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How Supply Chain Risks can be incorporated into the Supplier Selection Process

Master of Science Thesis in Supply Chain Management

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Göteborg, Sweden, 2012

Report No. E2013:004

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Abstract

Supply chains have become more vulnerable today when factors such as globalization and outsourcing have increased. At the same time companies have become more dependent on their suppliers since they stand for a larger part of the value of the final product. Due to these factors, companies need to increase the visibility of their supply chains in order to be able to manage them. To avoid disruptions in the supply of components, risks and vulnerable elements in the supply chains have to be identified and mitigated.

This thesis is carried out as a case study at the purchasing department at Volvo Powertrain (VPT). Today VPT has limited knowledge and visibility of its supply chain beyond the first tier suppliers. This means that all the risks related to a specific supplier are not incorporated when a new supplier is selected. Therefore the purpose of the thesis is to: *“Develop a model that helps VPT to mitigate the impact of supply chain risks by incorporating them into the sourcing process”*. To fulfill this purpose, it has been broken down to the following research questions:

1. Why is it important to extend the network horizon beyond the first tier suppliers?
2. Which parameters make supply chains more vulnerable to disruptions?
3. How can the vulnerability of the supply chain be incorporated into the supplier selection process at VPT?

To answer these questions 35 interviews have been held with employees from different departments within Volvo and with some suppliers about supply chain risks. Some incidents that have caused disruptions in Volvo’s supply chain have been investigated as well. In addition, a theoretical framework has been built where important findings from the literature are presented that will later be used to analyze the empirical findings.

The main conclusion of the thesis is that VPT must extend its network horizon in order to become aware of the structure of the supply chain and the present risks. The supply chain risks need to be assessed already during the supplier selection and it needs to be done in a standardized way by considering the vulnerability of the supply chain as one parameter in the sourcing process. The information should be captured by using a self-assessment form in the Request For Quotation (RFQ) that is sent to potential suppliers. To get a supply chain perspective it is also important to encourage the suppliers to do a similar risk assessment on their suppliers. The information gathered during the sourcing phase can also be used later during the ongoing operations. If an event causes a disruption, VPT knows what to do and can act before its competitors.

Keywords: Purchasing, supply chain risk, supply chain disruption, supplier selection

Acknowledgements

This master thesis was carried out at the purchasing department at Volvo Powertrain (VPT) in Gothenburg during the fall of 2012. The thesis was performed within the master's program Supply Chain Management at Chalmers University of Technology. For us it has been a great opportunity to do this thesis in cooperation with VPT and there are many people that have helped us with our work.

We would like to thank and express our appreciation to everyone who has given valuable input to the results of this thesis. First of all we would like to thank our supervisor at VPT, Mourad Hedna, for initiating this project and giving us the opportunity to write this thesis. We would also like to thank Patrik Elfving, Jenny Lilliehöök and Amy Wilandh for their valuable input, support and encouragement throughout the thesis.

Secondly, we would like to thank all employees at VPT who have contributed with knowledge and valuable information by participating in our interviews. In addition we would like to thank the suppliers that have been assisting us in our project.

From the academic side we would like to thank Arni Halldorsson, our supervisor from the division of Logistics and Transportation at Chalmers. He has been very supportive throughout the thesis and come up with ideas from an academic as well as a practical perspective. Furthermore, he has come up with challenging questions and constructive input to help us to achieve best possible result.

Gothenburg, December 2012

Marcus Larsson

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List of Abbreviations

CDT – Cyclododecatriene

EDI – Electronic Data Interchange

FAQ – Frequently Asked Questions

GSC – Global Sourcing Committee

GSCF – Global Supply Chain Forum

GTT – Group Trucks Technology

JAMA – Japanese Automotive Manufacturing Association

JIT – Just-In-Time

MMOG/LE – Material Management Operations Guidelines – Logistics Evaluation

PC – Panel Committee

QDCF – Quality Delivery Cost Feature

RFI – Request For Information

RFQ – Request For Quotation

RTS – Review of Technical Specification

SCM – Supply Chain Management

SEM – Supplier Evaluation Model

TCO – Total Cost of Ownership

VPT – Volvo Powertrain

1. Introduction

This chapter aims to introduce the subject and why it is important. It starts with a brief academic background and after that the case company is presented. The chapter also introduces the purpose and the research questions. Finally, the scope and limitations are presented.

1.1 Background

In today's competitive environment, firms cannot longer compete as single entities but instead the competition is between different supply chains. A supply chain consists of all companies that are involved in the processes from raw material to the final consumer (Christopher, 2011). However, in most cases the supply chain is not a straight line of companies but rather an extensive and complex network consisting of several businesses and relationships (Lambert & Cooper, 2000).

All firms in the supply chains must work together and coordinate their activities in order to create systems that can respond to the fast changing market conditions and at the same time be consistent and reliable (Christopher, 2011). In this new landscape, the success of a single company depends on the management's ability to integrate the company's network of business relationships. The management of these business relationships across the supply chain is called supply chain management (SCM) (Lambert & Cooper, 2000).

Since all relationships are connected, companies' networks are borderless. However, due to limited resources it is impossible for companies to have a clear view of their entire network structure and therefore all companies have an own network horizon, which determines how large part of the network they are aware of (Holmen & Pedersen, 2003).

The increasing demands from end customers force companies to focus on their core competence and let the suppliers carry out a larger part of the work than before. This makes companies much more dependent on their suppliers which increases the need of coordination and adoption of SCM. It also means that a larger part of the supply chain has to be managed and to do this the network horizon must be extended. This needs to be done in order to create more efficient processes but also to reduce the risk of disruptions (Christopher, 2011) (Holmen & Pedersen, 2003).

The risk dimension is of great importance since a disruption that affects one entity anywhere in the supply chain can create supply shortage situations and even production stops for companies downstream. Due to this fact, companies must not only consider risks in their own operations but also risks related to other entities in their network. However, these risks will be more difficult to assess the further away in the supply chain you get (Jütter, 2005).

1.2 Introduction of the Case Company

Volvo was founded in 1927 as a small local car producer in Gothenburg, Sweden. Since then, Volvo has developed into a one of the world's leading manufacturers of heavy trucks, buses, construction equipment and drive systems for marine and industrial applications. The group has around 100 000 employees, production facilities in 20 countries and sales in over 190 markets around the world (Volvo Group 1, 2012).

The Volvo Group has recently introduced a new organization that will be implemented during 2012. The purpose of the restructuring is to better utilize the global potential of the brands and products within the truck operations. Other benefits are an increased customer focus and a more agile organization (Volvo Group 2, 2012).

The new organization is illustrated in the organizational chart in Figure 1. The first five operations called Group Trucks gather all the functions related to Volvo Trucks. The sales department is divided into three regions including Americas (North and South), EMEA (Europe, Middle East and Africa) and APAC (Asia and Pacific). Volvo Group Trucks also consists of Operations that is responsible for production and spare parts as well as Technology, which includes product development and purchasing (Volvo Group 2, 2012).

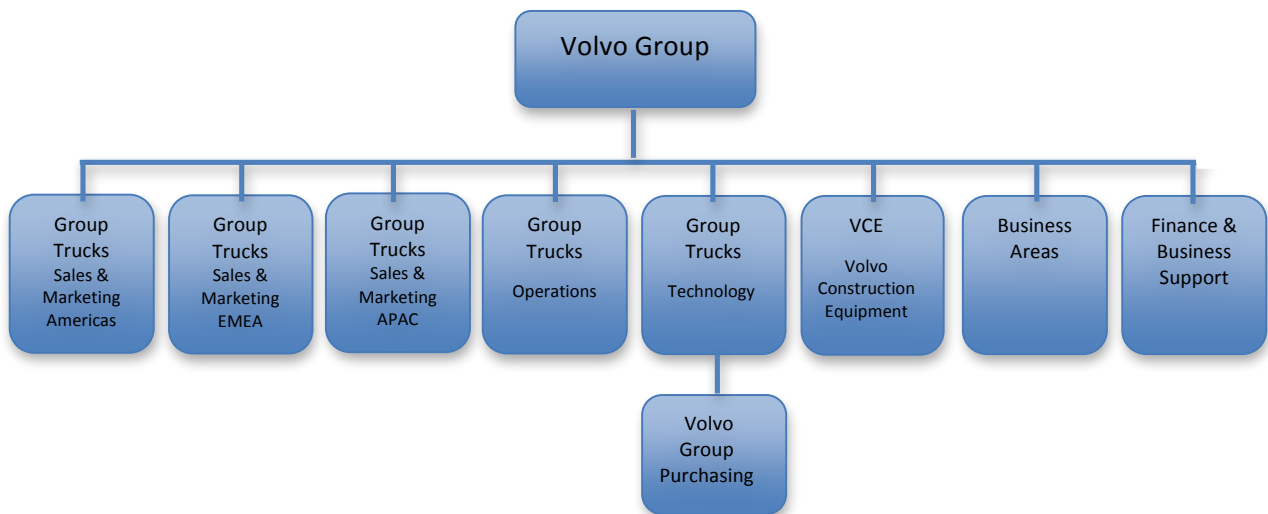


Figure 1: Volvo Group organizational chart (Volvo Group 1, 2012)

Volvo Group Trucks Technology (GTT) covers the entire value chain from long-term research and planning to final delivery of complete vehicles and services to the Volvo Group sales organization. It comprises product development and the purchasing department, which is the department where this thesis is conducted (Volvo Group 2, 2012).

Since the new organization was not fully implemented when the work with this thesis started, the focus has been on investigating the old Volvo Powertrain (VPT) organization. This business unit was responsible for all activities related to engines and transmissions.

1.3 Purpose

Supply chains have become more complex and risky as outsourcing and globalization have increased. The fact that Volvo has experienced supply shortage situations in the past further highlights the importance of the subject. Despite this, the impression is that VPT is often not aware of the structure of its supply chains beyond the first tier suppliers, and consequently not the present risks. Due to this fact, these risks are usually not incorporated when a new supplier is selected and hence all costs related to a specific supplier are not considered in the selection process. The purpose of this thesis is therefore to:

Develop a model that helps VPT to mitigate the impact of supply chain risks by incorporating them into the sourcing process

The model aims to visualize the structure of the supply chains and to facilitate an analysis of the present risks. Parts of the work are to define what should be included in the model, how the necessary information should be gathered and how this information should be assessed. In addition to the model a presentation will be held for the purchasers at VPT where takeaways from some relevant supply shortage situations should be presented in order to raise the awareness of these kinds of issues at the purchasing department.

1.4 Problem Analysis and Research Questions

The main problem to be addressed in this thesis is the limited supply chain risk assessment when selecting new suppliers. As of today, VPT has a supplier evaluation process, but it usually lacks the supply chain perspective. This means that VPT is often not aware of the supply chain structure beyond the first tier suppliers and consequently not the present risks. To make the purpose more manageable it has been broken down into three research questions with a clear sequential logic. The first two questions are about supply chain risks in general while the last one will focus on the supplier selection phase.

In order to develop a model that incorporates supply chain risks, it is necessary to first understand why it is important to see beyond the first layer of suppliers and to adopt a supply chain approach. An extended network horizon is the first step to fulfill the purpose since it then will be possible to identify and later mitigate the supply chain risks. Therefore the first research question is:

1. *Why is it important to extend the network horizon beyond the first tier suppliers?*

When the structure of the network is known it is possible to analyze the supply chain and its present risks. Since most supply chains have different structures and characteristics it is difficult to analyze the risks in a generic way. However, there are some parameters determining how vulnerable a supply chain is to disruptions. To facilitate the risk analysis of a specific supply chain the second research question is:

2. *Which parameters make supply chains more vulnerable to disruptions?*

Once the structure of a supply chain is known and the parameters have been identified, the next step is to determine the vulnerability of the supply chain and incorporate this information into the supplier selection process when evaluating offers from potential suppliers. Consequently, the last research question is:

3. *How can the vulnerability of the supply chain be incorporated into the supplier selection process at VPT?*

1.5 Scope and Limitations

The thesis will only investigate the supply chain risks and hence no risks within Volvo. The focus will be further upstream in the supply chain since this is where Volvo has least visibility today. The risks that are looked upon are limited to the ones that result in supply shortage with large potential consequences for Volvo, for example natural disasters, political instability, fires, major breakdowns of critical machines etc. The focus is to mitigate the

impact of the risk by making the structure of the supply chain more robust rather than reducing the probability of the risk.

The investigated organization is Volvo Powertrain and therefore the study will focus on its processes. Some supply shortage situations and other findings explained in this thesis concern not only VPT and in those cases Volvo is written instead of VPT. During the time this thesis has been written, a large reorganization has taken place at Volvo Group. Since this reorganization was not finished when the work with the thesis started, the processes described are the ones used in the old organization. However, the findings will be applicable for the new organization as well since all units work in a similar way.

The overall discussion about the importance of the topic and how to assess supply chain risks in general can also be applicable to other organizations. However, the model that is developed for VPT is more specific and therefore needs to be modified before it can be used by other organizations.

2. Methodology

This chapter presents the research methodology that has been used throughout this thesis. It will be explained what type of research that has been carried out and how the data has been collected. Furthermore, it will be presented what type of data that has been used to analyze the different research questions. Finally, there is a discussion about the validity and reliability of the findings.

2.1 Research Method

Research methods refer to systematic and focused collection of data for the purpose of obtaining information that can be used to solve a particular research problem. The two main research methods are qualitative and quantitative research. Both methods have their advantages and which method that is most appropriate to use depends on the research problem and its purpose (Ghauri & Grønhaug, 2005).

This thesis is based on qualitative research, which emphasizes words and understanding rather than numbers in the collection and analysis of data. The method is flexible and aims to generate new theory (Bryman & Bell, 2011). It is appropriate to use when there is a need to gain deeper understanding of specific phenomenon, which there is little known about (Ghauri & Grønhaug, 2005). In this thesis, the investigated phenomenon is how supply chain risks can be incorporated in the supplier selection process at VPT. It is appropriate to have a qualitative research method since Volvo does not work much with these issues today and therefore there is no available data to analyze in a quantitative way.

The quantitative research method, in contrast to the qualitative one, emphasizes quantification in the collection and analysis of data. The method is used to test and verify theory rather than to generate new. Usually, a hypothesis is created from existing theory and then tested using quantitative figures (Bryman & Bell, 2011).

Quantitative research has historically been the dominant method although the qualitative method has become more influential since the mid of the 1980s. Even though there are significant differences between the methods, the distinction is not always clear and it is also possible to combine both strategies (Bryman & Bell, 2011). It is for instance common to collect qualitative data through interviews and observations, translate these data into quantitative figures and then apply statistical analysis. Hence, the two different methods can be applied during different stages of the research (Ghauri & Grønhaug, 2005).

This thesis has been carried out as a case study of the sourcing activities within VPT. The case study approach is popular and widely used in business and management research (Bryman & Bell, 2011). Case study research is particularly useful when the investigated phenomenon is difficult to study outside its natural setting and when data is difficult to quantify. It is also well suited for new research areas or areas where existing theory seems inadequate (Ghauri & Grønhaug, 2005).

All these criteria are in line with research problems addressed in this thesis. This subject is difficult to study outside VPT since there is a need to study internal processes to obtain a valuable result. Being within VPT also enables observations of current practices and

increases the confidence of the interviewees. Another benefit is the access to internal documents.

Theory developed from a case study has strengths like novelty and independence from prior literature or past empirical observations. Case studies are highly complementary to incremental theory developed from normal science research (Eisenhardt, 1989).

What distinguishes a case study from other research is the focus on a bounded situation or system. The investigated case can be an organization, department, location, person or a single event (Bryman & Bell, 2011). In this thesis, the case is the purchasing department at VPT. When using a case study it is common to combine different data sources such as archives, interviews, questionnaires and observations. In this thesis the main data sources have been interviews, internal documents and academic literature (Eisenhardt, 1989).

Case study research is not limited to studying a single case and multiple-case studies have become more common in business and management research. This approach has been used as a part of this thesis with the aim to illuminate different cases, or incidents, where supply shortage situations have occurred. The purpose is to compare the different situations and highlight similarities as well as differences between them.

The way cases are used in this thesis is in line with literature since the multiple-case approach often is used to compare and contrast the findings of each case. This encourages researchers to consider what is unique and what is common across the cases and promotes theoretical reflections on the findings (Bryman & Bell, 2011).

The selection of cases is crucial and should be based on the opportunity to learn and therefore the cases where the learning is expected to be greatest should be selected. In this thesis, the different cases have been chosen with the aim of highlighting different types of events that have caused supply shortage situations, such as natural disasters, fires and major machine breakdowns (Eisenhardt, 1989).

2.2 Research Process

The first step of this thesis was to create an understanding of the topic from an academic perspective by performing a literature review. In parallel, initial interviews were held with purchasers and their managers to learn how VPT works with supply chain risks and how they are used in the supplier selection. For a complete list of interviewees, please see appendix 1. The purpose of these initial interviews was not to get a perfect understanding but to learn about VPT's organization and its sourcing process more in general. It is important to understand the current practices in order to identify potential improvements.

The next step was to search for incidents, or cases, where Volvo has faced the risk of supply shortage. This was done with help from the supervisor at VPT and by asking for this during the interviews. Interviews were mainly held with employees who have been involved in solving the supply chain shortage situations that have occurred from these events. There have been interviews with people working with purchasing, logistics, capacity planning and leaders for crisis teams. The study of the cases has been carried out in order to find out how different parameters affect the supply chain vulnerability. The aim was to find different

types of cases that could illuminate different incidents and aspects. The goal was to identify the cause of the shortage situation, how the situation was solved and how to mitigate the impact of similar events in the future.

After studying the incidents, the next step was to learn more about VPT's sourcing process and how the company works with risk management. This was done by interviewing employees working with sourcing, risk management, quality assurance and capacity planning and by studying VPT's internal processes and tools more in detail. Interviews were also held with some suppliers to get their opinion about the subject. The interviewed suppliers were selected in cooperation with VPT.

VPT's current practices were then analyzed with help from literature to identify potential improvements. Once deciding which type of model that would be appropriate to improve the current work with supply chain risks, a draft was created with input from both literature and the interviews. Input has mainly come from the interviews with employees working with purchasing, logistics, risk management and SCM.

The model has then been updated continuously as more employees and suppliers have been interviewed. During the interviews, the stakeholders were also asked how to assess the information generated by the model. When the model was considered complete, it was sent to a few suppliers to get some final feedback and make sure that all questions were understandable. With this information some minor changes were made to finalize it.

2.3 Research Design

The research design of a project can be categorized as exploratory, descriptive or causal. Exploratory research is appropriate to use when the problem is unstructured and poorly understood. The exploratory design is flexible since it makes it possible to change direction when new pieces of information are available (Ghauri & Grønhaug, 2005).

When using the descriptive approach the investigated problem is structured and well understood. The procedure for data collection must be constructed in a way that variation of the gathered data becomes as small as possible. To achieve this, there must be strict rules, a clear structure and standardized procedures (Ghauri & Grønhaug, 2005).

The last type of research design is the causal design that also requires a structured problem. However, in contrast to the descriptive approach the research also includes problems dealing with causes and effects. The main issue with this design is to isolate the causes and conclude to what extent they result in effects (Ghauri & Grønhaug, 2005).

This thesis can be characterized as exploratory since the problem was not fully defined in the beginning of the research. VPT does not work with supply chain risks in a standardized way today and therefore the problem is not to improve an existing model but rather to create a new one. As more information, both from literature and interviews, has been obtained the problem has changed and become clearer.

2.4 Research Strategy

The two main research strategies are the inductive and deductive strategy. The inductive strategy means that theory is the outcome of the research and the process of induction means that generalizable conclusions are drawn out of observations. In other words, induction means that theory is created from observations. This strategy is often associated with qualitative research even though this is not always the case. Much qualitative research does not generate theory and theory is often used as background to quantitative studies (Bryman & Bell, 2011).

In contrast, deduction means that observations are carried out in order to test existing theory. The researcher formulates a hypothesis on the basis what is currently known about a subject and then data is collected to test the hypothesis. Depending on the outcome of the hypothesis testing, the results might lead to a revision of the existing theory (Bryman & Bell, 2011).

In this thesis the inductive strategy has been used since the aim is to create new theory rather than to test existing one. Again, the problem is to create a new model for VPT rather than improve an existing one and this requires an inductive approach.

2.5 Data Collection

The data that has been used in this thesis comes from both primary and secondary sources. Secondary data has been collected through a literature review of relevant books and articles. Internal documents at VPT, collected mainly from the intranet, have also been a useful source of secondary data.

Secondary data is information that is collected by others for purposes that can be different from the one of the thesis. The data can be useful not only to solve the research problem, but also to better understand and explain the research questions. The main advantage of using secondary data is the savings in time and resources. The easy access to data broadens the base from which the scientific conclusions can be drawn. The most obvious drawback of secondary data is that the information often is collected for another purpose and might therefore not completely fit the problem of the specific thesis (Ghauri & Grønhaug, 2005).

Primary data is collected for the purpose of the particular project. In this study interviews have been the primary collection method of primary data. Another source of primary data has been observations at VPT. The main advantage of primary data is that it is collected for the particular study and therefore more consistent with the research questions and research objectives. The main disadvantage is that it takes much time and resources to collect the data (Ghauri & Grønhaug, 2005).

2.5.1 Literature Review

To get a deeper understanding of the research field and to investigate the previous research, a literature review of relevant secondary sources has been made. The approach used in the literature review has been to use a wide scope in the beginning of the study in order to get a better understanding of the subject and why it is important. When this was done, the review narrowed down to specific subjects that can be used to answer the research questions.

The main part of the secondary information comes from books and academic articles. These have mainly been found in online databases provided by the library at Chalmers University of Technology. Systematic searches were made including keywords such as; supply chain disruption, supply chain risks, network horizon and supply chain turbulence. All concepts have also been combined with the keyword automotive since this is the focus of the thesis. The findings were scanned in order to determine if they were relevant for the thesis or not. The relevant ones were then categorized and used for a more in-depth learning.

For the cases of supply shortage situations secondary data was used in addition to the information from the interviews. The information used comes mainly from internal documents collected from the intranet and from people involved in the supply shortage situations that have access to relevant databases. In addition, articles found on Internet were used as source of secondary information for this task.

2.5.2 Interviews

The main method to collect primary data has been interviews. Bryman & Bell (2011) distinguishes between two different types of interviews; structured and qualitative interviews. Structured interviews are usually used in quantitative studies where a predetermined set of questions has to be answered during the interview.

Qualitative interviews focus much more on the interviewee's point of view. Bryman & Bell (2011) argues that qualitative interviews can vary a lot depending on the approach taken by the interviewer and they can therefore be divided into two categories; unstructured and semi-structured interviews. An unstructured interview is more of a discussion around a certain topic where the interviewee is allowed to talk freely. The interviewer can then follow up interesting points by asking specific, but not predetermined, questions. In a semi-structured interview, the interviewer has an interview guide with fairly specific questions. The interviewee is still allowed to talk freely around the questions and if interesting topics are brought up, questions can be asked about that instead of following the predetermined interview guide (Bryman & Bell, 2011).

In the beginning of this study, unstructured interviews were held with employees at the purchasing department in order to get an understanding of how the purchasing and sourcing activities are performed today. Later in the study, interviews with employees at relevant positions in the organization were held in order to get a deeper knowledge in fields related to the research questions. These interviews were of the semi-structured type, where a list of questions was prepared before the interview. During the first interview within a new topic the questions were more open, but as more knowledge was obtained the questions could be more specific and concentrated to the areas where information was missing. To get a broader picture of the current situation and to get feedback on the proposed model, interviews with some suppliers were also performed.

Face to face interviews were preferred but when this was not possible telephone interviews were held. Notes have been taken during the interviews in order to catch information that was not outspoken, i.e. drawings etc. To increase the validity of what has been said, two interviewers have always performed the interviews. This allows the interview to be seen from different perspectives, which is valuable when the data is analyzed. Convergent

perceptions of what had been said also enhance the confidence in the findings. (Eisenhardt, 1989)

2.6 Data Analysis

During the entire project there has been an overlapping between the data collection and data analysis. This gives flexibility in the data collection to adjust what kind of data that is collected to what is needed in the analysis (Eisenhardt, 1989). Table 1 below shows evidence used to analyze the research questions.

Research Question	Theoretical Evidence	Empirical Evidence
1. Why is it important to extend the network horizon beyond the first tier suppliers?	<ul style="list-style-type: none"> - Literature about purchasing and supply chain management in general. - Articles about extending the network horizon and the risk of supply chain disruptions. 	<ul style="list-style-type: none"> - Interviews with employees from different relevant departments within VPT regarding the different cases of supply shortage. - Internal documents about the different cases as well as information from Internet.
2. Which parameters make the supply chain more vulnerable to disruptions?	<ul style="list-style-type: none"> - Literature about supply chain risks and supply chain vulnerability. 	<ul style="list-style-type: none"> - Interviews at Volvo about the cases. - Interviews at Volvo and suppliers about supply chain risks in general.
3. How can the vulnerability of the supply chain be incorporated into the supplier selection process at VPT?		<ul style="list-style-type: none"> - Interviews with employees at VPT. - Interviews with some suppliers regarding the topic and what kind of information that is possible to obtain.

Table 1: Evidence used to analyze the research questions

2.7 Reliability and Validity

The most important criteria for evaluation of business and management research are reliability and validity. These concepts measure the quality and wider potential of the research. Reliability explains the consistency of the measures and if the results of the study are repeatable or not. The term is more connected to quantitative research since there are more concerns about the stability of the measures when using this method. Reliability can be divided into external and internal reliability (Bryman & Bell, 2011).

External reliability measures how easy it is to replicate the study. It is very difficult to achieve a high external reliability in qualitative research, like in this thesis, since it is impossible to freeze a social setting and the circumstances to make it replicable. One example of something that is difficult to replicate in this thesis is the observations at VPT made by the authors. Internal reliability means whether the members of the research team agree about what is said and seen. This has been ensured throughout this thesis since there have been two interviewers at each interview agreeing what has been said (Bryman & Bell, 2011).

Validity is concerned with the integrity of the conclusions generated from the research (Bryman & Bell, 2011). The concept refers to whether the measures capture what they are supposed to. Validity can be divided into external and internal as well. External validity is concerned whether the results from the study can be generalized beyond the specific research context (Ghauri & Grønhaug, 2005). This type of validity is especially important for a qualitative case study since the researchers aim to study the specific case in detail but also to achieve a significant degree of theoretical generalizability. However, some argue that the particularization is the main strength of a case study and not the generalization. Therefore, the method should concentrate on the uniqueness of the case and develop a deep understanding of its complexity (Bryman & Bell, 2011). The model developed in this thesis has been created to fit VPT's context and hence it has been a focus on particularization. However, some findings can be generalized to fit other companies and industries even though some adaptations might be necessary.

Internal validity deals with the question if the conclusion that incorporates a causal relationship between two variables holds. In qualitative research it means whether there is a good match between the researchers' observations and the theoretical ideas they develop (Ghauri & Grønhaug, 2005).

To ensure a high degree of reliability and validity in the literature review, the data have been gathered from trustworthy sources. The largest part of the data is taken through databases provided by the library at Chalmers University of Technology. The data is collected from articles that have been published in journals and magazines focusing on the studied field and are considered credible.

The validity and the reliability of the interviews are mainly ensured by the fact that the authors have agreed what has been said. After each interview the information has been discussed and key facts have been written down. Notes have also been taken during the interviews to ensure that everything that has been said is captured.

To increase the validity and reliability of the gathered information, triangulation has been carried out. Triangulation means that more than one source of data has been used for the same subject (Bryman & Bell, 2011). When studying the supply shortage incidents and VPT's current processes both interviews and studies of internal documents have been performed. To further increase the triangulation at least two interviewees have been selected for each topic.

3. Theoretical Framework

This chapter presents relevant literature about the subject that later will be used to analyze the empirical findings. The structure of the framework can be characterized as a funnel. It starts broad with a general introduction to purchasing where relevant concepts are presented. Later on the funnel narrows and the focus will be on explaining the supply chain management dimension of purchasing. Finally the funnel is narrowed down to supply chain risks.

3.1 Purchasing

The purchasing function has traditionally only covered the buying process. It was argued that the purchasing function only should ensure products and services at the right quality, in the right quantity, at the right place and time, at the right price and from the right source (van Weele, 2010).

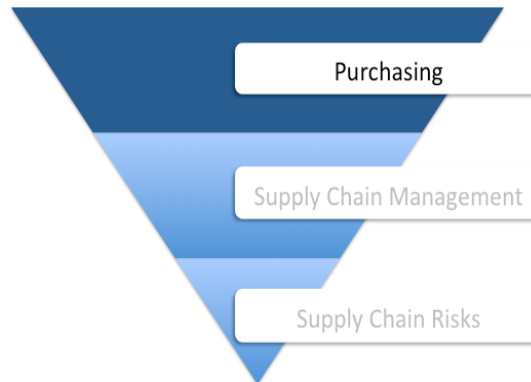
The goal was to find the best supplier for the current situation and hence purchasing was considered mainly as an operational activity. When applying this traditional model, each buying decision is treated as an isolated event but the problem is that all decisions are very much interrelated and the goal should be to optimize the overall situation rather than each separate buying decision (Gadde, Håkansson, & Persson, 2010).

Today, purchasing is considered more strategic but there is no dominant definition of the concept. Van Weele (2010) defines it as “The management of the company’s external resources in such way that the supply of all goods, services, capabilities and knowledge which are necessary for running, maintaining and managing the company’s primary and support activities is secured at the most favorable conditions.”

3.1.1 Integration of Purchasing into Business Strategy

When designing the overall business strategy, top management must consider the three major stakeholders which are customers, competitors and suppliers. These three stakeholders together constitute a strategic triangle, which can be seen in Figure 2.

The company should use marketing in order to reach the customers. To create and sustain a competitive advantage the company must benchmark against competitors and decide how to differentiate against them. The last part of the triangle is sourcing. The company should continuously analyze which activities that are the core competence and which are not. The non-core activities should be sourced from an appropriate supplier and a relationship with this actor should be established (van Weele, 2010).



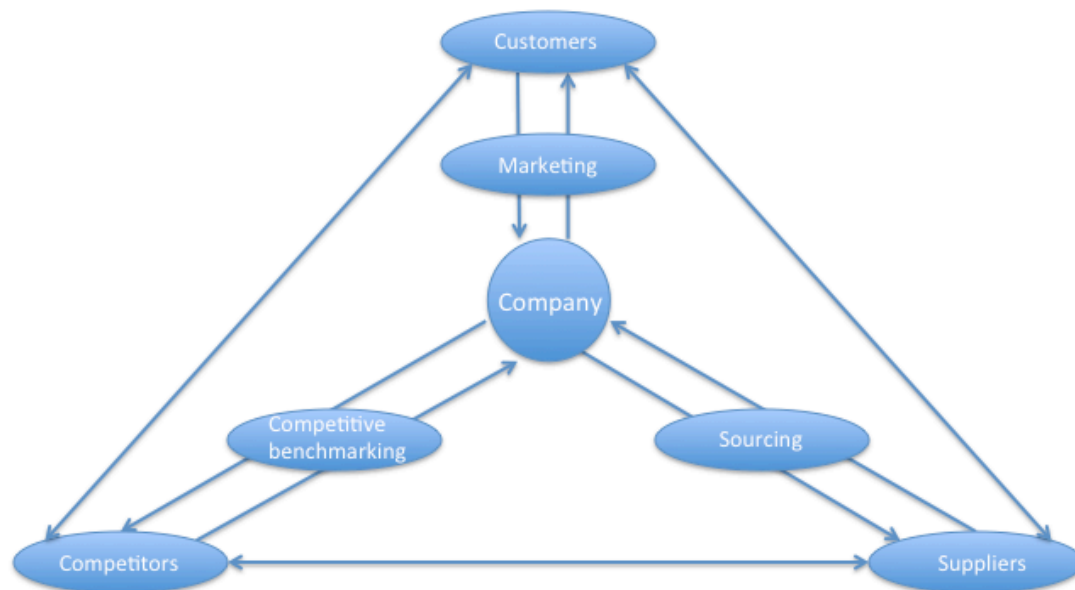


Figure 2: The strategic triangle (van Weele, 2010)

3.1.2 Purchasing at Different Organizational Levels

In today's competitive landscape, purchasing and supply professionals have several roles to play in organizations. They have a strategic role to analyze the amount spent on purchasing and to identify key suppliers. Based on this they should develop differentiated supplier strategies depending on the situation. On the tactical level they should work according to the defined strategy and standardize the purchasing process, establish effective information links with the suppliers and facilitate continuous improvement of supplier performance. On the operational level it is important to secure deliveries at the right time, quality and quantity at the lowest possible price (van Weele, 2010).

3.1.3 Increased Importance of Purchasing

Purchasing has become more important as the global competition has intensified. A larger part of companies' revenues is spent on purchased products and services and hence purchasing represents a great potential for cost reduction. The proportion of purchasing costs in relation to cost of goods sold can be seen in Figure 3. Two main reasons to the increased amount spent on purchasing are increased outsourcing and that many companies buy finished products instead of components due to lower labor costs in other parts of the world (van Weele, 2010).

Another reason to the increasing purchasing cost is that many companies need to deliver turnkey solutions to solve their customers' complex problems. To be able to do this, it is necessary to buy complex and expensive products from specialist suppliers. A last reason to the increased spend on purchasing is that the fast technological development makes it hard to afford investments in several different areas. Instead, manufacturers must focus on their core competence and rely on specialized suppliers for the remaining activities (van Weele, 2010).

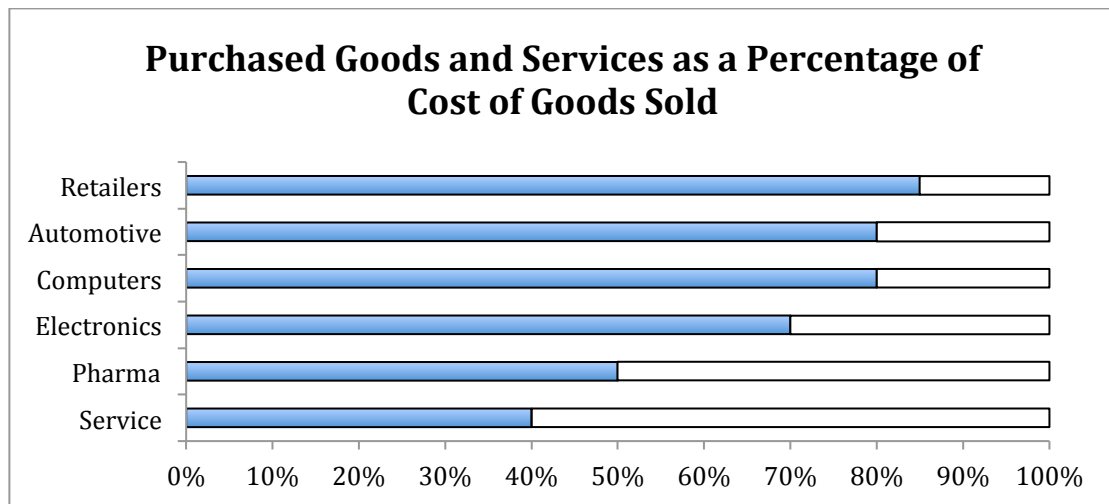


Figure 3: Purchasing costs in relation to cost of goods sold (van Weele, 2010)

Besides reducing the price of the purchased products, it is also possible to lower the total cost by shortening lead times, reducing inventory levels and increasing quality of the purchased components. In addition, it is possible to reduce costs by reducing the number of transactions and make the purchasing process more efficient by installing different kinds of IT solutions (van Weele, 2010).

Purchasing does not only provide great opportunities to reduce costs, it can also help to increase the revenue. As of today, when companies have outsourced many of their activities, suppliers are now a major source of innovation. Suppliers involved in the product design at an early stage can provide valuable information that enable simpler manufacturing processes, lower costs, improved quality and a shorter time to market (Gadde, Håkansson, & Persson, 2010).

The time aspect becomes more important as the product life cycles become shorter. To obtain a shorter time to market it is necessary to develop a professional project management and have collaboration not only between the supplier and the buyer but also between different departments within the organizations. It is important with cross-functional collaboration between departments like R&D, product development, production and purchasing (van Weele, 2010).

It is not only the financial impact that has made purchasing more important. The outsourcing of manufacturing has in many cases been followed by outsourcing of product development. Even though suppliers in some cases only account for a marginal share of the costs they possess more or less unique technical capabilities. In addition, many companies require just in time (JIT) deliveries, which further increase the dependence on the suppliers (Gadde, Håkansson, & Persson, 2010).

3.1.4 Purchasing Process

The general purchasing process consists of several activities that in most cases are very interrelated. The different steps are shown in Figure 4.



Figure 4: The purchasing process

During the initial stage of the process, needs and requirements are specified. Drawings describing the technical requirements or functional specifications describing the required functionality are created. The advantage of using functional specifications is that this provides better opportunities for suppliers to apply their expertise. Besides technical or functional specifications, there can be specifications about the quality, budget, logistics, maintenance and environmental performance (van Weele, 2010).

The specifications are summarized and a long list with potential suppliers is created. A request for information (RFI) is sent out to these suppliers who are supposed to submit information that will help them to qualify for the order. Based on the gathered information, a short list of suppliers is created and a request for quotation (RFQ) is sent out to them. The suppliers should submit bids in such a way that the buyer can compare them. The purchasing department will analyze all relevant aspects such as price, quality, logistics, legal aspects etc. Usually the buyer tries to use a total cost of ownership (TCO) approach, which means that all costs during the lifetime of the product are considered. During the comparison of the quotes, risks should be considered as well (van Weele, 2010).

After one or several suppliers have been selected, contracts have to be signed. The content of contracts varies but some factors that are common to include are price, payment terms, quality requirements and warranty conditions. When the contract is signed, purchase orders can be placed. The supplier should usually send a confirmation before the expediting, which is the process to ensure delivery, is started (van Weele, 2010).

The last step in the process is the evaluation phase where factors like maintenance and warranty claims are handled. In addition, it is important to keep track of the suppliers' performance to make improvements but also to use that information in the next buying decision (van Weele, 2010).

3.1.5 Sourcing Strategy

Sourcing aims to develop the most appropriate supplier strategy for a certain commodity or product category. The sourcing strategy includes factors like how many suppliers to use, what type of relationship to establish with them and what type of contract to negotiate (van Weele, 2010).

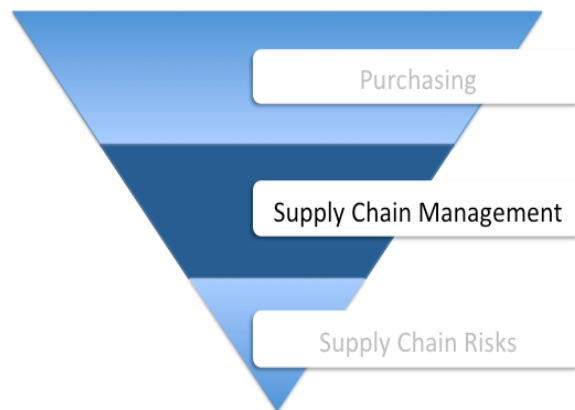
One important factor in the sourcing strategy is to determine if the company should use single or multiple sourcing. Single sourcing means that the company purchases the component from only one supplier. This usually means lower prices and transaction costs as well as the possibility to establish a closer relationship with the supplier. However, the company will be more dependent on the supplier, which will increase the risk. One way to reduce risk is to use multiple sourcing which means that the component is purchased from

more than one supplier. However, this strategy will not generate the same economies of scale nor the same possibility to establish close relationships (van Weele, 2010).

Another element of the sourcing strategy is to decide whether to source locally or globally. Many companies have chosen a global strategy since this in most cases enables a lower unit price. However, the distribution and logistics will be more complicated and the communication will be more difficult due to different cultures and languages. Global sourcing also means higher uncertainties regarding quality and on-time delivery (van Weele, 2010).

3.2 Supply Chain Management

One of the most significant shifts of business management is that companies no longer compete as single entities but rather as supply chains. In this new competitive landscape, the success of a single business will depend on the management's ability to integrate the company's network of relationships. Strictly speaking, the supply chain is not a chain of companies but rather a network of multiple companies and relationships (Christopher, 2011).



The management of multiple relationships across the supply chain is called SCM. There are several definitions of the concept. One definition developed by the Global Supply Chain Forum (GSCF) is “The integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders” (Lambert & Cooper, 2000).

Van Weele (2010) describes it as “Management of all activities, information, knowledge and financial resources associated with the flow and transformation of goods and services up from the raw materials suppliers, components suppliers and other suppliers in such a way that the expectations of the end users of the company are being met or surpassed.” Christopher (2011) defines it as “The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole”.

SCM involves a significant change from traditional arm's-length relationships to closer relationships characterized by trust and cooperation. The goal is to achieve a more profitable outcome for the chain even though this can be in conflict with the goals of the single companies. Transferring costs upstream or downstream will not make the company more competitive since the costs still are incorporated in the final price paid by the consumer (Christopher, 2011). Figure 5 below shows a model of a focal company and its supply chain.

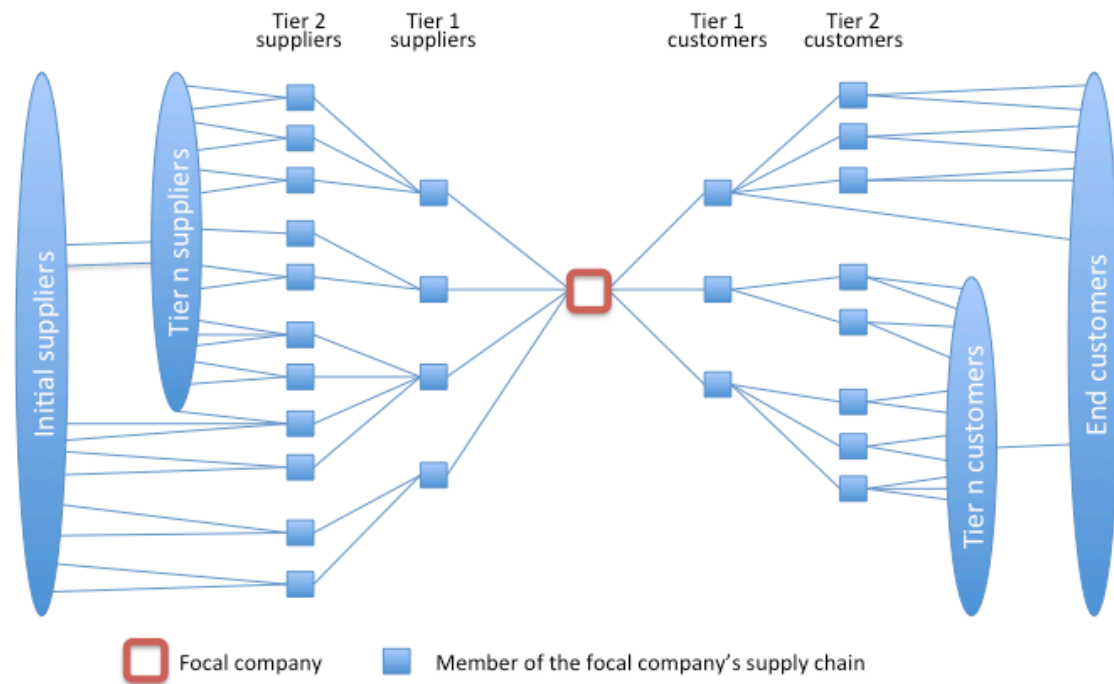


Figure 5: A model of a supply chain (Lambert & Cooper, 2000)

Managing all businesses and relationships in the supply chain is a very challenging task, especially since the supply chain often is an extensive network of companies. Usually executives prioritize to manage the part of the supply chain between the company and the end users since the company having the relationship with the end user has the power in the supply chain. However, it is very important to manage the relationships with the companies upstream in the chain as well (Lambert & Cooper, 2000).

3.2.1 Framework of Supply Chain Management

Lambert & Cooper (2000) describes a framework of SCM consisting of three parts; network structure, business processes and management components.

3.2.1.1 Network structure

The network structure consists of the members of the supply chain and the links between them. The members include all companies and organizations that the focal company interacts with, either directly or indirectly through its suppliers or customers. It can be useful to distinguish between primary and supporting members. The primary members are the ones carrying out value adding activities in the business process designed to produce a specific output. The supporting members provide resources, knowledge, utilities or assets that the primary ones use. Some examples of supporting members are banks lending money, companies providing logistics services or supplying production equipment. One factor making the network structure more complex is that companies can perform primary activities for one process and supporting activities for other processes (Lambert & Cooper, 2000).

The network structure consists of several elements. The horizontal structure refers to the number of tiers or the length of the supply chain. The vertical structure shows how many suppliers or customers there are at each tier, which can be interpreted as the width of the

chain. The last element of the structure is the horizontal position of the focal company, meaning where in the chain it is located. There are several decisions affecting the structure of the network. Increased outsourcing means longer chains and moving from multiple to single sourcing makes the chain narrower (Lambert & Cooper, 2000).

3.2.1.2 Business Processes

A successful SCM requires a change from managing functions to integrating activities into supply chain processes. The customers should be the primary focus and the response from them should be transferred as quickly as possible upstream the supply chain. Some key supply chain processes that should be integrated are:

- Customer relationship management
- Customer service management
- Demand management
- Order fulfillment
- Manufacturing flow management
- Procurement
- Product development and commercialization
- Returns

It is not appropriate to have the same degree of integration for all business links and the level of integration should vary from link to link and also over time. It is important to carefully allocate the scarce resources among the different links to achieve best possible result (Lambert & Cooper, 2000).

3.2.1.3 Management Components

The level of integration and management of each link is a function of the number and level of management components added to it. Hence, adding more management components or increasing the level of each component will increase the level of integration. Some management components that are appropriate to add are: (Lambert & Cooper, 2000)

- Planning and control
- Work structure
- Organization structure
- Product flow facility structure
- Information flow facility structure
- Management methods
- Power and leadership structure
- Risk and reward structure
- Culture and attitude

3.2.2 Network Horizon

All relationships between firms are connected and therefore the entire business network is borderless. The network horizon is defined as “how extended an actor’s view of the network is”. The part of the network the firm is not aware of is defined as its environment. The network horizon includes all firms and relationships the focal company is aware of, whether

these are important or not. The part of the network horizon the firm considers relevant is the firm's network context (Holmen & Pedersen, 2003). Figure 6 shows the different parts of a firm's network.

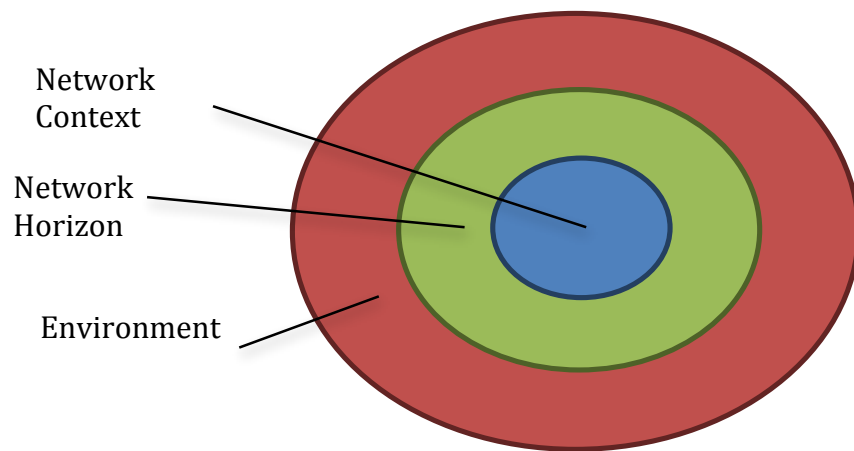


Figure 6: Parts of a firm's environment

An important aspect for a firm is to define an appropriate network horizon and network context. A broad network horizon enables more opportunities to act upon and provides a deeper understanding of the network. However, due to limited resources, it is not appropriate to have a too wide network context. In addition, it might not be possible to extend the network horizon as much as the firm wants since this depends on the counterparts' ability and willingness to share information (Holmen & Pedersen, 2003).

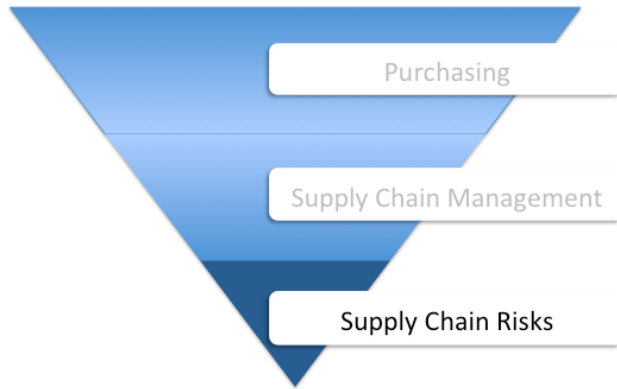
Lambert & Cooper (2000) describes the network horizon in another way. A firm has several links with other companies and all these links should receive different degrees of attention. The links can be categorized as:

- Managed business process links
- Monitored business process links
- Not-managed business process links
- Non-member process links

The managed links are those with the direct suppliers and customers but also some of the most important links beyond the first tier. The monitored ones are not as critical to the focal company but they need to be monitored even though they are not actively managed. The not-managed links are links that the focal company is not actively involved in and they are not critical enough to monitor. The focal company trusts other members of the network to manage these links or leaves it up to them due to limited amount of resources. The non-member links are links between members of the focal company's supply chain and companies that are not part of the chain. Even though they are not a part of the supply chain structure they often affect it (Lambert & Cooper, 2000).

3.3 Supply Chain Risks

Risk is an important factor to consider in all business decisions. A broad definition of risk that is commonly found in the literature is “the chance of danger, loss, injury or any other undesirable consequences” (Harland, Brenchley, & Walker, 2003). Several others, more scientific definitions incorporating more parameters, can also be found in the literature. A common one is stated by Mitchell (1995) as “... the probability of loss and the significance of that loss to the organization or individual”.



This definition of risk is often used when assessing the risk of disturbance in a supply chain. To get a risk profile of the supply chain the definition can be developed into the following concept: (Christopher, 2011)

$$\text{Supply Chain Risk} = \text{Probability of disruption} \times \text{Impact}$$

The model is intended to find risks in the supply chain where the resources and managements’ attention should be focused. However, a weakness with this approach can be that too little attention is given to the supply chain risks where the probability of occurrence is very small, but the impact would be large. An example of this can be severe natural disasters, where the probability of occurrence is very small but the impact could be huge for all actors in the supply network (Christopher, 2011).

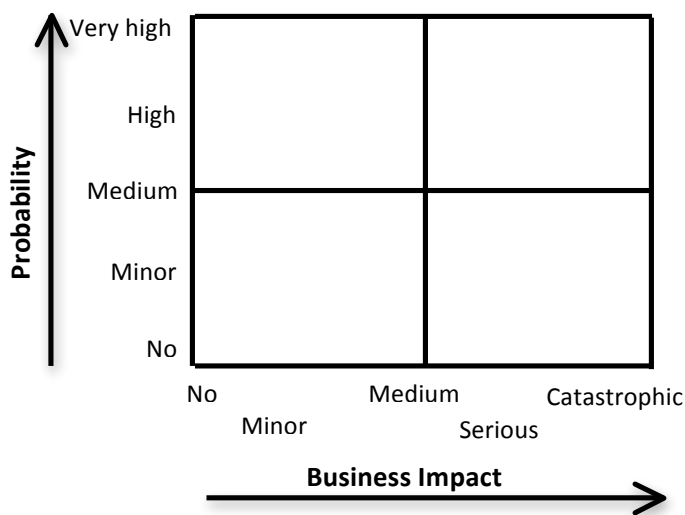


Figure 7: Probability and business impact of risks (Norrman & Jansson, 2004)

The supply chain risk concept is often illustrated in a risk matrix, where different types of risk can be classified depending on their probability of occurrence and their impact on the business, see Figure 7 (Norrman & Jansson, 2004).

3.3.1 Types of Risks

A way to sophisticate the risk definition is to divide the risk factors into several categories. This has been done in many ways and from different perspectives in the literature. One simple and commonly used framework by Christopher & Peck (2004) divides risks into three different categories depending on where they come from. The first category includes risks that are internal to the firm. The second one includes risks that are external to the firm but internal to the supply chain network such as demand risk and supply risk. The demand risk is defined as disturbances in the flow of products and cash between the focal firm and the market while the supply risk is defined as disturbances of products or information upstream of the focal firm. The last category includes risks that are external to the network such as natural disasters and political risks.

Another way to classify risks is presented by Trkman & McCormarck (2009), where the uncertainties or risks are divided into two groups depending of their origin. The first group consists of the endogenous risks, which are the ones that arise within the supply chain and can lead to changed relationships between the suppliers and the focal firm. Some examples are turbulence in the market or the introduction of new and fast changing technologies. The other group is the exogenous risks, where the source of uncertainty comes from outside the supply chain. These risks can be further divided into continuous risks and discrete events.

The continuous risks include risks that are relatively easy to predict and where the costs of potential changes are continuous. Typical examples are fluctuations in raw material prices, inflation and currency rates. These risks can often be covered by different kinds of insurance instruments such as future and forward contracts.

The discrete events consist of risks with a low likelihood of occurrence but a high impact. Examples are terrorist attacks, natural disasters, fires and labor strikes. These types of incidents are often very difficult to predict and the consequences difficult to measure. However, it is often possible to estimate the likelihood of these event in a qualitative manner since they often, but not always, are more or less likely to occur in different geographical areas (Trkman & McCormarck, 2009).

Endogenous Risks	Exogenous Risks	
<ul style="list-style-type: none"> - Quality issues - Changes in customer preferences - Changes in technology - Market turbulence 	<i>Continuous Risks</i>	<i>Discrete events</i>
	- Interest rate fluctuations	- Terrorist attacks
	- Raw material price fluctuation	- Natural disasters
	- Inflation fluctuations	- Labor strikes
	- Consumer price index fluctuation	- Political uncertainty
- Currency fluctuations	- Transportation disruptions	

Table 2: Classification of risks

One way to estimate this is to use some sort of index, like the one the World Risk Report has developed in cooperation with the United Nations. This index indicates the probability that a

country or region will be affected by a natural disaster. However, the report points out that it is not only the exposure to different disasters that will determine the effects. The structure, processes and framework conditions within a society is at least as important for the final impact (Alliance Development Works, 2012).

In order to take all these parameters into consideration the index consists of four different factors. The first one is exposure to natural hazards such as earthquakes, floods, storms and sea level rises. Susceptibility is the second one and is measured as a function of public infrastructure, housing conditions and the general economic framework. The third one is how well the country can cope with disasters, which is a function of governance, disaster preparedness, medical services and social and economic security. The last parameter is how well the country can adapt to future natural events and climate change. All these parameters are brought together to create the World Risk Index map that can be seen in Figure 8 below (Alliance Development Works, 2012).

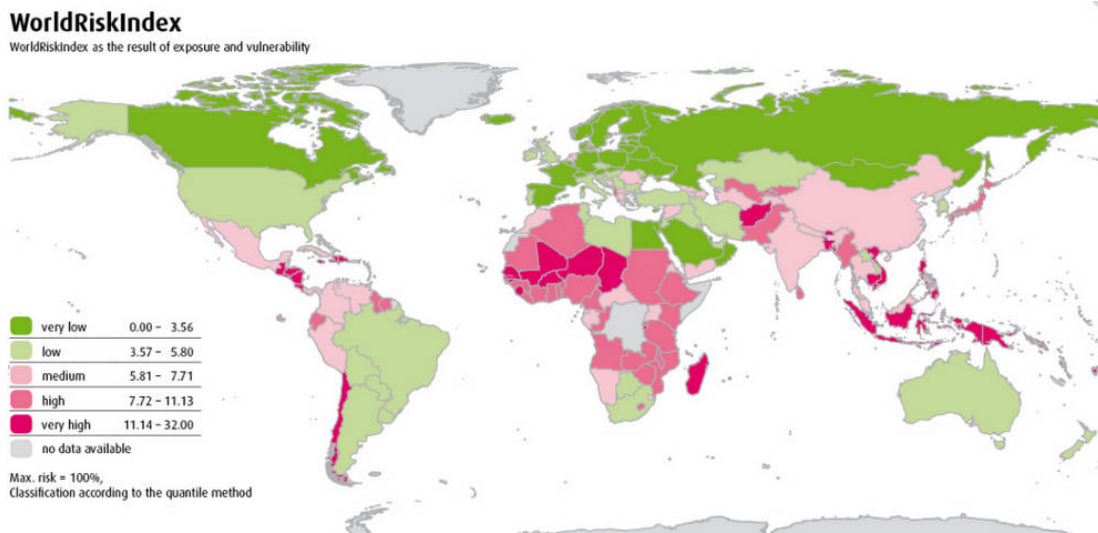


Figure 8: World Risk Index 2012 (Alliance Development Works, 2012)

3.3.2 Supply Chain Vulnerability

While risks are the factors leading to a supply chain disruption, they are not the only determinant of the final impact. The structure of the supply chain is of great importance when assessing how large impact a certain event will have (Wagner & Bode, 2006). Christopher (2011) defines supply chain vulnerability as “an exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain.”

Christopher (2011) also states that several trends during the last decades have made modern supply chains more vulnerable against disruptions. The trend of reducing the supplier base is one example of this. The intention is often to establish closer relationships with the remaining suppliers to create better opportunities for mutual product development and improved quality. Since each supplier will be responsible for greater volumes it will also often be possible to reduce the price. However, when a firm concentrates its sourcing activities to a smaller number of suppliers the possibility to switch to another supplier in case of disruption becomes limited (Wagner & Bode, 2006).

Another trend affecting the vulnerability is the increased globalization of supply chains. This includes both offshore sourcing and companies moving manufacturing and assembly plants to low cost countries. The motivation is usually cost reduction or to access competences that do not exist in the home market. However, the result is often a more vulnerable supply chain with extended lead times, greater buffer stocks and fluctuating exchange rates. The visibility and transparency is often poorer which leads to many hidden risks as well as longer reaction times if a disturbance occurs (Christopher, 2011) (Wagner & Bode, 2006).

The recent years' focus on efficiency in form of lean and just in time practices has also increased the vulnerability of many supply chains. Reduced safety buffers and an increased reliance on the suppliers to deliver on time often make the impact of a disruption more severe. Another popular way of making the supply chain more efficient is to use centralized production and focused factories. Economies of scale can be achieved in manufacturing by producing larger volumes in fewer sites. Focused factories mean that companies go from producing the full range of products at every site to focus their factories by producing fewer products exclusively at each site. As a result, the vulnerability will increase since a disruption at one single site will affect the whole supply chain. The products also have to be transported longer distances, which will increase the risk even more (Christopher, 2011).

3.3.3 Supply Chain Resilience

Another trend in today's market is higher levels of turbulence and volatility. The uncertain economic and political environment makes many supply chains exposed to unexpected shocks and disruptions. In order to cope with this uncertain environment the emphasis today should be upon resilience rather than cost minimization (Christopher, 2011).

Resilience is defined as the ability of the supply chain to cope with unexpected disturbances. To create a resilient supply chain it is important that all actors are aware of vulnerable parts of the chain. These critical parts can for example be where production is dependent on one single supplier, a bottleneck in a process or a supplier with long replenishment lead times. An important factor that can improve the resilience is access to information and visibility of upstream and downstream risk profiles (Christopher, 2011).

3.3.4 Balance between Price and Risk

Cost reduction has for a long time been the top priority for many purchasing organizations. Widely used strategies to achieve this have been global sourcing and reductions of the supplier base. As a result, small suppliers have faced declining margins, which in many cases has put them out of the market with only a few large and powerful companies left (van Weele, 2010).

These actions have in many cases created cost efficient supply chains when operating in a stable environment. However, when a disruption occurs these supply chains can suffer serious damages and cause huge costs to the companies involved. The increased vulnerability has to be incorporated when offers from different suppliers are compared. To make this possible the supply chains have to become more visible and transparent than before (Manuj & Mentzer, 2008).

With the increased focus on outsourcing, suppliers have also become an important source for innovation. Suppliers are often requested to contribute to a large part of the development of new products. Through this strategic long term relationships are created where both risks and revenues have to be shared (van Weele, 2010).

3.3.5 Mitigation Strategies

When developing models aiming to mitigate supply chain risks, a categorization of different risks can be useful. Trkman & McCormarck (2009) argues that the division into endogenous and exogenous risks is important because these types of risks require different mitigation approaches. Endogenous risks can be reduced by a proactive approach achieved through a proper relationship with the supplier. Characteristics of such a relationship can be information sharing, visibility, joint review and relationship development.

Exogenous risks on the other hand cannot in general be reduced. Instead a proactive approach has to be taken in order to minimize the effects of such event. Efficient actions to take are to create a resilient and quick responding chain. Harland, Brenchley, & Walker (2003) argues that firms are far more able to control and manage their supply chain efficiently when they are part of a stable network of actors. Some important actions to create this stability are:

- Design an appropriate supply network structure
- Choose the appropriate type of relationship with suppliers
- Develop and use adequate procedures for selection, evaluation and monitoring of suppliers
- Design and use a system for incentives, risk sharing practices and reward for suppliers
- Use tools to identify and control opportunistic behavior

One important aspect is that both risks and benefits are shared among the members of the network. It is preferred to create long term agreements to ensure commitment and sharing of sensitive information, knowledge and competences. (Harland, Brenchley, & Walker, 2003)

Harland, Brenchley, & Walker (2003) presents a process that helps to identify, assess and manage risks in the supply chain, see Figure 9.



Figure 9: Risk management process (Harland, Brenchley, & Walker, 2003)

The first step in the process is to map the network in order to illuminate the different kind of risks that can occur. This clarifies roles, responsibilities and ownership within the network. The next step is to identify the specific type of risks and where in the network they can occur. Only risks that could cause a severe potential loss for any actor in the network should be considered. After the risks are identified it is necessary to assess the likelihood of occurrence. An analysis of which part of the network that is exposed for the risk, potential triggers and losses needs to be done as well.

The risk management will take part in step 4 where the risk approach has to be determined. Depending on if the approach is reactive, defensive, prospective or analytical different network structures and relationship strategies should be developed. In step 5 and 6 the chosen network structure and relationship strategies are merged to a collaborative supply network risk strategy. This strategy is then implemented and then a new map is created which put the process back at step 1 again.

3.4 Summary of Theoretical Framework

The theoretical framework presents relevant concepts from the literature that will be used later in the analysis to answer the research questions. As explained earlier, the chapter starts broad by presenting general concepts to create an understanding of the importance of the subject. Later the framework narrows down to explain supply chain management and how this can be used to improve purchasing performance. The last section is even narrower and is about supply chain risks. The section below provides a brief summary of the most important findings in the theory chapter and how they are used later to answer the research questions.

3.4.1 Purchasing

The theoretical framework starts broad by describing purchasing in general. This section aims to explain why purchasing has a large impact on the entire company and how the general purchasing process looks like. This information is used when all the research questions are answered.

- The purchasing function has traditionally only covered the buying process where the goal was to find the best supplier for the current situation. Today purchasing is considered to be a more strategic function.
- In today's competitive landscape, purchasing and supply professionals have strategic, tactical and operational roles to play in organizations.
- Purchasing has become more important today since the cost for purchased goods and services represent a larger part of the total revenue. This means that purchasing enables a great potential for cost reduction.
- The general purchasing process consists of several activities that in most cases are very interrelated. The process consists of the following steps: define specification, supplier selection, contracting, ordering, expediting and evaluation.

3.4.2 Supply Chain Management

After describing the purchasing in general, the framework narrows down to explain supply chain management. In this section important concepts are presented that are mainly used to answer the first research question. The most important findings are the following:

- Companies are no longer competing as single entities but rather as supply chains. This is used to explain the importance of cooperation between the different actors in the supply chain in order to reduce the total risk exposure.
- A useful framework consisting of three parts; network structure, business processes and management components. The network structure consists of the members of the supply chain and the links between them. Business process means a change from managing functions to integrating activities into supply chain processes, while management components are the integration and management of each link in the supply chain.
- The network horizon is a concept used to describe a company's visibility of its supply chain and is defined as "how extended an actor's view of the network is". This concept is used in the first research question.

3.4.3 Supply Chain Risks

In this section the framework narrows down even more to different risks in the supply chain. The chapter starts with a general risk definition followed by a classification of risks. This is used when analyzing what kinds of risks Volvo considers today. The information in this section is also used to answer the second research question.

- A common definition of supply chain risks is the probability of occurrence times the impact. This definition will be used later when determining which risks Volvo focus on today.
- Risks can be divided into endogenous and exogenous risks. The exogenous risks can further be divided into continuous risks and discrete events. The focus in this thesis is on the discrete events.
- The structure of the supply chain is of great importance when assessing how large impact a certain event will have. Several trends during the last decades have changed the structure of the supply chains, which have made them more vulnerable.
- Cost reduction has for a long time been the top priority for many purchasing organizations which have created cost efficient supply chains when operating in stable environments. However, when a disruption occurs these supply chains can suffer serious damages and cause huge costs to the companies involved and therefore the increased vulnerability has to be incorporated when offers from different suppliers are compared.
- Exogenous risks cannot in general be reduced. Instead a proactive approach has to be taken in order to minimize the effects of such event. In this chapter a process that helps to identify, assess and manage risks in the supply chain is presented. This process is used when answering the third research question.

4. Empirical Findings

This chapter presents the empirical findings of the study. The chapter is independent from the theoretical framework and the findings will be used later in the analysis to answer the research questions. It starts with a description how purchasing and sourcing activities are performed at VPT. To be able to answer the last research question it is important to know how the sourcing process is performed today. The second part presents seven cases where supply shortage situations have occurred. This part is mainly used to explain why the subject is important but also to answer the second research question. The content of this chapter is mainly based on interviews and internal VPT documents.

4.1 Purchasing at Volvo Powertrain

Purchasing at VPT consist of a variety of different functions. However, it only covers the commercial part of the material supply process, while the different sites consuming the purchased material handle the physical flow. An important process handled by the purchasing department is to set a sourcing strategy. Critical parameters when setting a sourcing strategy for a new component are quality, delivery, cost and feature (QDCF). Quality is one of Volvo's three core values and it is therefore essential for all purchased components to meet the quality requirements. Delivery includes the logistics network that ensures deliveries at the right time and quantity. Since purchased components represent a large part of the value of the finished vehicle, this cost is very important to ensure a satisfying margin. Feature includes the technical specifications of the component, which is important for the performance of the vehicle.

When the strategy is set, the purchasing department also has the responsibility for selecting suppliers and signing contracts. The responsibility also includes managing the relationship with the supplier and to ensure and improve the quality of the components on a continuous basis.

Purchasing is seen as an important process at VPT and therefore the purchasing department has a strategic role. As seen in Figure 10, the value of the purchased goods equals 78% of the total turnover. This means that a cut in the purchasing expenditures will have a large impact on the financial result of the company.

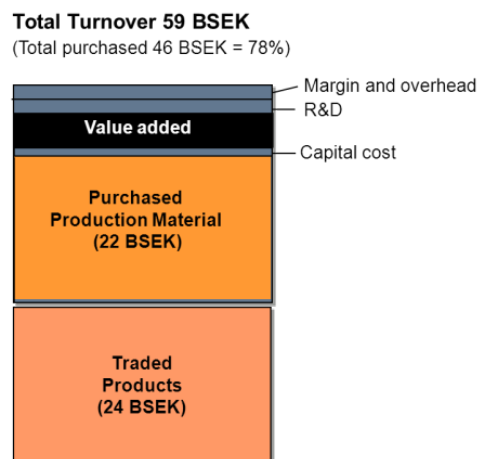


Figure 10: Purchasing spend in relation to total turnover at VPT

To make the purchasing more efficient a large reduction of the supplier base has been made during the recent years. As seen in Figure 11 the nine largest suppliers account for as much as 50% of the purchasing spend at VPT.

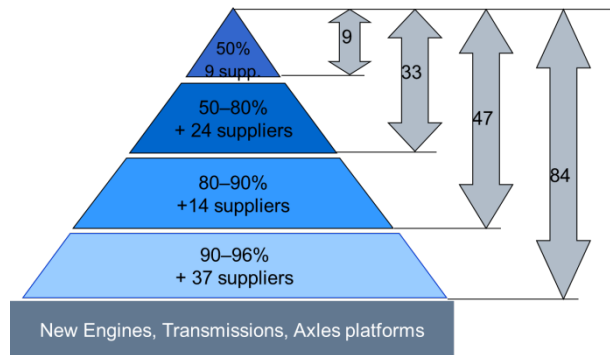


Figure 11: Allocation of purchasing spend to suppliers

The way of working has gone from having a transactional approach with many suppliers to a relationship approach where value can be created together with fewer suppliers. An example of this is when employees from both VPT and the supplier together develop components, which creates a higher value since competences at both companies are used. When using fewer suppliers higher volumes can be assigned to each supplier, which means that the price often can be reduced due to economies of scale.

The role of the purchaser in a business relationship has changed from being the only one that has contact with the supplier to the one being responsible for the relationship. As seen in Figure 12, other functions now have contact with their counterpart at the supplier. This can for example be product development, quality, aftermarket and the logistics department. The relationship approach is built upon information transparency where competences are shared in order to create a win-win situation.

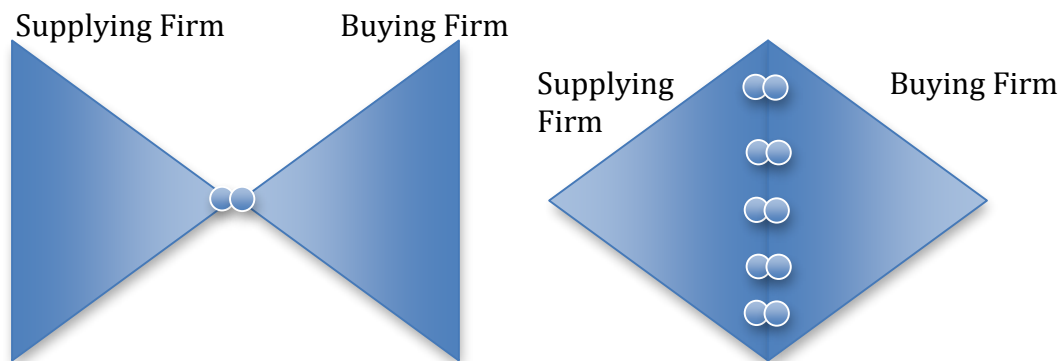


Figure 12: Interaction between supplying and buying firm

The purchasing function has a global approach, meaning that the purchaser buys the component to all Volvo sites in the world. Volvo also has a global supplier base with many large suppliers and sub suppliers located all over the world. The fact that Volvo in many cases uses large suppliers supplying all factories enables economies of scale and close relationships but also extensive and complex supply chains.

The global approach results in long lead-times for some components, which makes the supply chain less flexible. If a quality issue for a component is discovered, weeks of supply will already be on boats and can therefore not be changed. These aspects have to be taken into consideration when choosing a supplier in a country far away from the Volvo sites. To reduce this risk, suppliers far away need to have a warehouse near each Volvo site with at least four weeks of supply. The inventory can be used as safety stock for disruptions in the supply chain but will not solve the problem with inflexibility since it will tie up even more components.

To create a more flexible supply chain the location of the suppliers has got an increased importance at VPT. For some of the most critical components long distance suppliers are avoided in order to retain flexibility in the deliveries. However, one factor to consider is that some countries give tax reliefs if domestic sites add a certain part of the value of the vehicle. These so-called local content rules are common in many emerging markets where Volvo aims to grow in the future.

4.1.1 The Decision between Single and Multiple Sourcing

An important decision when defining a sourcing strategy is whether to use single or multiple sourcing of the component. In a risk perspective, it is preferable to get the component from several sources since the impact if one site becomes unable to supply will be lower. This can be achieved by choosing more than one supplier or by choosing a supplier with multiple sites.

The decision of which strategy to use often depends on a lot of factors and the departments at VPT often have different perspectives on the decision. Product development often wants to have one supplier to make it easier to have mutual product development. The quality department often prefers to purchase from one site since this will make the quality more consistent.

Within the purchasing department several parameters have to be taken into consideration. In some cases multiple sourcing is too expensive for VPT because too low volume to each supplier will result in a higher price. This is especially the case for components that require expensive machines to be produced. It then becomes too expensive to buy machines for several sites and the capacity utilization at each site will be too low. To overcome the problem with too small volumes VPT sometimes allocates 75-90% of the volume to one supplier while another supplier delivers the rest. This is an effective strategy since it is much easier to ramp up the volume than starting from zero with a completely new supplier. However, this strategy still requires multiple sets of tools and machinery and is therefore seen as too expensive for many components.

In some cases it is not possible to use multiple sourcing since there only exists one supplier having the competence and capacity to produce the article. These suppliers are often large global companies making it difficult for VPT to influence in which and in how many of their sites the components should be produced. The advantage with the large global suppliers is that they often have sites all over the world, which can reduce transportation costs when the sites are located at the same continents as Volvo's factories. In this case, sourcing from

multiple sites will not only reduce the risk, it will also reduce the transportation costs. Another case where sourcing from multiple sites is used is when local content rules exist.

A common opinion among the purchasers is that VPT in some cases is aware of the risks of using single sourcing, but that it is too expensive to do something about it. Demands from other departments like product development and quality are also in many cases considered more important than the risk aspect.

4.1.2 Volvo Powertrain Sourcing Process

VPT has a standardized sourcing process that is divided into eight steps. An overview of the process can be seen in Figure 13 below:

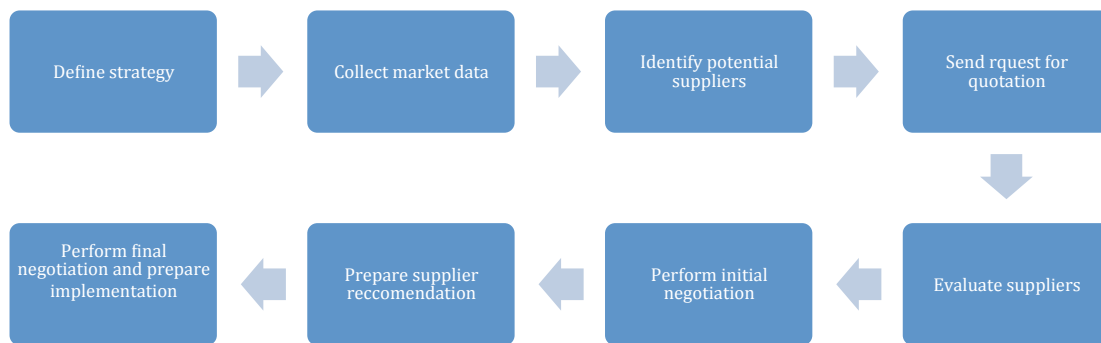


Figure 13: The sourcing process at VPT

The first step is to define the overall sourcing strategy. Inputs are general purchasing directions and strategies from different departments such as technology, manufacturing, logistics and aftermarket. The output is a list of current as well as new potential suppliers. In this step, an analysis of the technical evolution and the supplier market is conducted as well.

The next step is to collect market data. The information is mainly obtained through a RFI that is sent to relevant suppliers. However, before the RFI can be sent the suppliers need to sign confidentiality agreements. In the RFI there are questions about the company in general, ownership and financial status. There are also questions about product capabilities, current customers and competitors. Besides the RFI, information about potential suppliers is obtained from fairs, continuous dialogues with existing suppliers and through Internet.

To reduce the number of potential suppliers, the RFI answers as well as other information are evaluated. At this step of the sourcing process, the Supplier Evaluation Model (SEM) should be updated for all existing suppliers and a short version of the SEM should be completed for all new potential suppliers. The suppliers are ranked and a potential supplier list should be created and also be approved in the Global Sourcing Committee (GSC). This committee is cross-functional with representatives from purchasing, product development, logistics, quality and aftermarket. If the purchased part is considered strategic the potential supplier list must also be approved in the Panel Committee (PC), which is a similar committee but with more senior managers. Usually, there are about five to ten suppliers on the potential supplier list although the number varies from case to case.

When the list is approved, a RFQ is sent out to the remaining potential suppliers. In the RFQ VPT provides general information about the quotation, technical specifications, volumes, target costs and a time plan for the supplier selection process. The suppliers are supposed to provide contact information as well as a price and a cost breakdown. They are also requested to describe risks and opportunities that might impact the price, tooling costs or the time plan. In the RFQ package there are also some agreements that the suppliers have to sign and submit. There is a purchase agreement, warranty charter, price agreement and Electronic Data Interchange (EDI) agreement. The RFQ package also includes performance expectations for logistics, quality and aftermarket.

A problem when evaluating the RFQ answers is that some suppliers do not answer all questions. VPT asks the supplier in the RFQ for a price breakdown of the different parts of the component but this is often difficult to get. This is especially the case for large suppliers since VPT then has less power. Some suppliers consider this information confidential and are therefore not willing to share it. Another reason can be that the supplier early in the sourcing process has not yet chosen sub-suppliers and therefore do not have all the requested information. However, many suppliers already sell similar components to Volvo or other customers and therefore already have all the information about the supply chain that is needed for the new component.

The received quotes are compared using the QDCF criteria. The VPT employee responsible for the evaluation should check with representatives from quality, logistics and aftermarket to make sure that the suppliers' quotes fulfill all VPT requirements. At this step, a full SEM and a Review of Technical Specifications (RTS) should be conducted as well. The RTS means that the suppliers should check the feasibility of Volvo's proposal and also suggest changes of the drawings that might enable cost reductions or improved quality.

A common opinion at the purchasing department is that risks are not considered enough when the potential suppliers are evaluated. It seems that there is not any standardized process how to take risks into consideration, instead the risk aspect is handled differently from case to case depending on who is performing the evaluation. Another problem is that the different stakeholders at VPT consider different parameters to be important when making the selection. Product development wants to have local suppliers since it then is easier to develop the product together with them while purchasing usually wants the lowest price, often offered by a long distance supplier.

The quotes are evaluated and a short list including only a few suppliers is established. Negotiations are initiated with the aim of reaching the lowest possible cost. There are usually discussions about elements such as unit price, payment terms and delivery conditions.

When the negotiations are finished, the QDCF terms for all suppliers are compared. It is also common that the responsible purchaser asks other purchasers about their experiences since it is often the case that the potential supplier of the new component already delivers other parts to Volvo. The suppliers are ranked and the responsible VPT purchaser should present a preferred supplier to the GSC that needs to approve the selection. The strategic parts must

be approved in the PC as well. If the functionality of the component is considered very critical for the performance of the vehicle, VPT sometimes also selects the tier-2 suppliers to increase control.

The last step in the sourcing process is to perform a final negotiation and prepare for implementation. The necessary contracts should be signed, quality test should be carried out and orders should be created in the purchasing IT system.

4.1.3 Supplier Evaluation Model

SEM is a tool used to investigate if a potential supplier meets Volvo's requirements. The purpose is to assess which risks and consequences a certain supplier selection will have. It is a worldwide evaluation tool that Volvo uses everywhere independent of country and culture. The purpose is to have a standardized evaluation tool that can be understood everywhere by using the same criteria and grading guidelines.

The criteria that the potential suppliers are investigated upon are:

- Company profile
- Management
- Environment
- Quality
- Logistics
- Aftermarket
- Competence
- Product development
- Finance
- Productivity
- Sourcing

Each criterion consists of several sub criteria that are more specific. For each sub criterion there are some assessment guidelines telling how to grade a potential supplier. The grading scale is 0-3 and there are guidelines telling what the supplier has to achieve in order to get a certain grade. Some criteria are so called stopping parameters, which mean that the supplier cannot be chosen if any of them are rated zero.

When a long list of potential suppliers has been created a short SEM is sent out to the candidates together with the RFQ package. The short SEM is a self-assessment form, which the potential supplier is asked to fill in and send back to Volvo. The answers are then analyzed and graded according to the assessment guidelines.

Later in the sourcing process, when a short list of potential suppliers has been created, an ordinary SEM is performed. During this process, a SEM auditor together with some specialists from different Volvo departments visits the potential supplier's site where the component is going to be produced. The purpose of the visit is to get better information about the investigated areas than is possible with a self-assessment. During the visit some important aspects from the short SEM are investigated more in detail and there is also an inspection of the supplier's facilities. After the information is gathered the SEM auditor

grades the supplier according to the assessment guidelines for each criterion. A total score expressed in percentage is calculated making it possible to compare the result with other suppliers.

If the potential supplier gets below 60% of the max score or if a stopping parameter is graded zero, it cannot be selected. If the score is between 60-90% the supplier has to show a plan of how to improve the score if being selected.

A common opinion at the purchasing department is that SEM is used too late in the sourcing process to have enough impact on the supplier selection decision. To save resources a full SEM audit is often only carried out at the supplier that is considered to be the best choice. Only if that supplier fails in some important aspects in the assessment other suppliers are tested as well. This makes the SEM audit more of an approval of an already chosen supplier than a tool used to compare different candidates.

Other opinions at the purchasing department are that the SEM does not have enough focus on risks. The auditors are often specialized in quality issues, which makes that these parameters get higher priority during the audit. Another shortcoming is that the SEM is used to assess the supplier and not the specific components and its supply chains. Several suppliers deliver a wide range of components but the characteristics of each are not considered in the SEM. In addition, a complete SEM is only performed when selecting a new supplier. If an existing supplier is selected only an update of the SEM is performed.

In the management criterion of the SEM there is a sub criterion about risk management. The SEM team investigates if the supplier has a risk mitigation strategy and an assigned risk manager. They also check if the company does regular risk analyses of its own business. Areas that are investigated are for instance protection against fire, flooding, earthquakes and computer system breakdown. The SEM team also investigates if the supplier has a backup plan in case of unforeseen events, such as back up factories or cooperation with another company that can produce the same product. Extra points are given if the risk management also includes sub suppliers.

Another parameter that is investigated is the supplier's sourcing process. The analyzed areas are supplier evaluation, supplier selection and supplier switching process. To get a high grade the supplier needs to have a systematic sourcing process that is well documented. An important part is if the sub suppliers are certified regarding quality, environment and social responsibility.

4.1.4 Other Self-Assessment Forms

The procedure of using an initial self-assessment form that is later followed up is used for other areas as well. A form that is used by Volvo is the Material Management Operations Guidelines – Logistics Evaluation (MMOG/LE) created by the international automotive organization Odette. The form provides an international standard how to evaluate an organization's logistics processes. Volvo uses the document in the sourcing process to grade the potential suppliers' logistics processes. The form aims to have a supply chain approach but is mainly focusing on the tier-1 supplier.

To ensure that the suppliers follow the Volvo Group's code of conduct self-assessments regarding corporate social responsibility and environmental responsibility are sent to the suppliers as well. Volvo checks if they follow the social and environmental standards but also if they have ISO certificates. The suppliers should fill in the assessment and send it back to Volvo but they are also asked to be prepared to show documentations or other evidence since Volvo will do follow up audits to confirm the answers.

4.1.5 Mapping of Supply Chains

Supply chain mapping can be a powerful tool to get an overview of the structure of a supply chain. Mapping can be performed in many different ways and include several different parameters. A simple map can only show the actors in the chain, while more advance models include geographical location, number of sites, how much value that is added in each step etc.

An important feature of the mapping tool is that it can be used to find critical paths in the supply chain. This can for example be single manufacturing points for critical components, a raw material that can only be bought from one source, bottleneck machines etc. When these critical paths are found, they can be monitored closely and resources can be spend to make them more robust. Figure 14, made by Odette shows how an organization can identify critical paths by using supply chain mapping.

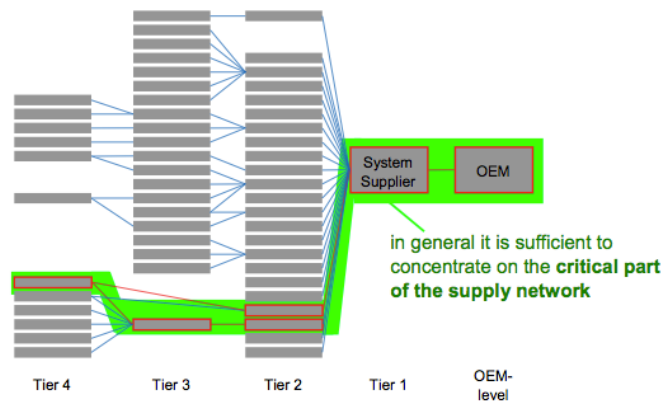


Figure 14: Map showing critical part of a supply chain

Volvo has mapped the internal flow of material between the different sites. At the purchasing department an ongoing project is to map the supply chains of the components with the highest spend. However, this is an attempt to make a cost break down of the different components rather than to find the critical paths in the supply chain.

Several employees have mentioned that a map of the supply chain would be a good tool for them to identify risks in supply chains. Today VPT often does not have an overview of the structure beyond the first tier supplier and this makes it difficult to identify weak links. Some employees have mentioned that it would be good to have a map that visually shows the structure and geographical location of the actors in the supply chain to mitigate this problem.

There exist different software tools to make this geographical visualization. One example is Sourcemap, which is a tool that gives a clear picture of the geographical location of the different actors in the supply chain and the links between them.

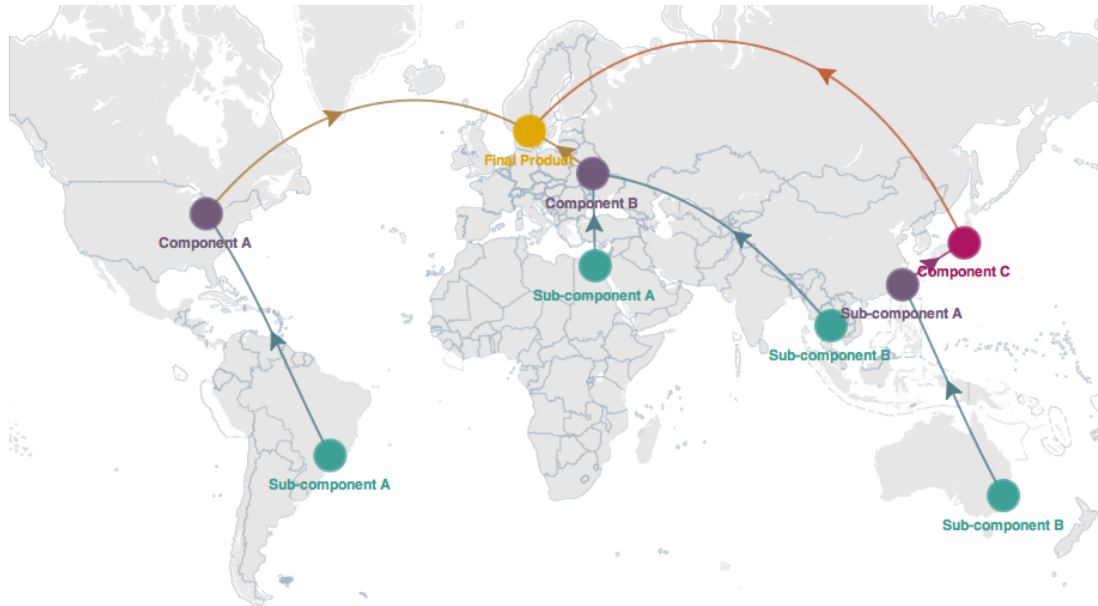


Figure 15: Geographical map of a supply chain. (Sourcemap Inc., 2012)

4.2 Cases of Supply Chain Disruptions

In the following section some examples of supply chain disruptions caused by some different factors are presented. Most of the cases have affected Volvo but the last one is from another industry and aims to show potential consequences of a supply chain disruption. Due to confidentiality reasons the involved suppliers are made anonymous.

4.2.1 Flooding in Thailand

During the second half of 2011, Thailand was hit by its worst flooding in 50 years. Heavy and widespread rainfall caused by monsoon storms hit the central part of the country, including Bangkok and parts of the neighboring provinces. Since this area is a cluster for production sites and businesses, the flooding had a huge impact on the economy. The GDP growth forecast had to be revised downward from 2,6 % to 1 % even though the flooding was concentrated to a limited area of the country (Setboonsarng, 2011).

The reason why so many industries are concentrated to this river valley area, which is sensitive to flooding, is the closeness to Bangkok and thereby access to capital, suppliers and customers. The industry sectors that suffered most were automotive, electronics, electrical appliances and optical instruments. (Chongvilaivan, 2012) Thailand is important for the global automotive supply chains and some of the automotive manufacturers that were hit most severely were Honda, Toyota, Nissan and Ford (Setboonsarng, 2011).



Figure 16: Map showing the affected area

VPT was also affected by the flooding. One of its suppliers, Supplier A, contacted VPT in the middle of November and informed that the company was facing disturbances in its supply chain. One of its suppliers of printed circuit boards, Supplier B, was unable to supply from the factory located in affected area and therefore all VPT's components coming from Supplier A were affected. The other factories had limited capacity and were not equipped with the same technology meaning that it was not possible to move production to these sites. The supply chain that was affected by the flooding can be described as:



Figure 17: Supply chain affected by the flooding

The recovery time for the flooded factory could not be determined at this early stage but Supplier B estimated that the production could start in January 2012 as earliest. Supplier A created a crisis team with the objective to secure supply to VPT and other customers. The crisis work started with an initial meeting with employees from VPT representing purchasing, production, capacity planning and the legal department. During the meeting representatives from Supplier A informed about the crisis and presented current stock levels as well as a recovery plan. There were weekly meeting throughout the crisis where this information was updated. Before every meeting a FAQ with relevant questions and answers was created. This

was a success since employees from several departments could access relevant information and obtain a clearer picture of the situation.

Initially, it was not known how long it would take until VPT would run out of components and therefore the first step for VPT was to investigate this. All inventory levels throughout the supply chain were calculated. The situation at Supplier B was very severe but as it improved, more components at the flooded site could be secured. Since the components from Thailand were transported by sea there was also some stock in transit. Once the inventory levels were determined, they were together with the forecast used to calculate the time to shortage for all article numbers.

Supplier A had no second approved source for the components produced in the flooded factory. Two other suppliers were approached but none of them could meet the requirements so instead a third supplier located in China was contacted. This was an existing supplier to Supplier A and production at one of its sites would incur minimal product modifications even though some modifications were unavoidable. This temporary solution was expected to be used for at least six months and then the components should be moved to Supplier B's plant in Thailand again. However, the period could be extended depending on the situation in Thailand.

Supplier A needed VPT's approval to source from this new factory. Supplier A required VPT to absorb premium costs such as a higher unit price as well as extra costs for transportation and for Supplier A's validation of the parts from the new factory. To avoid supply shortage, the production might need to start before all tests could be carried out. In this case, Supplier A should not be responsible for quality and warranty issues until full validation was complete. The last requirement was that Supplier A could not accept commercial responsibility for any delivery disruption since the company considered this situation to be out of its control and thereby a force majeure case.

VPT responded that the company would support Supplier A in the process of switching supplier but that VPT would not pay the extra costs since this was Supplier A's responsibility. It might be a force majeure case between Supplier A and supplier B but VPT cannot control which suppliers Supplier A selects and was not even aware of that Supplier A used single sourcing for this critical component. Generally, VPT has strict requirements about the functionality and quality of purchased components but not as strict requirements regarding the suppliers' sourcing activities.

After some discussions, VPT agreed to share the validation risk. The most important validation was already done with good results and VPT wanted to start the production at the new site before the validation was complete in order to avoid stop in Volvo's production. After extensive discussions the companies finally agreed that this was not a force majeure case between VPT and Supplier A and hence VPT did not pay the requested amount.

All the affected components have now been moved back to Supplier B's plant in Thailand. Before this could be done it was necessary to perform extensive quality tests of the factory. Even though all components are produced in this factory today, Supplier A has the temporary factory as a backup and hence the risk in the supply chain has been reduced.

4.2.2 Japan Tsunami

In March 2011 Japan was hit by one of the largest earthquakes since modern record keeping began. The earthquake triggered powerful tsunami waves that travelled up to 10 km inland, causing heavy damage to buildings and roads. The earthquake also caused a meltdown at the Fukushima nuclear power plant, which forced the government to evacuate all citizens within a 20 km radius.

The Japanese automotive manufacturers are mainly located in the south parts of the country and were not directly affected since the earthquake and tsunami occurred in the northern parts. Instead there were mainly sub suppliers up to tier 6 that became affected. As many as two thirds of Japans engine and transmission manufacturers had to stop their production, which created large problems for many automotive companies. The Japanese automakers, such as Toyota and Honda, were hit hardest, but also North American and European manufacturers were affected.

Volvo's factory in Ageo, Japan was located in the affected area and got some damages to the buildings. The production had to stop, but after inspections it could start again just three days after the earthquake. Parts of the infrastructure around the factory were heavily damaged, which made it difficult for some operators to commute to their work at the factory. This created some additional disturbances in the production during the first weeks after the disaster.

However, the largest problem for the production was that some of Volvo's suppliers had been so heavily damaged that they could not continue their production for several weeks and sometimes even months. This was not only affecting the plant in Japan, all Volvo factories worldwide had some Japanese suppliers and were therefore facing the risk of supply shortage. To avoid this, crisis teams were created at the different business units within Volvo Group.

Their first task was to identify which first tier suppliers that were affected and if there would be any disturbances in their supply to Volvo. A more difficult task was to identify the suppliers further up in the chains that were affected. Since that information had to travel through the entire supply chain before it reached Volvo, it took about two weeks until all affected suppliers and sub-suppliers were identified. The segments that were affected hardest were after treatment for engines, electronics and pigments to some metallic colors. Volvo got a lot of help with collecting information from suppliers, competing automotive companies and from the Japanese Automotive Manufacturing Association (JAMA). According to the leader for the crisis team all actors worked together in order to solve the situation, regardless if they were competitors or not.

Since Volvo had long supply chains for most of the affected components, with long transports and safety stocks, the inventory was enough to supply the factories for some weeks. In the meantime, many of the suppliers were trying to rebuild their factories or move the production to other buildings that had not been damaged. It was common that companies offered a competitor with a damaged factory to move production into their own buildings to help the competitor to continue with their operations. Japan has an export

driven economy and the fear of losing production to other countries also made many companies to recover fast.

The crisis teams at Volvo identified the critical components and ranked them according to time to shortage. For the most critical components it was important to investigate the need in all the factories and business units within Volvo. To avoid sub optimization and cannibalization between the business units, one team leader had responsibility for all crisis teams. He, together with top management, made the decisions to which factories the most critical components should be shipped in order to minimize the damage for the entire Volvo Group. The crisis teams' hard work paid off since the Ageo factory was the only one that had to stop production due to component shortage, and this only lasted for a few days.

According to the leader for the crisis team the main reason that the impact on Volvo became limited was the attitude among the Japanese people to work together to get a fast recover. An example was that factories that were estimated to take six month to rebuild were up and running after just a few weeks. The fact that competitors worked together and that the Japanese government provided a lot of support enabled this fast recovery. To solve the power problem, the people helped to save electricity by turning off their air conditions and some even worked during the weekends in order to help the industry to smooth out energy peaks during the weekdays.

Since Japan is a country that is used to earthquakes, the citizens and the government were prepared and knew what they had to do in order to rebuild the country again. If this situation would occur in another country, the recovery would probably not be that fast and Volvo would be much more affected. According to the crisis team leader it is therefore important to be prepared for incidents like this, even if the cost was limited for Volvo this time.

4.2.3 Explosion at a Factory Producing Material for Plastic Production

In March 2012 a fire broke out at a plant located in Germany. The factory produced a material used for plastic production. Two employees died in the fire and there were severe damages on the facilities (Evonik Industries, 2012).

The affected company is one of the largest producers of this plastic material, which is used in fuel handling and brake systems in the automotive industry. Other applications of the material can be found in the solar cell industry, in offshore pipelines, sporting goods and household goods (Evonik Industries, 2012).

Since the automotive industry has worked a lot to reduce inventories in the supply chains, this disaster had severe consequences. Executives from some of the largest automotive companies met shortly after the fire to discuss the shortage situation and to try to find possible alternatives. One problem for the automotive companies was that some other industries, especially the solar cell industry, were able to pay more in order to get prioritized since they have much higher margins.

A factor making the situation even more complex is that the industry the affected company operates in can be characterized as an oligopoly with only two other competitors, which

both also bought material from Supplier A. After the fire, Supplier A lost about 80% of its capacity and the two competitors about 20% since the material they bought from the exploded factory no longer was available. This complicated situation can be seen in Figure 18.

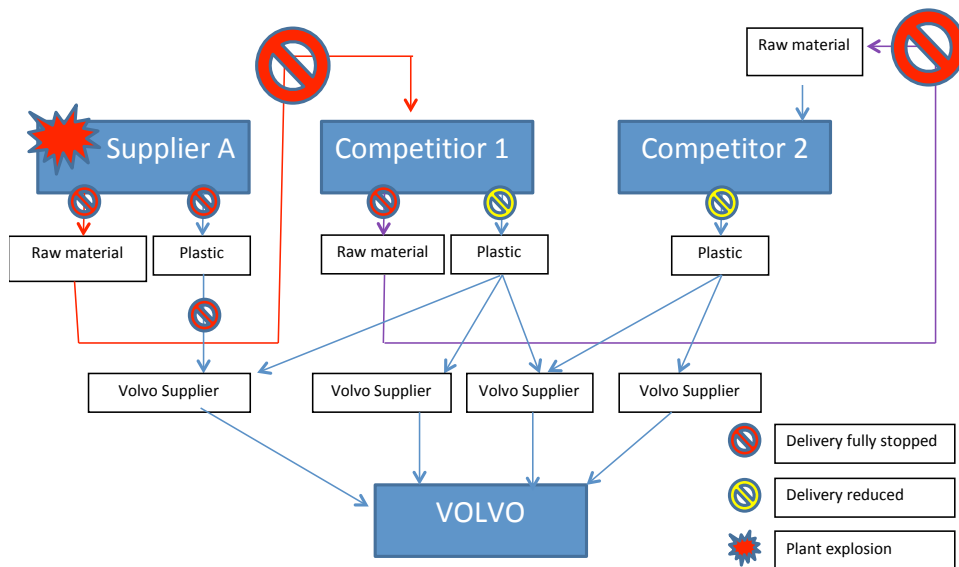


Figure 18: Map of the complex material flow

When Volvo became aware of the disaster, the company created a project team that was supposed to handle the shortage crisis. The team’s main objectives were to secure supply and to avoid stop in Volvo’s production system. As a first step it was necessary to find out which of Volvo’s components that included the plastic material and to obtain a clear picture of the affected supply chains. A typical supply chain that was affected by the disaster can be seen in the figure below:



Figure 19: General supply chain affected by the explosion

The materials included in the purchased components were not fully documented so in order to obtain this information it was necessary to have a dialogue with the suppliers. Some components including the material were very difficult to identify since even some suppliers did not know the exact content of their products.

Volvo had some previous experience of shortage for this material since the company faced capacity shortage for the material during 2010 when there was a fast ramp up after the financial crisis. When facing these capacity problems Volvo analyzed the supplier market and investigated the possibility to switch material for some components. In the end, the

suppliers were able to manage the ramp up without having to switch material but Volvo gained valuable knowledge about the market and alternative materials.

The project leader for the previous shortage situation now helped the new project leader in the beginning of the crisis. In addition, the project team was more or less the same as last time, which helped Volvo in the beginning of the crisis. The team was cross-functional and consisted of about 10 employees from different departments that worked very close together.

Since the fire hit a company far up in the supply chain, there was some available material throughout the supply chain and it would take at least one month before Volvo would run out of material. However, the situation was still very severe. The prioritization of the purchased components was based on the time to shortage, meaning that the components that would run out of stock first were considered the most critical and therefore got the highest priority. The purchasers had daily contact with the affected suppliers, which helped the crisis team to monitor stock levels and find all components that included the plastic material.

Since most companies within the automotive industry have the same supply chains the available amount of the material quickly ran out and it was of great importance for Volvo to ensure delivery of as much as possible. To do this, Volvo had a continuous dialogue with the affected supplier even though it was located further upstream in the supply chain. Since the companies had a good relationship already before the fire, Volvo was allocated a large proportion of the available material compared to its competitors. Volvo also contacted competitors to the affected supplier to further increase the delivery.

Besides trying to receive more material, Volvo investigated the possibility to switch material for some of the affected components. Volvo identified a material with similar characteristics as the affected one but before changing it was necessary to make extensive tests to ensure the quality of the new material. It was also important to make a thorough prioritization of which components it was appropriate to switch raw material for. Volvo avoided switching material for components impacting the safety performance of the vehicle like pipes for the fuel, brakes etc. Instead, Volvo switched material mainly for pipes at the chassis. One problem with the new material was that it was stiffer than the old one. This led to longer cycle times in the production since the new material was more difficult for the operators to work with.

During the analysis of switching material, it was necessary to balance the requirements from the product development department and the purchasers. The employees at product development had very strict requirements regarding the characteristics of the material while the purchasers were more focused on commercial factors and keeping the same suppliers.

Car manufacturers were not facing the same strict requirements as the manufacturers of commercial vehicles and companies within this business changed material for several components. The fact that Volvo changed material for some components and that car manufacturers changed material as well enabled more material for Volvo's most critical components.

During the crisis, Volvo managed to avoid stop in the production. The recovery of the plant was finished in the end of November 2012 and after that there was a three month ramp up time. When the factory will produce on full speed, Volvo plans to switch back to the old material for some components but keep the new for others.

4.2.4 Fire at a Supplier's Plant in Poland

In August 2008 a fire broke out in a supplier's manufacturing facility in Poland. The fire started in the attached warehouse, but spread fast to the manufacturing line as well. A full shift of workers was operating the line but all of them were evacuated to safety and no person became injured. However, less than an hour after the fire started, parts of the building's roof collapsed.

The company was both a first and second tier supplier to Volvo. Volvo quickly got information about the fire directly from the supplier. The first action was to put together a crisis team that could handle the situation. Its main task was to secure deliveries of the affected parts in order to avoid a stop in the production.

To get a better picture of the situation, Volvo sent a team to the damaged factory. However, the collapsed roof made it very dangerous to be inside the building and in the beginning no one was allowed to go inside to inspect the damages. Because of this, it was very difficult for the team from Volvo to get an overview of the damages and an estimation how long it would take before the production could continue. However, they could see that the building had severe damages and that it probably would take a long time before production could start again.

To secure deliveries Volvo started to analyze the possibility to get supply from other alternatives. A supplier in Brazil that was supplying Volvo's factory in Curitiba with the same components became an interesting alternative. All the capacity at this supplier's factory was already occupied, but after some negotiations the company agreed to introduce another shift in order to increase the output. These additional components were transported by air to Europe, but it was far from enough to avoid a stop in Volvo's manufacturing.

The supplier hit by the fire succeeded to save some finished components from the factory and warehouse in Poland. The Volvo team worked hard to get prioritized to buy these stocked components and the team partly succeeded. The supplier also worked hard to solve the situation and the production was moved to another factory they owned in Germany. A factor that facilitated this move was that there were unused machines and tools in the German factory, since the production of these components had been carried out there before. The crisis team at Volvo had daily meetings with the supplier and stated that Volvo would not accept any compromising regarding the quality.

The logistics department at Volvo had a key role in the crisis since it allocated the available output to the different Volvo sites. The department monitored inventory levels at the affected supplier, the airfreight deliveries from Brazil and the deliveries from the factory in Germany. All available output was distributed to the Volvo factories that needed the components for the moment. Thanks to this work Volvo avoided production stop in all

factories. Eight months after the fire the manufacturing facility and the warehouse were rebuilt and the production could be moved back to Poland.

Key learning's from this crisis was that it is very important to fast send a team to the incident area. Even though the team members cannot do so much to solve the situation at the site they show that they take the situation seriously. It is also possible to create a better relationship and make sure that Volvo gets prioritized.

4.2.5 Major Machine Breakdown at a Supplier

In March 2011 the plant manager at a supplier called VPT and told that there had been an accident when a critical tool had become too warm due to the high pace in the production. This tool is unique and expensive and there only exists two of this size in the world. Before the production could continue it was necessary to stop the production for three weeks in order to carry out maintenance activities. This stop would not affect Volvo's production since there were enough parts in stock to cover the demand during the period.

However, the plant manager also said that it would be necessary to have a six weeks stop for maintenance during the summer. Volvo would close down its own production for four weeks but the last two weeks would be very problematic since there was no stock left and it would not be possible to build up new buffers until then.

VPT created a crisis team to handle the situation. The issue escalated in the hierarchy all the way up to the manager of VPT. He contacted the owner of the supplier to obtain necessary information and make sure VPT was a prioritized customer. A group of VPT employees also visited the factory to get a better picture of the situation and further make sure that VPT would be prioritized.

The crisis team also carried out a thorough analysis of which article numbers that should be prioritized. The manufacturing of some axels could be moved to the supplier's site in India and some were moved to another supplier located in the Czech Republic. Thanks to these actions VPT managed to avoid stop in the production. However, the deliveries from India had to be made by flight, which meant significantly higher costs.

After the incident, VPT created a new strategy for the affected components, which meant that some article numbers were moved from the affected supplier to one in Germany. The affected supplier lost a significant part of its volume since several of its customers moved parts of their purchased articles to other suppliers. The lost volume has made that the company now faces problems with its profitability. If the supplier will go bankrupt, the costs for VPT would be large and therefore one alternative would have been to keep the entire volume and use the tool in Germany as backup.

VPT was aware of this vulnerable element in the supply chain before this crisis but did not want to use multiple sourcing since this option would incur higher costs. Another contributing factor to the decision was that the German supplier does not use exactly the same steel. Since VPT's production in Skövde is adapted to the steel from the affected supplier, the other type of steel incurs longer cycle times and more wear on the tools.

4.2.6 Changed Management at an Asian Supplier

In the spring of 2012 one Asian company supplying vital components to Volvo and other automotive manufacturers suddenly changed its CEO and rest of its top management. Most of the key employees changed positions and therefore lack knowledge about the area they now are responsible for. In addition, knowledge has been lost since several employees have left the company.

After this large reorganization the supplier has changed approach of doing business. Parts of what Volvo and the supplier have agreed on before are no longer valid. The communication does not work and Volvo gets no information about deliveries through EDI anymore but instead the company has to call the supplier in order to obtain this information. Employees at Volvo have visited the supplier but have only received limited response. The fact that the company is located far from Europe in a country with a different culture has made the communication even more difficult. The relationship has gone from being successful to a relationship characterized by risk and uncertainty.

In this unstable situation, the supplier has increased quality inspections of the components, which have led to longer lead times and reduced output. The shortage of components has made it necessary for Volvo to use deliveries by air in order to avoid stop in the production. The uncertainty creates a risk that there will be stop in the production if the relationship is not improved. To handle the crisis, Volvo has created a crisis team led by the purchaser responsible for this supplier. The case is still ongoing and therefore the outcome is not known yet.

4.2.7 Fire at a Supplier Delivering to Nokia and Ericsson

In late afternoon in March 2000 a lightning bolt hit a major power line in New Mexico USA, causing power fluctuation throughout the entire state. At Philips' chip manufacturing site, located in Albuquerque New Mexico, the power fluctuation made some cooling fans to stop. This resulted in a small fire at one manufacturing line inside the production facility. From a factory perspective, the fire was small and the operators quickly managed to put the fire out before the fire brigade arrived. However, the fire occurred in one of the factory's "clean rooms", where sensitive chips were manufactured and no dust or other particles are tolerated. The smoke together with water from the sprinkler system destroyed many of the tools and made them unusable (Norrman & Jansson, 2004).

The largest customers to the affected plant were Nokia and Ericsson who together bought over 40% of the produced chips. These two telecom companies both bought radio-frequency chips to use in their mobile phones. The chip is an essential part of a phone and due to the complex manufacturing method, only a few companies in the world were able to produce it (Latour, 2001).

Both Nokia and Ericsson got noticed first three days after the fire had occurred. The first reports from Philips said that the damage was small and that the production would be up and running within a week and hence that there was no reason to be worried for supply shortage. Even though both companies got noticed at the same time, the actions taken to minimize the damages were very different (Latour, 2001).

Employees at Nokia found out that something was wrong already a few days after the fire. The orders in the system were not confirmed as they used to be. Nokia contacted Philips officials, who admitted that the accident was more serious than what had been communicated earlier. Nokia put the components that came from the Albuquerque plant on a special monitor list and created a crisis team that had daily contact with Philips (Latour, 2001).

Through the contacts Nokia got information that it now would take several weeks to start production again and months of chip supply would be affected. Top executives at Nokia now started to work with the situation and try to find alternative supply. Of the five components bought from the affected factory, two were crucial for the production and could not be replaced. For one of these, Nokia had several other suppliers with available capacity. However, for the remaining one it was much harder to find alternative suppliers. The executives at Nokia realized that this was a very serious problem that could cause stop in the production of mobile phones and they therefore made this to a top priority task for the entire company (Latour, 2001).

Top management at Nokia went to Philips' headquarter in Amsterdam to meet with the CEO and his team. Nokia claimed that the company was the biggest customer and required to buy all chips in stock. They also demanded to see detailed information about capacity at other Philips plants to see if it was possible to move production. They pushed Philips really hard to reroute capacity to other plants and sell these chips to Nokia. The work gave result when Philip managed to move production to one plant in Eindhoven, Holland, and to one in Shanghai, China. These chips were made exclusively to Nokia (Latour, 2001).

Nokia had two other suppliers of the chip, one in Japan and one in USA, which were punched hard to double their production. Another solution Nokia was working with was to redesign some of its chips so that they could be produced somewhere else (Latour, 2001).

At Ericsson on the other hand, things were not moving as quickly. The company got information at the same time as Nokia but it was more of one technician talking to another and no formal information reached top management. The first reports from Philips said that it only was a minor fire and therefore the information was not taken seriously. When the updated information from Philips explaining the severity of the incident finally arrived, it took some additional time before the information went from the middle managers further up in the organization. This was partly because Ericsson lacked a strategy how to deal with this kind of situations, which made the middle managers unsure what they should do with the received information (Norrman & Jansson, 2004).

By the time top management became aware of the incident, several weeks had passed. Philips informed that the company was not able to produce enough chips to meet the orders. Ericsson tried to quickly find other ways to get supply but the alternatives were few. In the mid-1990s, Ericsson introduced a strategy aiming to save money by reducing the supplier base. Because of this, the company now only had Philips as supplier for this essential kind of chips. Ericsson tried to find capacity in other Philips factories but Nokia and other competitors had already bought everything (Norrman & Jansson, 2004).

In the annual report the year after, Ericsson stated that due to component shortage, the wrong product mix and marketing problems the company was unable to produce seven million handsets demanded from the market during the year. By the time, mobile phone sales were booming around the world and Ericsson was just on its way to introduce a new key product. The timing of the production stop was really bad and it is estimated that Ericsson lost \$400 million in potential revenue (Latour, 2001).

Ericsson’s market share went down to 9% from 12% the year before. Nokia took advantage of Ericsson’s problems and took the market share that Ericsson lost. This accident also had a significant impact on Ericsson’s decision to withdraw from the mobile phone business one year later (Norrman & Jansson, 2004).

4.2.8 Summary of the Cases

The presented cases show that several different unforeseen events can affect several actors in the supply chain. However, there are several actions that can be taken to mitigate the impact of the event, both before it happens but also after. Table 3 below summarizes the actions taken to mitigate the impact of the investigated situations.

Case	Action used
Flooding in Thailand	Switch supplier
Japan Tsunami	Collaboration between involved actors (companies government citizens)
Factory producing material for plastic production	Relationship with the affected actor, switch material
Fire at a supplier in Poland	Switch factory
Major machine breakdown at a supplier	Backup factory, backup supplier
Asian Supplier	Not Known
Ericsson Nokia	Nokia used other suppliers and factories. Relationships. Contingency plan

Table 3 Actions taken to solve the cases

Most of the used mitigation strategies can be specified and implemented already before an incident occurs. These predetermined actions can together with the riskiness of the supply chain be considered already during the sourcing phase where it would be possible to not select suppliers with a too risky supply chain. It is then also possible to identify risky elements in the specific supply chain to be able to quickly react if something happens later on in the ongoing operations.

5. Analysis

This chapter analyzes the empirical findings with input from the theoretical framework. The analysis is structured according to the three research questions with one section for each question.

5.1 Why is it Important to Extend the Network Horizon beyond the First Tier Suppliers?

When developing a model incorporating supply chain risks in the sourcing process it is important to first analyze and extend the network horizon. There are several reasons for companies to extend their network horizon and they will be analyzed in this section.

5.1.1 Increased Importance of Purchasing

In the literature review it is stated that purchasing has become more important in today's competitive environment and should be assigned a strategic role within organizations. Van Weele (2010) divides purchasing activities into three different categories; strategic, tactical and operational. This is very much in line with how purchasing activities are carried out at VPT. The buyers perform strategic activities such as identifying key suppliers and developing differentiated supplier strategies. On the tactical level they work to strengthen the relationship and facilitate continuous improvement of supplier performance. Operational activities such as order placement and delivery assurance are not performed by the buyers but instead by employees at the different Volvo plants.

At VPT, purchasing costs represent as much as 78% of the value of the final product and thereby purchasing has a substantial impact on the company's financial result. The fact that the purchased components represent a large part of the vehicle also means that it is essential to have close and long term relationships with the largest and most important suppliers. There must be a close cooperation in order to secure an innovative and competitive product.

As the technical complexity of commercial vehicles increases and the product life cycle becomes shorter it is impossible for Volvo to have all the required competence in-house. Instead, it is necessary to have close relationships with specialist suppliers to take advantage of their competence as well. Sometimes Volvo chooses to develop new components together with the supplier in order to use both companies' competences. Since development of new complex components takes long time and require heavy investments a long-term approach characterized by collaboration is needed.

When a larger part of the vehicle is made by the suppliers, purchasing activities become more important to secure Volvo's three core values; safety, quality and environmental performance. Since Volvo promises its customers to fulfill these values it is necessary to ensure that all purchased material and the suppliers' manufacturing processes fulfill them as well.

5.1.2 Supply Chain Management to get Efficient Purchasing

In order to perform efficient and successful purchasing activities it is necessary to adopt a SCM approach. In the literature review Christopher (2011) stresses that the competition

today is no longer between firms but instead between different supply chains. Transferring costs between actors in the supply chain will not make the companies more competitive since the costs still will be incorporated in the price paid by the consumer. Hence, all companies must cooperate to be able to deliver competitive products to the consumers.

The companies in the supply chain can compete about the allocation of the total profit generated by the chain but this will hurt the relationships and the cooperation between them. In addition, if a company pushes its suppliers to reduce their margins they might experience financial stress and in long term some of them might be forced out of business. If an important supplier goes bankrupt this creates large turbulence in the supply chain and all actors will be hurt.

In the literature review Christopher (2011) states that it is necessary for a company to integrate its network of relationships to be successful with its SCM. VPT has a good integration with the most important suppliers since the company has close relationships with these partners. VPT usually has joint product development and work with them to improve efficiency of the performed activities. The relationships are also cross functional with links between different departments of the companies such as purchasing, product development, quality, logistics and aftermarket. The importance of cross functionality between departments at different companies is stressed by van Weele (2010) in order to reach a shorter time to market when developing new products.

5.1.3 Extension of Network Horizon

Even though VPT has a good integration with its first tier suppliers, the company must also strive towards a better integration with actors beyond the first tier in order to improve its SCM. This is not easy since the supply chains usually are extensive and consists of several actors and tiers. However, an extension of the network horizon is important to achieve a better collaboration but also to increase the transparency of the network and to identify vulnerable parts.

The work with extending the network horizon becomes more important since today's environment is characterized by increased outsourcing and a higher degree of globalization. The increased outsourcing means that every actor in the supply chains is responsible for a smaller part of the total work and therefore the supply chains include more tiers, or in other words become longer.

Globalization makes it more difficult for companies to work with SCM and to extend their network horizon. It becomes harder to have close relationships with suppliers and sub-suppliers when they are located all over the world. The large geographical spread makes the communication more difficult due to cultural differences, different languages and time differences. If the companies had been located closer to each other it would be much easier to obtain a better visibility without having to put in the same effort.

VPT is clearly affected by the trend of outsourcing and globalization. The company allocates a larger part of the work to suppliers located all over the world. The purchasing department works with a global approach where the buyers are responsible for the purchasing of the same component to all Volvo sites in the world.

Even though VPT works like this and has established close relationships with many of the suppliers, not enough resources are spent on increasing visibility beyond the first tier. As of today the company usually lacks information about the network structure further upstream in its supply chains.

5.1.4 Increasing Profit by Reducing Risk

The most common argument for adopting SCM is to increase the profit of the supply chain and thereby also of the individual companies. However, an important aspect to reach this is to minimize the probability and impact of risks and turbulences in the chain. A stop in Volvo's production is extremely costly and therefore it is of great importance to actively work to reduce the risk probability and the impact.

Increasing profit is not just about reducing the purchasing price, a minimization of risk is an important part as well. It is necessary to adopt a total cost of ownership approach where all factors including risks are considered. Christopher (2011) states that in today's uncertain environment the emphasis should be upon resilience rather than cost minimization. To create a resilient supply chain all actors must be aware of the vulnerable parts of the chain. The first step is to increase information sharing and visibility of the chain, or in other words to extend the network horizon.

The risk dimension of SCM and an extended network horizon have been more important today as the risk in the supply chains has increased due to the trends presented by Christopher (2011). Most companies, including VPT, have reduced their supplier base, which makes it more difficult to switch supplier in case of a disruption anywhere in the supply chain. The globalization means longer lead times and thereby a larger risk of disruption and more severe impacts.

In the literature review it is stressed that poor visibility and transparency of the supply chain lead to many hidden risks and longer reaction time if a disturbance occurs. Hence, to minimize the risk it is important for VPT to analyze its supply network and identify vulnerable parts where a disturbance would cause the largest impact.

If not focusing beyond the first tier, many risks will not be identified. One supply chain might look very robust at a first glance but with an extended network horizon it might be possible to find parts of the chain that are very vulnerable to disruptions. One example is if a company uses, or at least has identified, several potential first tier suppliers but all of them purchase a critical part or material from the same second tier supplier. The Figure 20 below shows why it is necessary to adopt a supply chain approach in order to identify risks in the supply network.

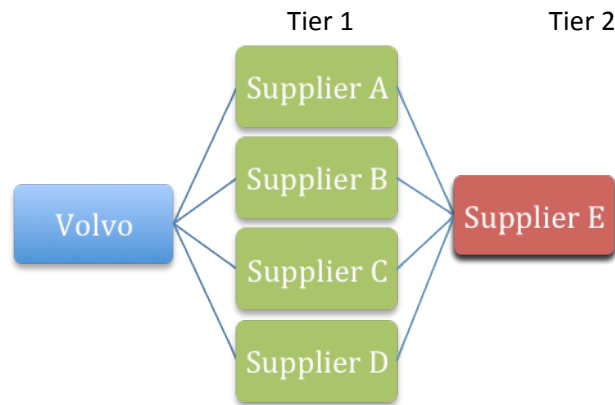


Figure 20: Example showing the criticality of the tier 2 supplier

If a company has an accurate map of the supply chain and identifies the vulnerable parts it is possible to act quickly if something happens. In addition, it will make it possible to allocate scarce resources on mitigation strategies for these specific parts. It can also be the case that VPT is a relatively small customer to the first tier supplier but uses a large portion of the output from the second tier supplier. If VPT knows this, it is possible to contact the second tier supplier directly if an incident occurs to make sure that material used in VPT's components is prioritized.

5.1.5 Lessons from Cases

The cases describing incidents where Volvo has experienced turbulence in its supply chains show the importance of having a clear picture of the entire supply chain before starting production. The flooding in Thailand affected a second tier supplier and VPT was not even aware of that the first tier supplier used single sourcing for this critical component. If VPT would have been aware of this situation, the company might have put requirements on the supplier to use multiple sourcing or at least have a backup supplier.

During the earthquake in Japan suppliers from several tiers were affected. Since Volvo did not have all information about which suppliers the company used beyond the first tier it took about two weeks to become aware of the affected supply chains. Volvo managed this disaster well but the time it takes until a company has the full information and can react is very critical. In the case with Ericsson and Nokia, Ericsson's slow reaction meant that Nokia had time to buy the available capacity on the market. Even though Volvo has been successful in mitigating the impact of supply disruptions, it is important to remember that if a company is not prepared for a disruption in its supply chain the consequences can be severe.

The explosion that hit the company producing the plastic material caused large problems in the supply chain. Volvo did not have the complete picture of the supply chain and did not know how critical the material and thereby this supplier actually was. Since Volvo had some previous experience of supply shortage for this material the company had some knowledge about the market structure. Furthermore, Volvo had a good relationship with the affected supplier that was important in order to be prioritized and get as much raw material as

possible. If Volvo would not have had this limited information and an established relationship, the consequences of the fire would have been far more severe.

One factor making the work with extending the network horizon difficult is that the supply chain is not always as straight as it appears. The same actor can have different roles and positions in different supply chains. One illustrating example of this is the case with the factory producing plastic raw material. The exploded factory did not only produce the plastic material, it was also supplying competing producers with raw material making the situation more complicated. This means that this supplier was located at different tiers for different supply chains. Another case showing this was the supplier in Poland affected by a large fire. This company is both a first and second tier supplier to Volvo, which made it even more complicated to solve the situation.

5.1.6 Balance Costs and Degree of Extension

Even though it is necessary for VPT to extend its network horizon the company must always balance costs and benefits. It is very costly to have a perfect visibility of the entire network since the company needs to collect information, store it and then also make use of it in an effective way. In addition, the networks constantly change in today's environment characterized by short product life cycles and a dynamic market. The Figure 21 below shows how to balance costs of risks and costs of avoiding them in order to reach the optimal risk exposure. If a company invests too much in mitigation strategies the risk will be heavily reduced but will incur too high costs. On the other hand, if ignoring the risks the cost of these will be too high. To do this the company should analyze the supply chains and focus the mitigation strategies on the most vulnerable ones.

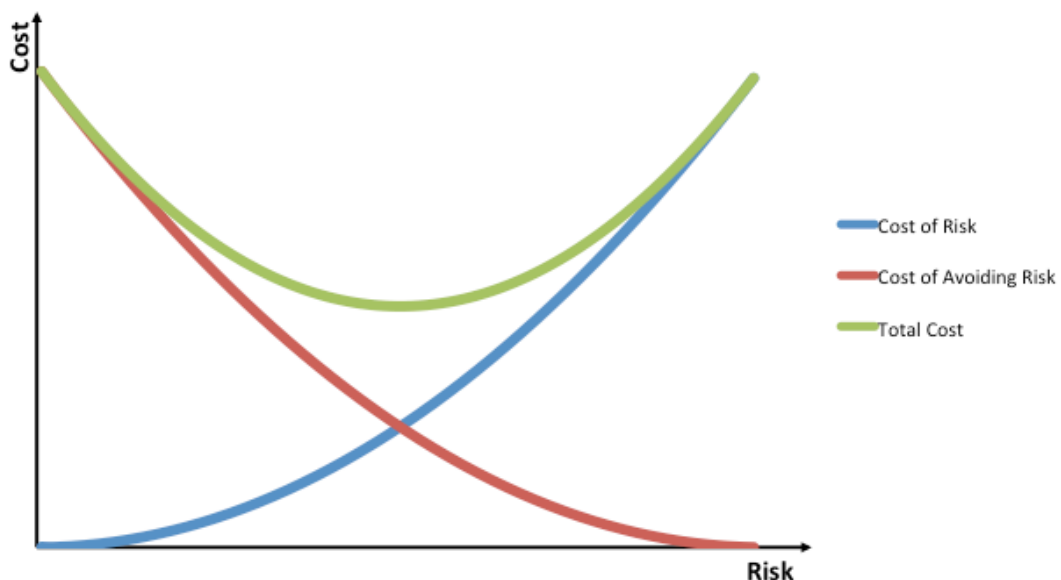


Figure 21: The balance between costs and risks

A major problem is also that the suppliers are not always willing to share information about actors further upstream in the network. The supplier might be afraid of sharing this information since that is part of the core competence and might make it possible for VPT to

bypass the supplier and start doing business directly with the second tier suppliers. In addition, the suppliers are afraid that their competitors might obtain this sensitive information.

To be successful with the collection of information it is important for VPT to have close and well-established relationships with the suppliers. VPT must also approach the suppliers in a way that the suppliers do not feel suspicious but instead that VPT wants to help them. A request from VPT can be an excellent opportunity to increase the visibility of the network for the supplier as well.

Transparency and information sharing are two important aspects of SCM mentioned in the literature review. It is important to explain this to the suppliers and that in the long term all actors will benefit from a better visibility of the network even though the suppliers might not feel that this is beneficial in the short term. Furthermore, it is important for VPT to explain that the supplier would suffer more than VPT if there would be an incident further upstream in the supply chain since the supplier then is closer to the disaster.

5.1.7 Prioritization of Links

Due to the costs and problems that an extension of the network horizon incurs, it is important to allocate the scarce resources to the most critical parts of the supply network. The literature states that it is not appropriate to have the same degree of interaction for all links but instead the interaction should vary among the links and also over time.

VPT needs to do a thorough analysis of the supply chain already during the sourcing phase and find the most vulnerable parts in order to put the most resources here. The company can categorize the links and then allocate the amount of resources according to this classification. In the literature review Lambert & Cooper (2000) presents a classification with managed links, monitored links, not managed links and non-member links that could be used.

Managed links are the ones with the direct suppliers but also the ones with other actors in the network that are considered critical. VPT partly works according to this today since the company has good relationships with the first tier suppliers. In addition VPT sometimes selects tier 2 and tier 3 suppliers for components that are critical for the performance of the vehicle.

The case of the explosion in the factory producing plastic shows that the company producing the unique material was very critical for Volvo even though this was a supplier further upstream in the chain. It is important to be aware of the criticality of this link to be able to react quickly if a disaster occurs even though it is not appropriate to manage the link actively. In addition, it is appropriate to have an established relationship with this supplier to ensure that Volvo gets prioritized in case of disaster. Hence, this type of link should be monitored in order to be aware of the vulnerability and maybe react to changes of the network.

The not managed links are the ones that are not critical to Volvo and hence resources should not be focused on these ones. The non-member links are not easy to identify since it is

difficult to find actors that are not part of the supply chain but still have an impact on it. Some of these links can be critical but it takes too much effort to find them.

Table 4 below summarizes the reasons why it is important to extend the network horizon.

Reasons to Extend the Network Horizon
Purchasing has a large impact on company performance
Competition is today between supply chains
Must be aware of the network to minimize risk exposure
Must identify and focus on vulnerable links

Table 4: Reasons to extend the network horizon

5.2 Which Parameters Make Supply Chains More Vulnerable to Disruptions?

After showing that it is necessary to extend the network horizon in order to visualize the supply chain structure and the potential risks, critical elements have to be identified. This can be done already during the sourcing phase by analyzing some parameters making supply chains more vulnerable to disruptions.

5.2.1 Categorization of Risks

When analyzing the vulnerability of the supply chain it is necessary to first assess what kind of risks the supply chain is exposed to. In the literature review, Christopher (2011) defines the supply chain risk as the probability of disruption times the impact. This is stated to be an efficient way of finding weak spots in the supply chain where resources can be put to make the most benefit.

When interviewing people at VPT and when analyzing the current supplier selection model, it can be stated that VPT to some extent follows this model. However, resources are mainly used to prevent the kinds of risk where the probability of occurrence is relatively high but the impact is limited. VPT uses the QDCF model when selecting a new supplier, where the parameters quality, delivery, cost and feature are investigated. The ones focusing on risk aspects are quality and delivery, where VPT assures that the supplier has sufficient capacity to be able to deliver according to the schedule and that the quality of the component corresponds to Volvo's high standards.

In the literature review, Christopher (2011) comments that a weakness with his definition of supply chain risks is that too little attention is given to the risks where the probability of occurrence is low, but the impact high. Some examples are natural disasters and fires, which can be fatal for the actor that is hit but also severely impact other actors in the supply chain. The case where a supplier to Nokia and Ericsson was hit by a fire shows how serious these kinds of events can be.

The interviews with employees at the purchasing department show that little attention is given to prevent these kinds of risks, both when the suppliers are selected and in the ongoing relationships. The interviews also show that it is important to be aware of these kinds of risks and to avoid them but at the same time the cost of doing it cannot be higher

than the benefits. Therefore, it is important to do something to reduce the risk exposure but it needs to be done in a cost efficient way.

In the literature Trkman & McCormarck (2009) divides the risks into endogenous and exogenous risks depending on their origin. Endogenous risks arise from inside the supply chain and can for example be fast changes in technology, changed customer preferences or quality issues due to poor production techniques. VPT is aware of these kinds of risks and has processes to limit the exposure and to mitigate the impact.

The exogenous risks come from outside the supply chain and they can be further divided into continuous risks and discrete events. Continuous risks are uncertainties that in some way can be predicted or hedged against and where the costs come gradually. Examples are fluctuations in interest rates, currencies and raw material prices. VPT takes these risks seriously and put in resources to mitigate the impact. The financial department is responsible for analyzing and mitigating these kinds of risks and they are taken into consideration.

The discrete events on the other hand are risks that VPT does not put enough attention to during the supplier selection. These risks are very hard to predict and are often unlikely to occur but will have a large impact if they do. Examples are natural disasters, terrorist attacks, fires and political uncertainty. VPT is aware that these risks can occur but the common opinion is that they are impossible to predict and therefore it is hard to do something about it. As stated earlier in the analysis, VPT is often not aware of the supply chain beyond the first tier supplier and consequently not either the present risks.

In all the cases presented earlier in the report discrete events have been the cause of the supply chain disruption. In two of the cases major natural disasters have destroyed both factories and infrastructure in the affected area. In other cases accidents like fires or explosions have made the entire factory unable to produce, and in one case a very important machine broke down due to an accident. The case with the Asian supplier that changed its management team shows that there are risks that can affect the whole company and not only a single factory.

The discrete events described above are all incidents with high impact. For Volvo the largest impact is a stop in the production since this is very costly for the company. Disturbances in the supply chain will also incur other costs like expenses for the crisis team, cost for airfreights etc., but since the cost for production stop is so much larger the main focus is to prevent this when a disaster occurs.

The cases show that there exist many different discrete events, with the similarity that they all disturb or completely stop the supply of components. To deal with these kinds of events, Harland, Brenchley, & Walker (2003) states that the focus should be on minimizing the effects by implementing a proactive approach since the risk itself in general cannot be reduced. A proactive approach should include establishing a resilience and quick responding supply chain. This thesis follows this strategy since the focus will not be on reducing the risk itself since all investigated risks have similar impacts. Instead, the focus will be on raising awareness of these risks and how to design the structure of the supply chain in order to

minimize the impact of a disruption. To do this it is necessary to assess which parameters that impact the vulnerability of the supply chain.

5.2.2 Increased Exposure to Risks

In the literature it is stated that several trends in recent years have made companies and their supply chains more vulnerable to supply chain disruptions. Christopher (2011), describes some major trends that have increased the vulnerability of many supply chains in recent years. The first one is reductions of the supplier base in order to create closer relationships with the remaining suppliers. VPT is no exception to this trend, in recent years the company has made significant cuts in the supplier base. A proof of this is that today as much as 80% of the purchasing spend at VPT is allocated to only 33 suppliers. The main reasons for this are to create better opportunities for mutual product development and to get economies of scale.

Another trend described in the literature is the increased globalization of supply chains. This is also a trend that VPT has followed since the company has become much more globalized in the last decade with both an international production and supplier base. The products have in general become more specific and advanced with the consequence that fewer suppliers have the knowledge to produce the components and it is therefore often necessary to go to markets far away in order to find the right competence. An example of this is that Volvo equips the vehicles with more and more advanced electronic equipment. The largest suppliers with the best knowledge within this area are located in Asia, which force Volvo to use long distance suppliers in order to secure the quality of the product.

It is very expensive for companies to obtain the specific knowledge that in many cases are necessary for producing the components delivered to VPT. This has made that many smaller suppliers have been acquired or forced out of business with only a few giants left. This change of the supplier market has further accelerated the supplier base reduction since VPT in many cases only have one supplier to choose, even if multiple sourcing would be preferable for the specific component.

Another trend presented by Christopher (2011) is the increased focus on efficiency in form of lean and JIT practices. This is a trend that has affected the automotive industry since the companies often have relatively low margins and high value products that are expensive to store. VPT has no own warehouses and is therefore completely dependent on the supplier to deliver on time in order to not affect the production pace.

5.2.3 Parameters Affecting the Vulnerability

As stated by Wagner & Bode (2006) risks are the factors leading to a supply chain disruption, but are not the only determinant of the final impact. The structure of the supply chain is also of great importance when assessing how large impact a certain event will have. Different parameters can be used to describe the structure of a supply chain and the most important ones are identified in the following section with help of the information from the different cases as well as from the interviews with employees at VPT and some of its suppliers.

The parameter that is stated as the most obvious during the interviews is whether to use single or multiple sourcing. This parameter illustrates how many different suppliers one

specific component is sourced from. Important to notice is that the parameter is independent on how many production facilities each supplier uses to produce the component. This means that this parameter considers the impact of risks affecting both an entire company and a single factory. An example of a company specific risk is the case with the Asian supplier that changed its management. Another example of a company specific risk is financial problems that can lead to bankruptcy, which is present in the automotive industry due to high fluctuations in demand.

A parameter that can be used to hedge against many risks is if the component is produced in one or several sites. This parameter does not require VPT to use several different suppliers, which will eliminate the problem of higher relationship costs when using several suppliers. If the supplier has one or several manufacturing sites often depends on the size of the company. A common reason for suppliers to make the components in several sites is that it has to deliver to Volvo factories at different continents. To reduce transportation costs and lead-time it is common that large suppliers have sites at the same continent as the factory they are serving. The aim of reducing transportation costs is a much more common reason to use a supplier with multiple sites than to reduce the risk.

In many of the cases described earlier the use of multiple sites is the fact that mitigated the impact of the disaster. An efficient strategy is to use a second site as back up if something happens to the main factory. A good example of this was during the Thailand flooding when the second tier supplier got its factory under water and became unable to supply for several months. The first tier supplier had already before the incident been in contact with another supplier in China that was producing the same kind of circuit boards. Since the contact already was established the production could be moved fast, which made that Volvo could avoid a production stop. To use back up suppliers, where the initial contact and sometimes also quality inspections already are done, is an efficient way to hedge against supply chain disruptions. To contact a completely new supplier after the incident has occurred is often not an option since it takes several months to initiate a relationship, perform quality inspections and ramp up production.

Another parameter affecting the vulnerability is the geographical location of the factories. The earthquake in Japan and the flooding in Thailand are examples of incidents that affected a whole geographical region. An effective way to mitigate this risk is to have factories in more than one geographical area since it is very unlikely that two different areas would be hit by a disaster at the same time. In countries like Japan where natural disasters are common, the knowledge and experience of how to deal with a disaster will to some extent mitigate the impact. The buildings are secured to stand an earthquake and there are emergency plans describing how to act if a disaster occurs. This means that even if some areas are more likely to be hit by natural disasters, they are also more prepared which will reduce the impact.

This view is further supported in the theoretical framework where Alliance Development Works (2012) states that parameters such as how vulnerable the society is, how well it can cope with severe disasters and if the society has taken any preventive measures are at least

as important as the exposure to natural disasters. The risk index shows that it is possible to lower the risks by avoiding some areas that are more vulnerable.

Political risks are also related to geographical location and can be mitigated by having factories in different countries. Countries with unstable governments can be avoided but some raw materials come from these regions, which force some industries to cope with these risks. In addition, local content rules might force companies to have business in these regions.

A parameter that is very much linked to the vulnerability of the supply chain is the availability of the component or material on the market. If it is a standard part that is easy to get from another source the impact of an disruption would be lower than if there is a specific component or material that only one or a few actors on the market has the competence to produce. It can be specific raw materials, like rare earth metals or specific polymers that only are produced by specialist suppliers. If the production of the components requires very expensive production equipment, entry barriers will be high making the market often consisting of only a few suppliers. An example of such an industry is the one the exploded factory operated in. The market for this specific plastic was an oligopoly since the entry barriers to start producing was very high which made it difficult to get supply from other sources during the rebuild of the factory. An additional example where expensive machines led to a situation with only a few players on the market is the case with the company owning a unique and expensive tool.

A factor that can be captured by having better market knowledge is the competition from other industries. When there is a supply shortage many industries will compete for the same available material. This is especially the case when the disruption is further up in the supply chain, since the output here is more generic and thereby used by several industries. Some industries, where the cost of the purchased material is small in relation to the price of the product, can pay a much higher price for the material in order to be prioritized. This was the case in the incident with the plastic material where the automotive companies competed with companies in the solar cell industry enjoying much higher margins. The competition with other industries is therefore important to consider when analyzing the criticality of the material.

Another important parameter is how specific VPT requires the raw material or component to be in the drawings. If it is possible to switch material or modify some components relatively easy the risk of production stop will be lower in case of a disaster. Again the plastic incident shows why this is important. Volvo partly solved the situation by switching to other materials for some components where the characteristics of the material were not that important.

When an incident happens, many of the cases show that it is important to act fast in order to limit the impact as much as possible. Contingency plans can be an efficient tool for handling crisis situations and therefore it is important to make sure that all actors in a supply chain have this. The case with Ericsson and Nokia shows that it is important to act instantly and to do this it is necessary to have the actions predetermined before the production has started. This case also shows that it is important to have a good relationship and directly

approach the affected actor in order to get prioritized and this can be one part of a contingency plan.

Parameter	Impact on Vulnerability
Multiple sourcing	- Mitigates company specific risks, like bankruptcy, change of management etc.
Multiple factories	- Mitigates factory specific risks, like fires, breakdown of major machines etc. - If the factories are located at different geographical locations it also mitigates risks like natural disasters and political instability
Location of factory	- The probability of a natural disaster and political instability is higher in some areas
Availability of the component/material on the market	- The impact will be larger if the component/material only is produced by one or a few suppliers
Component/material specification	- If the specification of the component/material is strict it will be harder to find alternative sources of supply
Contingency plan	- A contingency plan will reduce the reaction time and limit the impact

Table 5: Parameters impacting the vulnerability of supply chains

5.3 How can the Vulnerability of the Supply Chain be incorporated into the Supplier Selection Process at VPT?

After stating that it is necessary to extend the network horizon and what parameters that make supply chains more vulnerable to disruption, the next step is to analyze how these parameters can be incorporated in VPT's supplier selection process. In the literature review Manuj & Mentzer (2008) states that supply chains can suffer serious damages and costs in case of a disruption and therefore the increased vulnerability has to be incorporated when comparing offers from different suppliers. To make this possible supply chains have to become more visible and transparent than before.

5.3.1 Current Sourcing Process

In VPT's current supplier selection process there is not enough emphasis on risks. During the interviews with employees it became clear that there is a need to increase the focus on risks when assessing new potential suppliers. In the current sourcing process the main criteria are quality, delivery, cost and feature. Risks in general are to some extent included in these factors but is not given a high weight in the supplier selection process.

Furthermore, risk assessment is not carried out in a standardized way. Some purchasers use risk as one parameter when making supplier recommendations while others do not. Hence, there are not sufficient guidelines how to consider risks which creates a situation where everyone incorporates risks to different extents and in different ways. Some purchasers are just using risk as a qualitative factor while others grade this parameter and use it in the motivation for the recommended supplier.

Risks are incorporated in the supplier selection only to a limited extent and the supply chain risks, that are the focus in this thesis, are more or less not included at all. Risk assessment is to some extent included in the SEM but this is only one of several areas that are investigated in the model. Hence, a low score on risk management will only have a limited impact on the total score. Risk management is a stopping parameter and if the supplier is rated zero it cannot be chosen. However, if the supplier is rated one it can be selected even though the risk management is inadequate. In addition, SEM is more focused on quality risks and the employees performing the evaluation of the supplier have more knowledge about quality related issues and do sometimes not have enough competence about risk management.

A shortcoming of SEM is the focus on the risks associated with the specific supplier and not the purchased component. This means that risks associated with a certain component such as a unique raw material or a specific tool are not considered. The fact that many suppliers deliver a wide range of components makes SEM insufficient since the risks vary a lot between the different components even though the same supplier produces them. Furthermore, a complete SEM is only performed when selecting a supplier that is not used by Volvo today. This means that if a current supplier quotes for a new component, some of the SEM results are updated but no new evaluation is made.

In addition, SEM is mainly focused on evaluating first tier suppliers and not the entire supply chain. Some of the parameters should be investigated also for second tier suppliers but this is done only to a limited extent since the employees carrying out the assessment do not usually have enough time to investigate all parameters completely. Due to the fact that there is not enough focus on suppliers further upstream in the supply chains, VPT is usually not aware of the structure of the supply networks or the present risks.

5.3.2 Timing of the Risk Assessment

An important aspect of supply chain risk assessment during the sourcing phase is to analyze when during the process it should be carried out. The employees responsible for sourcing highlighted during the interviews the importance of performing a risk assessment relatively early in the sourcing process. At this stage before a supplier has been selected VTP has more power and hence it is easier to obtain information from the suppliers.

Early in the sourcing process VPT also has larger possibility to influence the selection of suppliers and the specifications of the purchased component. As the sourcing process proceeds more decisions are made and in the end there are not many potential suppliers and possible solutions left. If the risk assessment is done early in the process it will also be possible for VPT to eliminate suppliers that incur too high risk before large investments are made, both in the development of the component and in the relationship. Figure 22 shows how the possibility to influence is reduced over time.

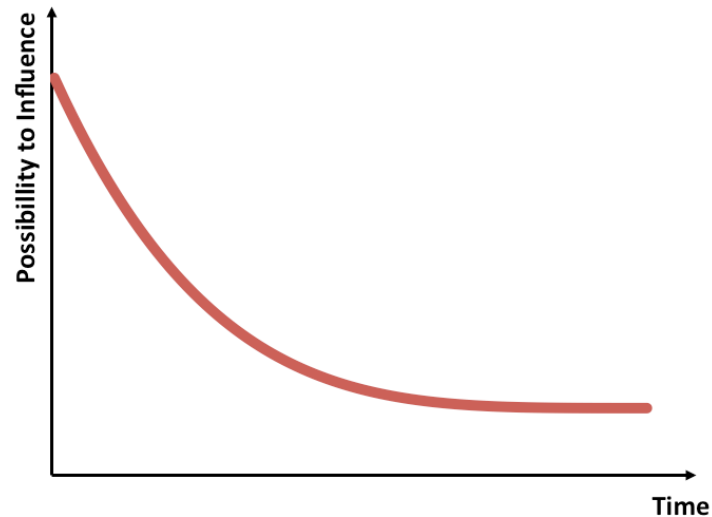


Figure 22: How the possibility to influence changes over time

An early risk assessment also enables a larger possibility for early supplier involvement, which is stressed as important in the literature review. With an early supplier involvement VPT can together with the suppliers make changes of the new components. It might be possible to make some minor changes of the drawings that do not impact the performance but reduces the vulnerability of the supply chain significantly. A small change might make it possible to change manufacturing process and avoid the dependence on a specific tool. In addition, it might be possible to change material if the initial material is very specific or is produced only by one or a few suppliers, as was the case of the plastic material.

If VPT becomes aware of the riskiness of the supply chain early in the sourcing process it will be possible to put more resources on the critical supply chains. VPT can initiate a relationship with an actor further upstream if this one is considered important. If the supply chain is considered very critical, one alternative can be that VPT is involved in the selection of second and third tier suppliers as the company sometimes is today.

Even though there are several advantages of carrying out the risk assessment early in the sourcing process there are some important drawbacks to consider as well. VPT has more power when the suppliers are eager to get the business but the supplier might not be willing to share information until the contracts are signed.

Another important factor is that the supplier might not at this early stage know exactly which suppliers that should be used. However, the interviewed suppliers stated that they have good knowledge about their supplier market and potential suppliers. They also have well-established relationships with many of them. In addition, when VPT wants them to produce a new component, they usually have produced a similar component before or already produce a similar one to another customer. In these cases, the supplier knows which suppliers that should be used for this new product. Table 6 below summarizes the advantages and disadvantages of having the assessment early in the sourcing process.

Advantages of Having the Assessment Early	Disadvantages of Having the Assessment Early
Supplier eager to get the business	Supplier not willing to share information before granted the deal
Larger possibility to influence design of the component and selection of supplier	Not willing to share information before a relationship is initiated
Early supplier involvement means lower costs to make changes	Supplier does not know which sub-suppliers to use

Table 6: Advantages and disadvantages of having risk assessment early in the sourcing process

After the interviews with the employees responsible for the sourcing activities it has become clear that the risk assessment should be done during the RFQ process. At this stage of the sourcing process it is still early but the design and manufacturing process are enough specified. Another advantage of having the risk assessment at this stage is that in the RFQ the supplier is requested to submit a large amount of information and hence it is convenient to carry out risk assessment at this stage as well. It also becomes easier to make the risk assessment in a standardized way which is a large problem experienced by the sourcing managers today. If it is included in the RFQ the risk of VPT employees not doing this risk assessment is reduced.

5.3.3 How Risks can be assessed

There are several ways to carry out an assessment of supply chain risks. Several interviewees have stated that one appropriate alternative would be to use a self-assessment form. The form can then be included in the RFQ package with the other documents that the potential suppliers are requested to fill in.

There are several advantages of using a self-assessment form. It is a simple and quick way to get a good overall picture of the supply chain risks. It is also a very efficient tool for both parties since it is easy to send to the potential suppliers and there is no need to arrange meetings. However, it is impossible to obtain all relevant information from a self-assessment form and therefore VPT needs to follow up the answers later in the process for the selected supplier.

Another advantage is that Volvo works like this for several other areas today making the company used to this kind of process. The SEM and the MMOG/LE are designed like this with an initial self-assessment form with a follow up audit later in the process. Volvo also uses the same process for assessing environmental and CSR issues.

Even though there are several advantages of using a self-assessment form, there are some important drawbacks as well. VPT needs to trust the supplier since it is very difficult to check the truth of the answers. To mitigate the risk of facing suppliers that only submit information that benefit themselves, it will be necessary to visit the supplier to validate the answers, as VPT currently does for the other self-assessments. However, it is important to remember that it is impossible for VPT to check everything and therefore it is necessary to trust the suppliers to a large extent.

An additional drawback with a self-assessment form is that it might be difficult for the suppliers to fully understand the questions and that there is no possibility for a dialogue.

This means that VPT faces the risk that the suppliers do not answer the questions in the correct way. To mitigate this it is important to think about the design of the form and to make it user-friendly. Furthermore, it is essential to inform the suppliers that they should feel free to contact VPT if they think something in the form is unclear.

Another disadvantage with a standardized form is that it should fit all types of components and suppliers. This is very problematic since VPT purchases a wide range of components and it is difficult to create a form that fits all these different situations. A factor making it even more difficult is that there is no chance for VPT to ask follow-up questions. To mitigate these drawbacks, it is again necessary to follow up the suppliers' answers. It will then be possible to ask follow-up questions and also to ask new additional questions about vulnerable elements identified after analyzing the answers from the self-assessment form. In this way, resources are put on the most critical supply chains and for the more robust ones it is possible to make a shorter follow up. Table 7 below summarizes the advantages and disadvantages of using a self-assessment form.

Advantages	Disadvantages
Efficient way to obtain information	Standardized and cannot capture everything
Volvo works like this for other areas today	Need to trust the suppliers to a large extent

Table 7: Advantages and disadvantages of using a self-assessment form

In the self-assessment form it is appropriate to have both qualitative and quantitative parameters and questions. The main advantage of having qualitative questions is that it enables the suppliers to explain what is the most critical in their specific supply chain. As explained earlier, the purchased components and thereby the supply chains vary significantly from case to case.

The main advantage of asking for quantitative figures is that it is much easier for VPT to summarize and compare the answers in a standardized way. Another advantage is that it reduces the risk of suppliers not writing all relevant information. Since there are both advantages and disadvantages of having qualitative and quantitative questions, it has been decided to use both type of questions to ensure that as much relevant information as possible can be obtained.

A relevant tool to use in the risk assessment is supply chain mapping, which is commonly used by the automotive association Odette for identifying weak links in supply chains. In addition, supply chain mapping is currently used by Volvo even though the purpose is cost optimization rather than risk identification.

Most of the interviewees claimed that mapping is a good tool to identify and highlight vulnerable links in a supply network. It makes it possible to reveal where the supply chains are narrowed down, meaning where there is one or just a few potential suppliers or factories. In addition, supply chain mapping is an excellent tool to visualize the identified risks and vulnerable links. It is very useful for the purchaser to show this to VPT managers if he or she wants to illustrate risks when presenting a supplier recommendation during the sourcing process. However, it is not only very helpful to visualize the risks internally. The picture can be shown to the suppliers to highlight vulnerable parts of the common supply

chain and to start a discussion about risks and mitigation strategies among different actors in the network.

An important aspect to consider when creating a self-assessment form is how much information that should be requested. Purchasers at VPT have explained that many potential suppliers do not fill in all the requested information in today's RFQ package. Therefore, it is necessary to balance the need of information and the risk of getting nothing. If the potential suppliers think that it is too time consuming or too difficult to fill in the self-assessment form there is a large risk that the form will be returned empty. In addition, as mentioned earlier in the analysis, much of the requested information is sensitive making it even more important to not request too much.

5.3.4 Creation of the Form

With the aspects described above in mind a self-assessment form has been created. The creation of the form has been a process and changes have been made as more information has been gathered. To be able to create a form that is as useful as possible, several stakeholders have been interviewed. At VPT, employees working within several areas such as purchasing, logistics and risk management have given their input.

Employees working with purchasing have been interviewed since they are the ones that have requested and will use the form. They also have valuable input about what type of information that the form should obtain. In addition, they are the ones that should use the gathered information in the supplier selection process. They also work with the strategic issues for the purchasing activities, which is what this form is supposed to facilitate. Since the buyer is responsible for the communication with the supplier and for sending the RFQ package they have valuable knowledge and experience about how the questions should be asked in order to be able to get as much information as possible.

Employees working with logistics are also involved in supply shortage situations and hence they have useful knowledge. Some of the interviewed employees at this department have led crisis teams when a supply shortage situation has occurred. Their experiences have given them knowledge how the risk of facing these supply shortage situations can be mitigated but also what actions that can be taken in order to reduce the impact of them.

Capacity planners at VPT work with risk management and have provided valuable input from supply shortage situations. When the purchasers become aware of that their suppliers are unable to supply they usually forward this information to their manager but also to the capacity planners and hence they also have experience and knowledge how supply shortage situation and the impact of them can be reduced.

Throughout the process of creating the self-assessment form some suppliers have provided their input. The suppliers are the ones that should fill in the form and therefore it is important to get their opinion about what type of questions that would not be too confidential and hence would be possible for them to answer. They have also read the form to ensure that the questions are understandable and provided feedback how the form can be more user-friendly.



Figure 23: Input to the self-assessment form

All interviewed stakeholders have different roles and thereby all of them have different opinions and needs. Some employees at VPT want for instance to have several questions with information that is sensitive for the suppliers to provide. On the other hand, the suppliers do not want to have too many questions since they have limited time to answer and they also do not want questions that are considered too sensitive to answer. An important part has therefore been to balance the need of the stakeholders in order to create a form that best fulfill its purpose.

5.3.5 The Self-Assessment Form

The final self-assessment form is one and a half page and can be seen in Appendix 3. It starts with a short description of the purpose and a motivation why it is important for the supplier to fill in. This is mainly to stress that the aim is not to force the suppliers to share information but rather a way for both parties to help each other to reduce the vulnerability of their common supply chain. After the introduction the first question is the following:

“-Have you experienced major supply shortage during the last 3 years? Please describe the event and the actions taken to prevent this to happen in the future. “

The purpose of this question is to get information about what has affected this supply chain before since there is a risk that it might occur again. It is also useful for VPT to know what actions the suppliers have taken in order to prevent this to happen in the future. These actions will also indicate how willing the supplier has been to invest in reducing risk exposure and impact of an event. The next question is:

“-Which elements in your supply chain are most sensitive to supply chain disruptions (unique raw-material, tool, factory or supplier)? “

This question has the purpose to get the suppliers’ opinion what they consider as most critical in their supply chain and hence would cause the largest impact if affected by an event. The question is open since VPT’s supply chains differ significantly. There are also some examples in brackets to help the suppliers in their analysis. Next question is:

“-What actions can be taken to reduce the impact of an unforeseen event affecting the element described above? Please specify.”

The aim of this question is to obtain information about what actions the suppliers have considered to take in order to mitigate the risk of the vulnerable element. Some of the ideas might be impossible for the supplier to realize alone but it might be possible to do it together with VPT. In addition, the answer shows how much effort the supplier has put in analyzing supply chain risks and possible mitigation strategies.

In the form there is also one question asking if the suppliers have a business contingency plan and if there is one it should be attached. Having a business contingency plan is important since after studying the cases it has become clear that the reaction time is very crucial for the impact. A business contingency plan is also a relatively inexpensive action to reduce the potential impact of an event. In order to cover a larger part of the supply chain there is also a question if the suppliers check if their suppliers have a business contingency plan as well.

The last question is if there are any other aspects missing in the form. This question is included in order to mitigate the downside of having a standardized form. When answering this question the suppliers can express whatever they want.

In the form there is also an attached Excel document, which can be seen in Appendix 3. The document includes a table where the suppliers are requested to fill in information about their supply chain for the specific component. The suppliers are requested to fill in all components that are purchased and also where they are produced. The same information should then be filled in for higher tier suppliers as well.

If the same component is purchased from two different factories or suppliers, the component should be mentioned twice and in this way it becomes obvious for VPT if the suppliers use single or multiple sourcing and if one or several factories are used. Earlier in the analysis it has been shown that the decisions between single or multiple sourcing and number of factories have great impact on the vulnerability of the chain and hence these two parameters are of great importance to obtain. Location is another aspect that has significant impact on the vulnerability of the supply chain and therefore this parameter is included as well.

In the table the suppliers are also asked to grade the robustness of the parts of their supply chain from one to five. This parameter is used to capture the suppliers' opinion about the robustness of the chain. Clearly, the suppliers usually have better knowledge about their supply chain than VPT and it is vital to transfer that knowledge to VPT. The following instructions are provided in order to facilitate this grading:

5: You have identified vulnerable elements (unique raw-material, tool, factory or supplier) in the supply chain and have back up plans for these (back up suppliers or factories, possibility to buy from a competitor etc.)

3: You have identified vulnerable elements and are aware of possible alternatives

1: There are vulnerable elements in the supply chain and you are not aware of possible alternatives or you have not tried to identify vulnerable elements in your supply chain

The last requested parameters in the table are the switching time for the supplier to change the current setup and the actions to do this. These parameters are requested to make sure that the suppliers know what to do in case of a supply chain disruption and also how long time it would take until the suppliers' production can start again. The time is an important factor when assessing the risk since a long switching time would incur a higher risk for Volvo to face stop in the production system.

Figure 24 below shows an example of how the suppliers are supposed to fill in the sheet. The same table is provided in the form in order to make sure that the supplier fully understands how to fill in the requested information. The laptop in this example corresponds to the component VPT purchases from its first tier supplier.

Tier 0 (You)	Tier 1	Tier 2	Tier 3	Location	Supplier name	Robustness	Switching time and action
Laptop				Gothenburg	You		
	Display			Detroit	A	3	1 month. Use the supplier in Kiev
		Glass		Sao Paulo	D		
	Display			Kiev	B	4	2 weeks. Use the supplier in Sao Paolo
		Glass		Cairo	E		
		Cable		Bangkok	F		
	Processor			Tokyo	C	2	3 months. Have identified another supplier
		Circuit board		Shanghai	G		
			Silicon	Sydney	I		
		Fan		Taipei	H		
			Plastic	Kyoto	J		

Figure 24: Table intended to capture information about the supply chain

When VPT obtains the information from the table it will be possible to map the supply chain in order to visualize the structure but also the present risks. Two types of mapping with different purposes can be carried out. The first one is to map the product flow. With the information given in the example above the flowing map can relatively easy be created in power point:

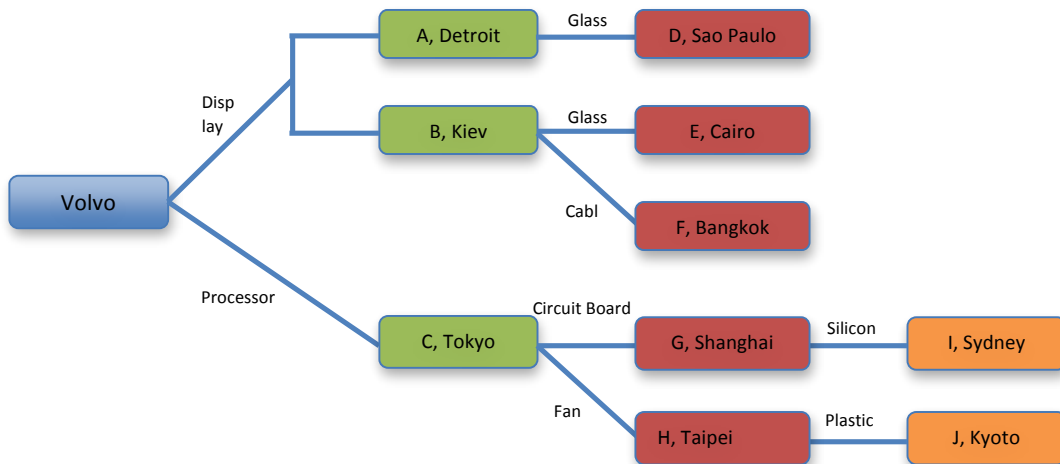


Figure 25: Mapping of the flow in a supply chain

The other type of mapping that can be done by using the information from the table is to map the supply chain geographically. By doing this it will be possible to show where the suppliers are located and hence if many of them are located close to each other and/or in an area incurring high risk of natural disasters or political instability. This type of map can be created during the sourcing phase and be used when assessing different potential suppliers. There are software tools enabling this mapping but selecting an appropriate tool for VPT is out of the scope of this thesis. However, one example is sourcemap.com where the following map can be created by uploading the Excel document:

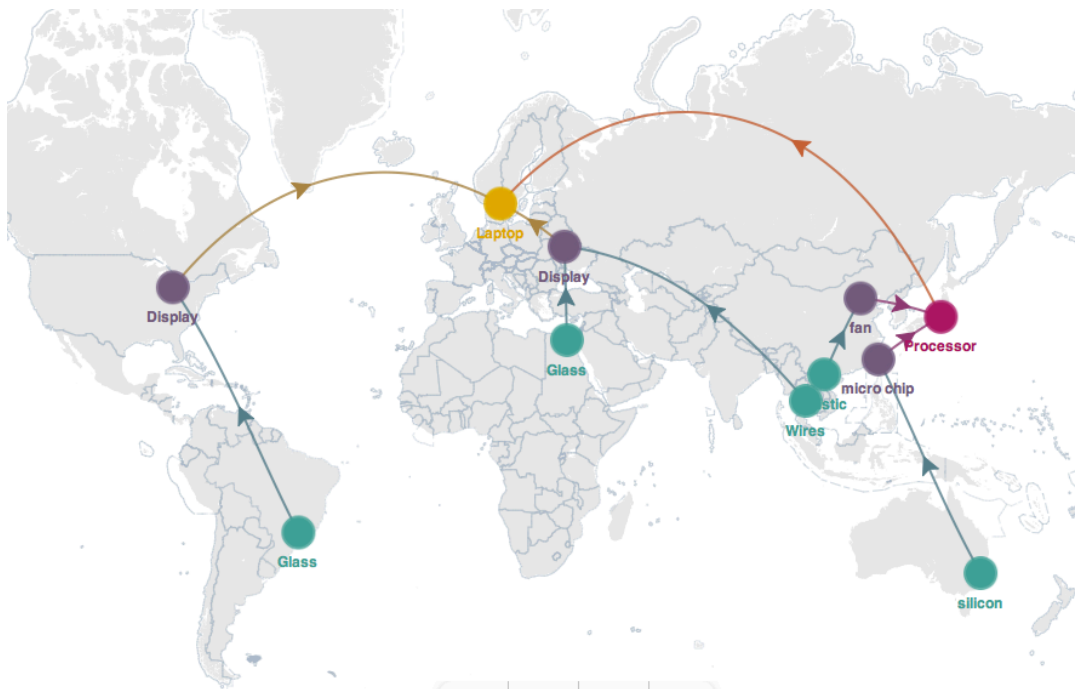


Figure 26: Geographical mapping of a supply chain (Sourcemap Inc., 2012)

This geographical map of the supply chain can be matched with a risk index map showing the exposure and vulnerability to natural disasters. This can be an efficient way to get an overview of the vulnerability to natural disasters for the specific supply chain.

The geographical mapping cannot only be used when selecting a new supplier but also in the ongoing relationship once a supplier has been selected. If a disaster occurs, VPT management and crisis teams can use the map to fast get an overview of the affected suppliers. This will reduce the reaction time and thereby the impact of the disaster.

5.3.6 Assessment of the Form

There are two main purposes of the self-assessment form. The first one is to compare potential suppliers when it comes to supply chain risks during the supplier selection. If one supplier uses a supply chain with single sourcing and single factories throughout the entire chain, the vulnerability is clearly higher than if a supplier has a supply chain with several suppliers and factories at each tier. If most of the factories are located in sensitive areas and if there are long switching times, the vulnerability will increase further. Since this vulnerability can have a large impact on a company it is necessary to incorporate this when selection a new supplier.

However, it is not easy to compare vulnerability between different supply chains. Some suppliers might for instance write several elements that would be sensitive to disruptions while other suppliers that actually face the same risks write fewer elements. It might also be the case that some suppliers have not even made an analysis of the supply chain risks and hence believe and write that there are no sensitive elements even though there are.

When assessing the parameters in the excel sheet it is also very difficult to make comparisons between them. The chain is not stronger than its weakest link and hence one supply chain might have several suppliers and factories at all tiers except at one. If this single supplier is very critical, the supply chain is vulnerable and this makes it problematic to use some kind of average number. It becomes even more difficult when adding other parameters such as location and switching time to the analysis. In addition, suppliers quoting for the same deal in most cases use the same raw materials and hence all suppliers face a similar risk for this element.

Due to the difficulty to assess supply chain risks, the second and the most important purpose of the form is to raise awareness about supply chain risks within VPT. If the quoting suppliers fill in the form, VPT will get valuable information from several sources about what is the most critical part in the specific supply chain used for this type of component. This information will help VPT to find weak links in the supply chain already during the sourcing phase and make it possible to monitor and allocate the scarce resources on these vulnerable links.

When a supplier is selected VPT will have a clear picture of the supply network, which is something that is missing today. VPT can also discuss the identified weak links with the supplier and make sure that the companies work together to reduce the vulnerability. If for instance a specific raw material is very critical and only manufactured by one actor further up in the chain it is necessary for both VPT and the first tier supplier to keep a close eye on this actor and in some cases establish a relationship.

Another benefit for VPT to work with supply chain risks is that it shows the suppliers that this is an important area and raise incentives for them to work with these issues as well. If

an incident occurs further up in the supply chain the suppliers will be located closer, meaning that the consequences for them will be even more severe than for VPT. Hopefully, the suppliers will realize this and use a similar tool for their suppliers as well. VPT will never be able to have control over the entire chain and therefore the aim should be to facilitate a SCM approach among all actors.

The information gathered from the form is also beneficial to have after the sourcing process. If an event impacts a critical actor, VPT instantly knows that this might cause severe consequences and can therefore contact this company directly before the competitors realize the severity of the situation. The fast reaction time together with the fact that VPT already has a good relationship will give a clear advantage compared to the competitors in case of a disaster.

5.3.7 Important Aspects to Consider when Using the Form

There are many benefits of using the form but there are some important factors to consider as well. It is difficult to capture everything in a standardized form and there is a limited possibility to have a dialogue with the potential suppliers. There is also a risk that they do not fill in the form in a correct way. To mitigate these downsides it is necessary to facilitate discussions and to have follow-up meetings when a supplier is selected to discuss the identified risks more in detail.

Another important aspect is that it might be difficult to obtain information. VPT will face the problem with adverse selection, which means that there is an information asymmetry between the two parties (Ross, Randolph, & Jeffrey, 2010). The suppliers might not provide or even hide some relevant information to benefit themselves. Information asymmetry is a problem for VPT and the way to mitigate this is to have more cooperation and information sharing. In addition, if important information is not provided, this can be used in discussions with the suppliers if a disaster occurs. Then the suppliers cannot expect VPT to help them with something they have not stated as critical from the beginning.

VPT might also face moral hazard problems when using the form. Moral hazard means that an actor will take on more risk since the potential costs will affect another actor than the one taking the risk (Ross, Randolph, & Jeffrey, 2010). Once the suppliers have got the deal VPT will not have the same power and the supplier might lose some commitment. The supplier might make changes that will increase the risk without noticing VPT. To mitigate this, VPT must again have follow up discussions regarding these issues.

5.3.8 Proposed Process to Handle Supply Chain Risks

To ensure that the employees responsible for assessing supply chain risks during the supplier selection do this in a unified way, the following process should be used.



Figure 27: Process to handle supply chain risks

The first step is to gather information about the structure and the characteristics of the analyzed supply chain by using the self-assessment form. The provided information should be used to map the structure of the supply chain. By analyzing the answers in the form vulnerable elements can be identified. When this is done, VPT has obtained valuable knowledge that should be used when selecting a new supplier. The information captured during the sourcing phase can also be used later in the ongoing relationship to mitigate the impact of different supply chain risks. Since the supply chains vary significantly there is no single action that works for all chains and instead the strategy should be to obtain knowledge and awareness. This process is very much in line with the one presented by Harland, Brenchley, & Walker (2003) in the literature review.

6. Conclusions

At the beginning of the thesis it was identified that VPT does not put enough emphasis on supply chain risks, especially not in the sourcing phase when comparing different suppliers. The company is usually not aware of the network structure beyond the first tier suppliers and therefore not either the present risks. Since large disasters always will occur it is necessary to mitigate the impact of them in order to avoid large losses. The purpose of the report has therefore been to:

Develop a model that helps VPT to mitigate the impact of supply chain risks by incorporating them into the sourcing process

The purpose was broken down to the following three research questions to make it more manageable:

1. *Why is it important to extend the network horizon beyond the first tier suppliers?*
2. *Which parameters make supply chains more vulnerable to disruptions?*
3. *How can the vulnerability of the supply chain be incorporated into the supplier selection process at VPT?*

There are several reasons why it is important for companies to extend their network horizon. Purchasing has become more important and has a large impact on companies' performance. A massive outsourcing has made companies more dependent on their suppliers and increased the need of visibility throughout the supply chain in order to reveal the present risks and enable collaboration among the actors. The members of the chain can then work together to mitigate the impact of supply chain risks and thereby increase profit for all individual companies.

Volvo has experienced several supply shortage situations during the recent years. The company has managed to limit the impact but examples from other industries have shown that the consequences can be far more severe if not actively working with these issues. However, when extending the network horizon it is necessary to do this in a cost efficient way. VPT must analyze its supply chains and allocate the scarce resources to the most vulnerable parts.

It is difficult to find these vulnerable parts since supply chains are very different and usually have a complex structure. Due to this, it is necessary to identify some parameters that indicate the criticality. The most critical parts of supply chains are the ones where an event would cause the largest impact. One of the parameters determining the criticality is whether one or several factories are used. If having more than one factory the impact of an event will be reduced. However, this parameter only considers factory specific risks and not risks affecting an entire company. Therefore, the use of multiple sourcing is even better in a risk perspective since it mitigates company specific risks as well. Furthermore, location of factories is important since some areas in the world are more sensitive to natural disasters and political instability and if several factories are located here the vulnerability will increase.

Another parameter determining the criticality is the availability of the material or component on the market. If it is strictly specified and only produced by a few actors it will

be more critical. The time aspect is an important factor to consider as well. If the members of the supply chain have contingency plans specifying how to react in case of a disruption, the potential impact will be reduced. The reaction time is very crucial since companies need to act faster than their competitors in order to avoid production stop.

VPT needs to incorporate supply chains risks in the sourcing process to make an appropriate selection. The information can also be used to implement actions aiming to mitigate the impact of supply shortage situations. The current risk management process does not have enough emphasis on supply chain management and is more focused on analyzing company specific risks than the ones linked to specific components. Supply chain risks should be incorporated during the sourcing process by using the developed self-assessment form in the RFQ package. The answers should then be followed up later on in the process when a supplier has been selected. The main advantages with this are that it is an easy way to get information and that Volvo currently works like this for other areas.

The main purpose of the self-assessment form is to raise awareness of supply chain risks and to identify the most critical elements and thereby the supply chains where a disruption would cause the largest impact already during the sourcing phase. The designed form includes open questions to help VPT to find out more about what drives risk in the specific supply chain and there is also a table where the suppliers are supposed to fill in information about the structure of the supply chain. After analyzing the gathered information it will be possible to select the appropriate supplier and then allocate resources to the most vulnerable parts and thereby mitigate the impact of supply shortage situations in a cost efficient way.

7. Discussion

Supply chains have become more vulnerable during the last decades due to trends such as reductions of the supplier base, increased outsourcing, globalization and increased focus on efficiency among companies. Volvo has clearly followed these trends and hence the company has become more dependent on other actors in the supply chain. As the dependence has increased and the supply chains have become more complex and extensive the risk has increased significantly.

Since Volvo has followed these trends it is surprising how little resources that are spent on analyzing and mitigating the risks. Of course it is not manageable and far too expensive to be aware of and handle all actors and risks in all supply chains. However, by revealing and analyzing at least some of the risks it will be possible to avoid too risky supply chains and allocate the scarce resources in a cost efficient way. By doing this it will be possible to implement several actions that would reduce the impact of supply shortage situations significantly without incurring too high costs.

The fact that VPT does not prioritize risks with relatively low probability but high impact is not surprising. Since these risks occur very seldom there is an opinion that they are too expensive to deal with and therefore most employees ignore them. However, since the impact can be enormous it is relevant to raise awareness among the employees by showing real examples of supply shortage situations. When a disaster occurs there is a large risk to suffer devastating losses but if a company is better prepared than the competitors it is also an excellent opportunity to gain advantage.

SCM is an area where there is a large potential for companies to improve. If all actors work together it will be possible to reduce the present risks, mitigate the impact of supply shortage situations and thereby also improve the profitability of the individual firms. To achieve this it is necessary to create win-win collaborations among the members. The actors must understand that all of them will be affected if a supply shortage situation occurs anywhere in the supply chain and therefore they must cooperate. It will not be possible for VPT to have collaboration with all actors in the supply chains but the company can approach the first tier suppliers in a way that encourages them to forward the approach to actors further upstream.

The developed model to handle supply chain risks during the sourcing process is developed for VPT. However, it is applicable for the rest of the Volvo Group since the different units work in a very similar way and this similarity will increase after the ongoing reorganization is fully implemented. The process can be applied for other automotive companies and also other industries since most of the elements are generic. However, some changes might be necessary to adopt the model to a new setting.

8. Recommendations

To help VPT improve its supply chain risk management during the supplier selection some recommendations will be given. First of all VPT needs to extend its network horizon to become aware of the risks that are present further upstream in the supply chains and this must be done already during the sourcing phase. Once this is done critical elements can be identified and the vulnerability of the supply chain should be one parameter when selecting a supplier. One option is also to add a risk parameter to the QDCF criteria to make sure that risks are handled in a standardized way.

When a supplier is selected resources can be put on the most vulnerable parts in order to make the supply chain more robust. Sometimes it is necessary to monitor, or have relationships with, critical actors or owners of critical elements even though they are located beyond the first tier supplier. The vision should be to work together in the supply chain in order to minimize the total risk exposure at the lowest possible cost.

To do this it is recommended to use the self-assessment form in the sourcing process. It should be included in the RFQ since this is relatively early in the process where the possibility to make changes still is relatively large. The developed self-assessment form is a recommendation of how to work with these issues. However, as the form has started to be used and information has been gathered and analyzed, it is important to work with continuous improvement of the form to secure that the requested information is the most relevant.

Even if the model should be used in the sourcing process, the gathered information can be used after a supplier has been selected as well. If critical elements have been identified in the supply chain, these should be followed up together with the supplier. VPT should use an approach that this is done in order to help the suppliers since reducing supply chain risks will gain them as well. The suppliers should also be encouraged to use a similar model and approach towards their suppliers since this will further reduce the exposure to supply chain risks.

In addition to implementing the self-assessment form, some other recommendations will be given to improve VPT's supply chain risk management. The first is that the documentation of supply shortage situations should be improved. During the thesis it was difficult to find information about these situations since no summarized learnings are documented. To prevent that the crisis teams have to start from scratch with every new situation, it is recommended to document the main takeaways in a place where they easily can be accessed.

During the interviews with purchasers it was found that they are not aware of any standardized process how to handle a shortage situation. Therefore it is recommended to implement such process and communicate it to the purchasers and other involved employees. A standardized process is important to reduce the reaction time when a supply shortage situation occurs by insuring that relevant information is quickly forwarded to the responsible employees. An additional recommendation is that VPT should analyze the possibility of implementing an IT tool that stores information about the geographical

location of the suppliers and sub-suppliers. This information can be used to fast get an overview of which actors that is affected in case of a natural disaster. The possibility to store information about the material used in the components should also be investigated. This could be useful to know if a shortage situation of a critical material occurs in order to fast mitigate the impact of the situation.

9. Further Research

There are several areas of further research that would be interesting to work with. First of all, it would be relevant to study how the model can be implemented in VPT's current sourcing process. It will be necessary to decide who should be responsible for this within VPT. It would also be good to study the outcome of the developed model. It would be interesting to find out how much information it would be possible to retrieve, how the information can be analyzed and also how actors in the supply chain would react when VPT launches this initiative.

A problem for some of the purchased components is that sub-suppliers cannot be selected when the first tier supplier gets the business since VPT and the supplier need to develop the component together before it is possible to select sub-suppliers. In this case it would be difficult to assess the supply chain risks during the sourcing phase and a topic for further research can be how to assess supply chain risks in these cases.

It would also be relevant to investigate how to store the gathered information in a useful way. It might be appropriate to design and create a database where it is possible to search for a geographical area or a specific material affected by a disaster, and then get all actors and supply chains that will be affected. Another interesting area for further research is to analyze how the model needs to be adapted if it should be used not only during the sourcing phase but also during ongoing relationship with existing suppliers.

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11. Appendix 1 – List of Interviewees

	Position	Topic
1.	Purchaser	VPT purchasing organization
2.	Purchaser	VPT purchasing organization
3.	Purchaser	VPT purchasing organization
4.	Purchasing Manager	Supplier selection criteria, Self-assessment form
5.	Global Commodity Manager	VPT Sourcing process
6.	Global Commodity Manager	VPT RFQ process
7.	Supplier Quality Assurer	Supplier Evaluation Model (SEM)
8.	Supplier Quality Assurer	Supplier Evaluation Model (SEM)
9.	Supplier Quality Assurer	Supplier Evaluation Model (SEM)
10.	Purchaser	Case: Flooding in Thailand
11.	Purchaser	Case: Flooding in Thailand
12.	Volume Director	Case: Japan Tsunami
13.	Security Manager	Case: Japan Tsunami, Self assessment form
14.	Capacity Manager	Case: Explosion at factory producing material for plastic production
15.	Project Manager	Case: Explosion at factory producing material for plastic production
16.	Purchaser	Case: Explosion at factory producing material for plastic production
17.	Purchaser	Case: Fire at supplier's plant in Poland
18.	Purchasing Manager	Case: Fire at supplier's plant in Poland, Major machine breakdown at a supplier
19.	Supplier Relationship Manager	Case: Fire at supplier's plant in Poland, Major machine breakdown at a supplier
20.	Global Director Logistics	Case: Major Machine Breakdown at a supplier
21.	Purchaser	Case: Changed management at an Asian supplier
22.	Capacity Manager	Case: Changed management at an Asian supplier
23.	Global Commodity Manager	Supply chain mapping
24.	Risk Manager	Supply chain risks
25.	Risk Manager	Self-assessment form
26.	Risk Manager	Risks, Self-assessment form
27.	Logistics Manager	Risks, Self-assessment form
28.	Director Value Chain Optimization	Risks, Self-assessment form
29.	Capacity Manager	Risk management, Self-assessment form
30.	Logistics Manager	MMOG/LE process
31.	Global Sourcing	Self-assessment form, MMOG/LE process
32.	Global Sourcing	Self-assessment form, MMOG/LE process
33.	Supplier	Self-assessment form
34.	Supplier	Self-assessment form
35.	Supplier	Self-assessment form
36.	Supplier	Self-assessment form

12. Appendix 2 - Generic Interview Guide

This is a generic interview guide that has been used throughout this the thesis. However, the guide has been adapted to each interview depending on the position of the interviewee and the topic of discussion.

- Can you please describe your job?
- What do you think are the main drawbacks with today's risk management?
- How do you think today's risk management can be improved?
- What do you think are the most important aspects to include in an assessment of supply chain risks?
- What do you think is the best way to assess the risks that are the focus in this thesis?
- What type of information do you think is possible to get from the potential suppliers?
- Do you have any other ideas you think is important for our project?
- Who else do you think we should interview?

When the interview has been about one of the cases the following questions have been asked in addition to the ones above:

- Can you please describe the incident?
- What was the reason that the situation occurred?
- How did you get to know about it?
- How was Volvo affected?
- How was the situation solved?
- What were the main lessons learned from the case?
- How can the impact of a similar event in the future be mitigated?

13. Appendix 3 - Self-Assessment Form

Supply Chain Risks – Self Assessment

The purpose with this questionnaire is to secure that you considered supply chain issues when making your offer and that you made an analysis aiming to mitigate disturbances in your supply chain.

The questions below will provide an overview of the robustness of the supply chain that you are responsible for and assess how you would mitigate the impact of an unforeseen event, such as natural disasters, fires, capacity shortage, financial distress, etc. that can happen to any company in your supply chain.

Company:

Part Number:

-Have you experienced major supply shortage during the last 3 years? Please describe the event and the actions taken to prevent this to happen in the future.

-Which elements in your supply chain are most sensitive to supply chain disruptions (unique raw-material, tool, factory or supplier)?

-What actions can be taken to reduce the impact of an unforeseen event affecting the element described above? Please specify.

Please fill in the document below that aims to describe the structure of the supply chain. Information sharing and transparency are important to determine the robustness/vulnerability of the supply chain.



Self assessment
table.xlsx

Do you have a business contingency plan? (e.g. including emergency, business continuity management, crisis communication and alternative production)

Yes No If yes, please attach a copy

Do you check if your suppliers have business contingency plans?

Yes No

-Are there other aspects that are missing in this assessment form? If yes, please describe.

Excel Document Attached in the Form

Example
 The following example shows how you should fill in the table. The laptop corresponds to the product you are supposed to deliver to Volvo. Each row in the table represents a factory in your supply chain. For instance, glass produced by supplier E in Kairo and cables produced by supplier F in Bangkok are bought by your tier-1 supplier in Kiev that you buy displays from.

Tier 0 (You)	Tier 1	Tier 2	Tier 3	Location	Supplier name	Robustness*	Switching time and action**
Laptop				Gothenburg	You		
	Display			Detroit	A	3	1 month. Use the supplier in Kiev
		Glass		Sao Paulo	D		
	Display			Kiev	B	4	2 weeks. Use the supplier in Sao Paolo
		Glass		Cairo	E		
		Cable		Bangkok	F		
	Processor			Tokyo	C	2	3 months. Have identified another supplier
		Circuit board		Shanghai	G		
			Silicon	Sydney			
		Fan		Taipei	H		
			Plastic	Kyoto			

* Please grade the robustness of the supply chain for the specific component 1-5. Only fill in for the components you buy from your tier-1.

5: You have identified vulnerable elements (unique raw-material, tool, factory or supplier) in the supply chain and have back up plans for these (back up suppliers or factories, possibility to buy from a competitor etc.)

3: You have identified vulnerable elements and are aware of possible alternatives

1: There are vulnerable elements in the supply chain and you are not aware of possible alternatives or you have not tried to identify vulnerable elements in your supply chain

**If your supplier is unable to supply, how fast can you get the item from another source and how would you do? (back up factories/suppliers, other suppliers in the market, buy from competitors, use a complimentary product etc.) . Only fill in for the components you buy from your tier-1.

In the next sheet the supplier are supposed to fill in the requested information.

Tier 0 (You)	Tier 1	Tier 2	Tier 3	Location	Supplier name	Robustness*	Switching time and action**

* Please grade the robustness of the supply chain for the specific component 1-5. Only fill in for the components you buy from your tier-1.

5: You have identified vulnerable elements (unique raw-material, tool, factory or supplier) in the supply chain and have back up plans for these (back up suppliers or factories, possibility to buy from a competitor etc.)

3: You have identified vulnerable elements and are aware of possible alternatives

1: There are vulnerable elements in the supply chain and you are not aware of possible alternatives or you have not tried to identify vulnerable elements in your supply chain

**If your supplier is unable to supply, how fast can you get the item from another source and how would you do? (back up factories/suppliers, other suppliers in the market, buy from competitors, use a complimentary product etc.) . Only fill in for the components you buy from your tier-1.