, is to identify the different sources of risk [1] in order to develop strategies to overcome them. It is imperative to find a balance between safety/security and competitiveness, investing resources in safety/security-related issues, affecting the least possible to logistic costs but reducing the vulnerability of supply chains.



Appendix B

Evidence of participation in 7th International Conference on Safety and Security Engineering



Appendix C

Evidence of Submission to: International Journal of Logistics Systems and Management

Status: Under review

**INDERSCIENCE Submissions**
Article submission and peer-review system

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IJLSM-38067	Quality Analysis as a foretaste for Supply Chain Risk Assessment: A Case Study	10-Feb-2020	View Details	Under Review 7%

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- **Incomplete** - Article submission has not been completed.
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- **Removed** - Article has been removed from the submission process by the Submissions Manager.
- **Query with Author** - Editor has asked the Author to check their submission.
- **Under review** - Submission has been screened and is undergoing peer-review.
- **Author Revising** - Editor has asked the Author to amend their article in light of Reviewer recommendations.
- **Re-Review waiting** - Author's amended article is waiting to be sent to Reviewers.
- **Re-Reviewing** - Reviewers are assessing the Author's amended article.
- **Final Review** - Editor is considering the reviews and making the final decision whether to publish.

Appendix D

Evidence of elaboration of the research project on Dow Chemical Company.



Santiago de Querétaro a 14 de Febrero de 2017

Sistema Nacional de Investigadores.

Por medio de la presente se hace constar que la Maestra Zahira Gabriela Cruz Netro, estudiante de Doctorado en Logística y Dirección de la Cadena de Suministro de la UPAEP, participó como investigadora en el Proyecto de Investigación: Supply chain risk assessment. Fase I: Valoración del Riesgo en la Cadena de Suministro para Dow Chemical Company; el cual fue desarrollado del 15 de julio del 2016 al 15 de enero del 2017.

El proyecto consistió en la identificación de los riesgos asociados a la cadena de suministro de la empresa de químicos Dow Chemical Company, planta Querétaro, utilizando como metodología a una adaptación del método Fine, con la finalidad de establecer la vulnerabilidad de cada proceso y determinar el status de seguridad en la cadena de suministro de dicha empresa, así como la documentación de los procesos existentes en mitigación de riesgos en las áreas de la empresa estudiadas.

Los resultados obtenidos a nivel teórico, mostraron que la empresa presenta 118 riesgos, un mapeo general de estos, mostró una priorización del riesgo según el nivel de exposición, probabilidad de ocurrencia y severidad del impacto, además de la identificación del área donde se presenta cada uno de ellos.

Agradeciendo la atención a la presente me despido de Ud., no si antes ponerme a sus órdenes para cualquier aclaración.

ATTE.

A handwritten signature in blue ink, appearing to read "Oscar Iván Carreón Martínez".

Dr. Oscar Iván Carreón Martínez
Regional Improvement Leader C&C
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Appendix E

Evidence of participation in Supply Chain Management: the Connected Hub the Extended Version – Summer Course

 Amsterdam University
of Applied Sciences

Faculty of Business and Economics

CERTIFICATE

Undersigned confirms that

Zahira G. Cruz Netro
born March 20, 1985 in Tamaulipas, Mexico
has successfully completed the following module on October 10, 2018.

**Supply Chain Management: the Connected Hub
the Extended Version - Summer Course**

Assigned to this module is the result: 8 (eight).
Total number of credits: 6 ECTS.

Amsterdam, October 10, 2018
AUAS summer school coordinator,


Grading scheme

The Dutch grading system, used from elementary to university education the 1 to 10 scale in the following table, in which 10 is the highest grade, 6 the minimum pass and 1 the lowest grade. However 2's are seldom given and 10's are quite rare. 1-3's are also not very often used.

Official Dutch grading scheme:

10	Excellent
9	Very good
8	Good
7	Satisfactory
6	Sufficient
5-1	Fail

Sometimes grades are not given but achievements are expressed in words. If that is the case a V is a pass and a VR is an exemption. The level of achievement is not specified above the minimum level.

The grading table requires universities to keep track of their grading practice and culture, which is good practice in many institutions across Europe. The ECTS grading table allows for simple, transparent interpretation and conversion of grades from one system or context to another, and therefore does justice to the level of academic performance of all learners. Used correctly, it bridges different grading systems as well as different cultures in the European higher education area and beyond.

The grading table presents how many students (in percentages) receive a specific grade. This provides all necessary information to convert the grade in any local grading system.

National / Amsterdam University of Applied Sciences Grades	Total number awarded in reference group	Grading percentages*
10	18,834	1%
9	122,955	6%
8	465,314	24%
7	780,451	39%
6	602,004	30%
Total	1,989,558	100%

* based on the total number of grades awarded in the degree programmes during four preceding years

Credit System
A student's workload is measured in ECTS credits. According to Dutch law, one credit represents 28 hours of work and 60 credits represents one year of full-time study. One semester is 30 ECTS.

Appendix F

Evidence of participation in PhD Summer Academy in the MIT-Zaragoza International Logistics Program



PROFESSOR	FROM	COURSE	STARTING DATE	ENDING DATE	HOURS
Mikko Ketokivi	IE	Empirical Operations Management Research	20/6	22/6	9
Robert Klassen	Ivey	Sustainability in Operations Management	21/6	23/6	9
Glen Krainer	Penn State	Doing Grounded Theory Research	23/6	24/6	9
Dorothee Honthon	UT Dallas	Inventory management of perishable products to minimize waste	25/6	28/6	9
TOTAL HOURS: 36					