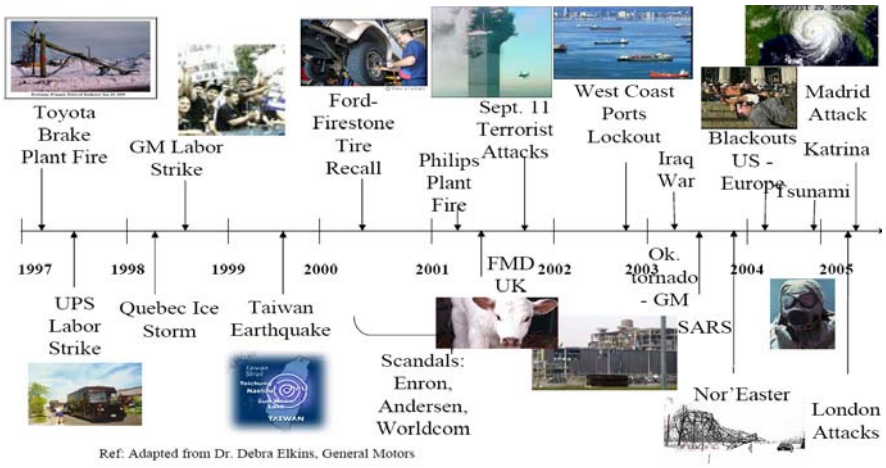
MScBA Supply Chain Management
Master Thesis

Ensuring Business Continuity under the Threat of Disruptions

Creating resilient supply chains



Ref: Adapted from Dr. Debra Elkins, General Motors

PROTECT WP3

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Executive Summary

The events of the last few years, varying from terrorist attacks including 9/11 to foot and mouth disease and SARS, have highlighted the vulnerability of many modern supply chains. In many companies, the vulnerabilities were strengthened because of the pursuit for a lean supply chain. Advanced logistic strategies (e.g. Just-In-Time) can increase operation efficiency but also the probability of supply chain disruptions. This paper seeks to explore the most frequently occurred supply chain disruptions in the Netherlands and what Dutch companies have done regarding these disruptions. It starts from a review of the existing literatures about supply chain disruptions and resilience. After that, a survey was carried out in cooperation with Dutch national organizations. It gathered 44 examples of supply chain disruptions from 35 Dutch companies, grouping them based on their causes and described the response activities of these companies. It found that the main causes of disruptions to these Dutch companies are labour strike unavailability, bankruptcy/unreliable SC partner (mainly supplier), unavailable infrastructure or transport, legislation problem, natural disaster, IT system down, fire, and no electricity supply. These companies were impacted by the disruptions and seeking to reduce disruption losses. In order to design a conceptual framework of resilience, this research also reviews the existing resilience frameworks of experts such as Christopher & Peck and Sheffi & Rice. By the cooperation of 5 managers in the large manufacturing company NXP semiconductors Nijmegen, a conceptual resilience framework was formulated as contribution to this research. Companies can go through the framework in three stages. The first stage assesses supply chain vulnerabilities and identifies a ‘vulnerability map’. After that, the second stage analyzes the failure mode of potential disruptions through FMEA (Failure Mode and Effect Analysis). Finally, the last stage is the analysis of resilience strategies and their trade-offs. When designing the conceptual framework, I tried to avoid the weaknesses of the existing frameworks. It finally got positive remarks from the 5 managers of NXP semiconductors and will be further discussed in their internal meetings. On the other hand, the comments of the 5 managers also helped me to improve the conceptual framework. However, one limitation of the framework is the generality to Dutch companies. It needs to be explored in future research.

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Chapter 1 Introduction

1.1 Background

The events of the last few years, varying from terrorist attacks including 9/11 to foot and mouth disease and SARS, have highlighted the vulnerability of many modern supply chains. In addition to the external challenges to supply chain continuity are those possible sources of risk that are internal to the supply chain. A number of concurrent trends, including for example the rapid growth in global sourcing and offshore manufacturing, the continued move to reduce the supplier base, industry consolidation and the centralisation of distribution facilities, have contributed to the vulnerability of many supply chains.

Peck (2003) indicates that modern supply chains are increasingly at risk of disruption and it can be argued that the greatest risks to business continuity lie in the wider supply chain of key suppliers and customers rather than within the company itself. For the vast majority of organisations, business continuity planning (if available) remains a one-firm focussed activity. As supply chain networks increase in complexity, as a result of outsourcing, globalisation and volatility in the trading environment, so too has the risk of disruption. The vulnerability of networks has increased as a result of longer, leaner supply lines between focused facilities within consolidating networks. Whilst many risks to the supply chain emanate from the external environment, e.g. war, epidemics and earthquakes, there is growing evidence that the structure of the supply chain is in itself the major source of risk.

In Figure 1, White III (2006) states some supply chain disruptions during 1997 to 2003.

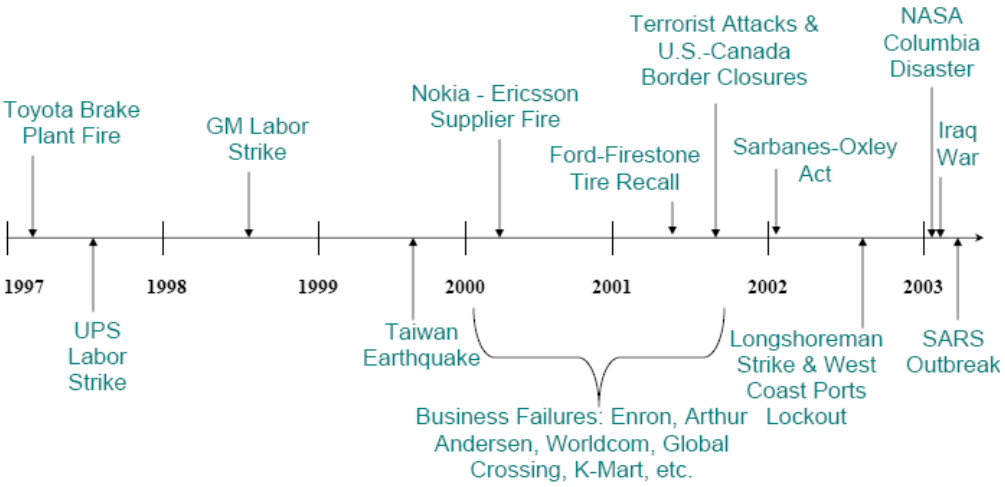


Figure 1 Supply chain disruptions during 1997 to 2003 (White III, 2006)

The above figure shows the main disruption events happened in the last few years. They vary from labour strike to natural disasters such as earthquake and SARS. All of them left big impressions to people.

1.2 An example of disruption in the Netherlands (Verduijn, 2004)

Storteboom Group BV is the leading company of Europe in the fresh chicken processing business. It is a private company with hatcheries, farms, slaughterhouses and processing plants in different locations of the Netherlands. The United Kingdom and the Netherlands are the most important markets to Storteboom, as the market share of Storteboom in these two countries is 85% and 25% (Verduijn, 2004). In addition, the chicken meat is also exported to France and Germany. The leading position in the European market is threatened by the cheap chicken meat from Asia (mostly China and Thailand). The logistics processes of Storteboom start from the two hatcheries (where the young chickens are born from eggs) in Bakkeveen and Oeffelt. The young chickens grow up in the 300 chicken farms in the Netherlands. They are sent to the four slaughterhouses Kornhorn, Putten, Barneveld and Rep & Roozendaal (Oostzaan) when the chickens are big enough. Finally, they are further processed in the two processing plants in Nijkerk (the largest in Europe) and Zoeterwoude, after which they are shipped to customers. The whole process achieves high standards of production in hygiene, flexibility, variety and food safety. Figure 2 shows the supply network of Storteboom.

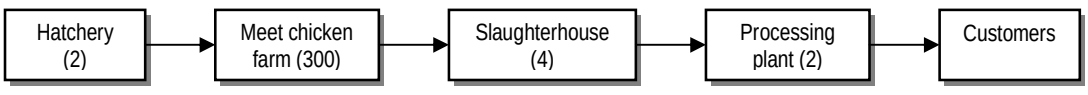


Figure 2 The supply network of Storteboom (Verduijn, 2004)

The Avian Influenza (a highly infectious disease to birds) broke out in the Gelderse Vallei in the centre Netherlands on 1st of March 2003. Besides Storteboom, there were also many other hatcheries, chicken farms, slaughterhouses and processing plants located in the area. In order to prevent the Avian Influenza spread further to other parts of the country, the Dutch national government adopted many emergency radical interventions (Verduijn, 2004):

- 1st of March, a 10 km square restricted zone was installed in which no transport of live chickens and eggs was allowed.
- 5th of March, the 10 km square restricted zone was extended because of the new outbreak of Avian Influenza in the Putten/Barneveld area.
- 27th of March, besides transportation of live chickens and eggs was not allowed, the transportation of chicken processing equipments and facilities was not allowed either.
- 27th of March, three compartments were set up: compartment A (restricted area), compartment B (a distinct area south of A and as a buffer to the province of Noord Brabant) and compartment C (the rest of the country). Transport equipment that visited a farm in one compartment was not allowed to visit another farm in another compartment within 72 hours.
- 3rd of May, a specific route was permitted by Dutch government to transport the meat chickens between certain compartments. Dutch government prohibited the import of German meat chickens to the Netherlands.

Verduijn (2004) describes in his book '*Dynamism in supply chain networks*', the disease was not detected in the chicken farm of Storteboom itself and thus it did not have a direct impact. The direct impact came from the Dutch government/authority interventions. As the results of the above mentioned interventions by the Dutch government/authority, two out of three slaughterhouses of Storteboom stopped running because they were located in the restricted area that all live chickens and eggs had to be destroyed and the transportation was prohibited. Storteboom lost most of its chicken supply and more than 60% of the slaughter capacity and finally went bankrupt on the 12th of May 2003 (Verduijn, 2004).

1.3 Research Motivation

From the perspective of supply chain management, the operations of Storteboom were disrupted by the interventions of government. As the direct consequence of this disruption, Storteboom went bankrupt.

It is mentioned that Storteboom takes up 85% of the Dutch market and 25% of the UK market. The retailers which were purchasing from Storteboom lost their supplier. The total loss of the retailers in the markets of the Netherlands and the UK could be much bigger than the loss of Storteboom. This example shows that factors outside the supply chain (such as governmental intervention) can disrupt business operations and cause big losses. Beside Avian Influenza, many events stated by White III (2006) in Figure 1 had also impact in the Netherlands. However, little is known about the practice regarding the disruptions and their impacts in the Netherlands and the way Dutch companies (including international companies which are located in the Netherlands) have handled disruptions in their supply chain. Many measuring methods of disruption and strategies of resilience have been provided by experts such as James Rice in the US, Martin Christopher and Helen Peck in the UK. Rice and Caniato (2003) groups supply chain disruptions by five Failure Modes (supply, transportation, production, communication and human resource) and states the optional reactions to each failure mode. The strategy is to create resilience through flexibility and redundancy (strategies mentioned here will be elaborated in later chapters). Peck (2003) firstly groups supply chain risks by supply, process, control, demand and environment. They indicate that FMEA (Failure Modes and Effect Analysis) can be used to measure the extent that companies are exposed to supply chain disruptions. However, it is also unknown if their method and strategy has been applied by Dutch companies. Many Dutch companies have international operations and thus their supply chains are vulnerable to the disruptions outside the Netherlands. Examples show that Dutch companies are experiencing supply chain disruptions (some of them occur outside the Netherlands) which are difficult to overcome (the examples are stated in later chapters). Thus, the researcher believes that it is worth to know the practice of supply chain disruption in Netherlands and the reactions of Dutch companies. Furthermore, it would be interesting to see if the strategies of resilience support Dutch companies to overcome supply chain disruptions.

1.4 Research objective and questions

The objective of this research is to provide an easy-to-use guideline for Dutch companies to make them less vulnerable to supply chain disruptions. Companies can build up their strategies/plans of resilience by consulting the guideline.

To achieve this objective, the following research questions need to be answered:

1. ***What are the main causes of supply chain disruptions to Dutch companies?***
2. ***What have Dutch companies done to overcome the disruptions?***
3. ***What can Dutch companies do to become more resilient to such disruptions?***

The first research question explores the main causes of disruption at corporate level and supply chain level. By answering this research question, the main threats to which Dutch companies are exposed become clear. The second research question explores the current recovery of Dutch companies to these disruptions. It links to the first research question and focuses on the activities of Dutch companies. The third research question tries to apply theories of resilience to practical operations of Dutch Companies.

1.5 Research strategy

As indicated by Verschuren and Doorewaard (1999), a research strategy is the coherent body of decisions about the way in which the researcher is going to carry out the research project. It refers especially to gathering relevant information/data and processing them into answers to the research questions and come up with solutions.

Instead of focusing on one single or few specific supply chains in certain industries, this research investigates the general situation regarding supply chain resilience in the Netherlands. A broad research is more adequate to this research.

In order to answer the first and the second research question, a questionnaire survey has been conducted among Dutch companies. By cooperating with colleagues at TNO, EVO, TLN and NDL, the researcher has sent out questionnaires to Dutch companies. The questions mainly concern the disruption events in the past (if any) and the performance on resilience of companies.

After the questionnaire survey, a few high profile disruption events have been selected to a further detailed research. The companies which report the high profile disruption events have been invited to join in an interview. During the interviews conducted by TNO, the researcher has collected more background information regarding the disruptions, and the suitable strategies to make them more resilient to such disruptions. In order to answer the third research question, the researcher reviewed

three existing resilience frameworks, analyzed their pros and cons and designs a new resilience framework which tries to keep the strengths and avoid the weaknesses. The new resilience framework was further consolidated through the case study to NXP-ITEC semiconductors. The case study provides a good demonstration about what Dutch companies can do to become more resilient to supply chain disruptions. The conclusions and limitations of the case study are provided in chapter 5.

1.6 Research method

This research is part of the project 'PROTECTing people, planet and profit – the development of reliable supply chains'. This project aims to contribute to the knowledge and insight that improve the performance of global supply chains in terms of their reliability. PROTECT is a Dutch research project (2005-2008) funded by the Dutch transport research fund TRANSUMO. Within PROTECT participate the Port of Rotterdam, Dutch Customs, EVO, TLN, NDL, TNO, DNV, RSM Erasmus University, TU Delft and Buck Consultants. The project proposal indicates the main activities of this research including 1) explore the state-of-art regarding supply chain disruptions to the companies in the Netherlands (the research was conducted via a survey); 2) make pilot analysis to supply chain disruptions cooperates with a Dutch company and 3) design a step-by-step approach based on the results of the first two activities.

The survey has been carried out by the researcher on behalf of TNO and the research cooperates with EVO, TLN and NDL. The questionnaire is designed by the researcher and consolidated by two colleagues at TNO and the staffs of EVO, TLN and NDL. The target group consists of the companies operating in the Netherlands. The questionnaires are sent out to the members of TNO, EVO, TLN and NDL. More specifically, most members of EVO are manufacturing/trading companies. In contrast, most members of TLN are Logistics Service Providers (LSPs). NDL members belong to both categories. The researcher assumes that these two categories of companies are exposed to different types of disruptions (for instance, the manufacturing/trading companies are more exposed to supply or production disruption; the LSPs are more exposed to transportation disruption). By considering the differences, the researcher decides to make two different versions of the questionnaire and perform the analysis to each category of companies.

The NXP pilot involves five managers of NXP-ITEC including a purchasing manager, supply chain

manager, logistics manager and two product development managers. Firstly, the researcher designs a preliminary resilience framework based on the review of existing resilience frameworks and the analysis results of the survey. Secondly, the resilience framework is used to assess the potential supply chain disruptions to NXP-ITEC semiconductors and generated appropriate measurements together with the managers. And the last, the usefulness of the resilience framework is explored

The resulting research framework is showed in Figure 3.

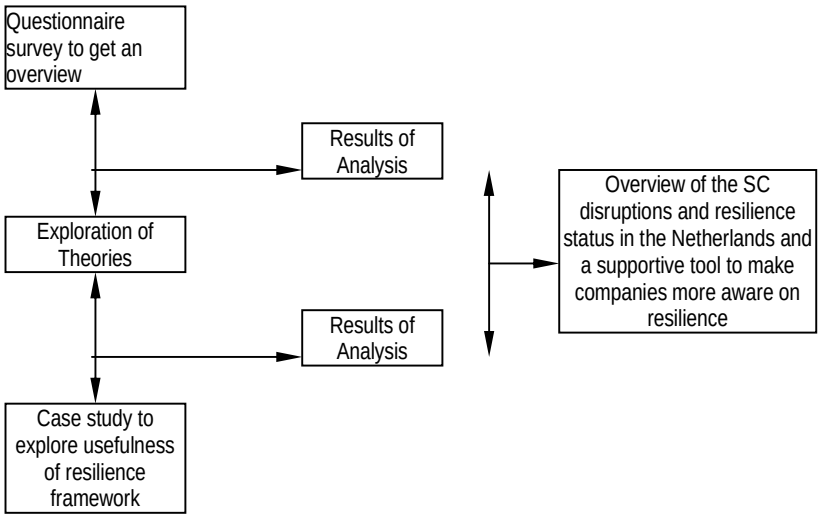


Figure 3 Research Framework

1.7 Thesis structure

Chapter 2 presents the theories used in this research and shows how they have been formulated and applied in previous researches. A review of various risks in supply chains is provided. The disruptions are described indicating drivers, failure modes and their impacts. This chapter also elaborates the concept of resilience. A review of existing strategies to achieve resilience is also provided. Chapter 3 refers specifically to the conceptual model and the design of the questionnaire survey. Chapter 4 presents the results of the survey. This chapter summarizes the most frequent disruption types, their causes, consequences and reactions of Dutch companies. These survey results provide the answers to the first two research questions. The first part of chapter 5 reviews the existing resilience frameworks and presents the new resilience framework designed by the researcher. The second part of chapter 5 elaborates the details of the case study, NXP-ITEC semiconductors pilot and the lessons learnt from this case study. In chapter 6 conclusions are formulated by summarizing the answers to the three

research questions. By comparing the results of the analysis and the theories, recommendations are provided to companies who want to become more resilient. Finally, the research indicates the limitations of this research and provides directions for further research.

Chapter 2 Literature Review

2.1 What is a Supply Chain Disruption?

Craighead et al., (2007) define **supply chain disruptions as unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain.** Materials/products flow and information flow are the main flows in the supply chain. Supply chain disruptions can occur in any node (such as supplier or manufacturer) and link (such as materials flow from supplier to manufacturer) of supply chains. Unplanned and unanticipated events do not occur regularly or periodically and are thus difficult to prevent.

The prior example of Storteboom can be used to illustrate this definition. Dutch government forbade the transport of live chickens and eggs because of the outbreak of 2003 Avian Influenza in the centre of the Netherlands. The supply chain of the Dutch chicken processing company Storteboom was badly influenced by the unanticipated event. The material flow (live chickens and eggs) between hatchery/meat chicken farm (supplier) and slaughterhouse/processing plant (manufacturer) was disrupted. The production of Storteboom was stopped due to no supply. Storteboom was not able to restore the transport and production. The disruption made Storteboom bankrupt.

2.2 Categories of supply chain disruptions

Kleindorfer and Saad (2005) categorize supply chain disruptions by:

(1) The events of **Operational Contingencies** which include equipment malfunctions and systemic failures, unanticipated discontinuity of supply, bankruptcy and other less severe forms of financial distress, and human-centered issues ranging from strikes to fraud;

(2) The events of **Natural Hazards** such as earthquakes, hurricanes, and storms. The examples are the Florida series of hurricanes in 2004 and the Taiwan earthquake in September 1999;

(3) The events of **Terrorism Attack and Political Instability.** The examples are 9/11 World Trade Center terrorism attack in 2001 and the political instability of Bangladesh in 2006. Kleindorfer and

Saad (2005) state that political instability has increased around the world and their effects to supply chains are also increasing.

Sheffi and Rice (2005) categorize supply chain disruptions by the matrix of disruption probability (from high to low) and consequences (from severe to light). They name the matrix as the vulnerability framework and provide several disruptions as examples to each category (see Figure 4).

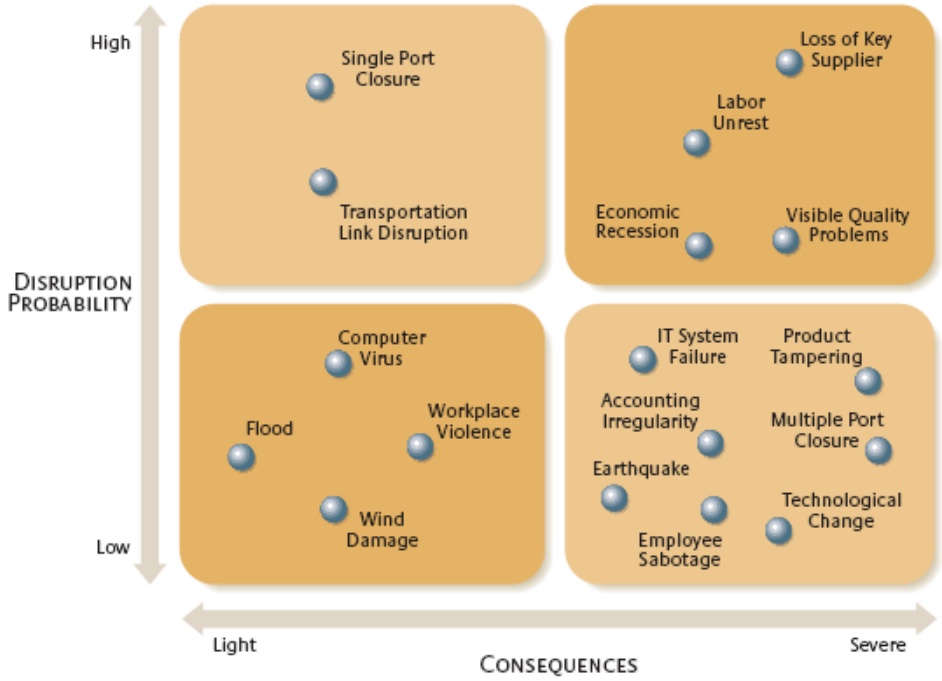


Figure 4 The Vulnerability Framework (Sheffi and Rice, 2005)

The framework is based on 20 case studies among American companies (mainly shippers). By this framework, they identify high vulnerability disruptions (high probability and severe consequence) and low vulnerability disruptions (low probability and light consequence). They advise companies to make priorities of their supply chain disruptions based on the probabilities and consequences. As their recommendation, companies should treat different supply chain disruptions in a different way. They consider improving flexibility (such as always setting up alternative supply sources or transport routes) and redundancy (such as building up safety stock buffering and use multiple plants/sites) as the strategies to make companies less vulnerable to supply chain disruptions.

2.3 Factors that make companies more vulnerable to supply chain disruptions

In the last decades, companies continually pursue lean supply chains by adopting advanced managerial systems such as Just-in-Time, Make-to-Order, Hub-and-Spoke distribution, single sourcing, zero Inventory and pull production. These systems help companies to reduce their operational costs and increase productivities; however, they also make the companies more vulnerable to supply chain disruptions (Kleindorfer, Saad, 2005; Craighead et al., 2007). Based on a study of nearly 800 instances of supply chain disruptions experienced by publicly traded companies, Hendricks and Singhal (2005) conclude the primary factors that make companies vulnerable to supply chain disruptions are:

Competitive environment: the competitive environment today initiated by intense market competition, volatile demand, customization, product variety and short product life cycle. The disruptions become more threatening because these factors all make it difficult for companies to balance demand and supply.

Increased complexity: off shoring requires good cooperation between manufacturers and suppliers. International operations are more complex than the domestic operations because of the differences in Culture, Economy, Society and Politics. Increased complexity makes companies more vulnerable to supply chain disruptions.

Outsourcing and partnerships: outsourcing and partnerships increase interdependence between companies. Companies become more vulnerable when their partners are exposed to certain disruptions. The increasing interdependence forces companies looking at their own vulnerabilities as well as the partners'.

Single sourcing: unavailability of alternative (back up) suppliers makes companies more relay on their sole supplier. The vulnerability is high when the supplier could not ensure on time delivery.

Limited buffers: the reduction of inventory and overtime production (when demand rises) could be a way to lower inventory cost. However, the ability to handle disruptions is lower than when there is sufficient inventory.

Focus on efficiency: too much focusing on efficiency leads to insufficient attention on the potential vulnerabilities. Most senior supply chain executives consider improving supply chain efficiency as their prime objective. Hendricks and Singhal (2005) emphasize that strategies for improving efficiency can increase risks of disruption.

Over concentration of locations: economies of scale, purchasing at volume discounts, and lower transaction cost are the motivations of companies to concentrate their operations at few/signal locations. Some companies even concentrate their suppliers or partners at the same location or nearby (such as TOYOTA and DELL). This increases the vulnerability of disruption because the businesses which in the same location or near by probably have the same threat such as hurricanes or earthquakes.

2.4 Failure modes of supply chain disruptions

Rice and Caniato (2003) conducted 20 case studies among companies (primarily shippers) in the US regarding the impacts of supply chain disruptions. The main contributions of their research are a categorization of impacts of supply chain disruptions and responding strategies to these impacts. They use the words 'failure mode' to describe the impacts of supply chain disruptions and suggest companies to build up resilience through increasing flexibility and redundancy to reduce these impacts.

Rice and Caniato (2003) describe failure modes as: *While there are many different types of risk, there are but a limited set of potential outcomes or impacts from any of the various risks. The term failure modes was used by several firms to connote this limited set of outcomes, effectively the few ways that the system could fail, regardless of the actual source of the disruption. Each failure mode could be generated by different causes, but the effect on the supply chain network is nearly the same. Despite the high number of threats and possible sources of disruption, the relevant failure modes are just a few, and they will probably remain the same even if new menaces appeared.*

Rice and Caniato (2003) indicate five types of failure mode:

Failure in supply: supply chain disruptions can result in a delay or unavailability in the supply of raw materials and spare parts from suppliers. This failure mode is particularly relevant to the companies relying on rare raw materials or spare parts; the companies rely on a supplier who has unique technology; and the companies operate on a lean supply/just in time base. The possible causes include

breakdown of suppliers' operations; exhaustion, monopoly or boycott in certain raw materials or spare parts; and also bankruptcy or merger & acquisition of suppliers, etc. Companies that use single sourcing are normally more vulnerable than those use multiple sourcing.

Failure in transportation: supply chain disruptions can result in a delay or unavailability of the transportation of raw materials, spare parts and completed products. In particular, companies that rely on international shipments are more exposed to this failure mode. (International) transportations are threatened by natural hazards such as storms, hurricanes, tsunamis and earthquakes; uncertain (import/export) regulation between countries such as the import/export quota between EU and China; terrorism attack and the responding actions by government such as 9/11 terrorism attack and blockage of ports, coasts and closure of national borders.

Failure in production (internal): supply chain disruptions can result in a delay or unavailability of plants, warehouses, office buildings, facilities/machines used in converting products. This failure mode is most relevant to companies that own high value assets and run manufacturing activities. Companies' productions can fail due to an on-site disruption (for example, a fire at the plant), a disruption at a supplier or a disruption in transportation processes. Compared to the first two failure modes, the failure in production could be the consequence of the failure in supply or transportation. It is especially true to manufacturing companies that operate just-in-time or have a single transport mode/route.

Failure in communication/information system: supply chain disruptions can result in a delay or unavailability of the communication and the information system. Besides physical goods flow (raw materials and completed products), information flow is also important in a supply chain. The development of internet technologies has resulted in many new patterns of business (such as e-commerce and Electronic Data Interchange/XML). Information flows and information systems play a critical role to companies that rely on electronic communication and transactions. Adopting/switching to a new information system (such as an advanced ERP system or WMS software) can disturb the existing operation of companies. Computer viruses can lead to loss of critical information/data or damage of the information system. In 2007 Coca-Cola Netherlands introduced a new ICT-system. After that a problem arises with the physical distribution of goods. During picking and sorting errors occur and as a result wrong orders arrived at customer. Coca-Cola Netherlands made use of other

production plants in Antwerp, Gent and Duinkerken to overcome the large demand of Coca-Cola, Fanta and Sprite (www.logistiek.nl, 2007)[1].

Failure in human resource: supply chain disruptions can result in a delay, loss or unavailability of human resources to continue operations. The most common failure in human resource is labour strike. Labour strikes can occur at suppliers, logistics service providers, manufacturers, distributors or retailers. One other failure in human resources is unavailability (temporary or permanent) of key personnel, who has specialized knowledge/skills or critical networks/relationships, due to illness or quit/retirement. This is especially true to companies that have intensive labour work or rely on the skilled labours that are rare/short in the labour market.

2.5 Stages of supply chain disruptions

Sheffi and Rice (2005) describe how companies' performances are changed by supply chain disruptions and restore back to original state. They divide the process of supply chain disruptions in eight stages (see Figure 5 below). Each stages defined by Sheffi and Rice (2005) are stated Figure 5.

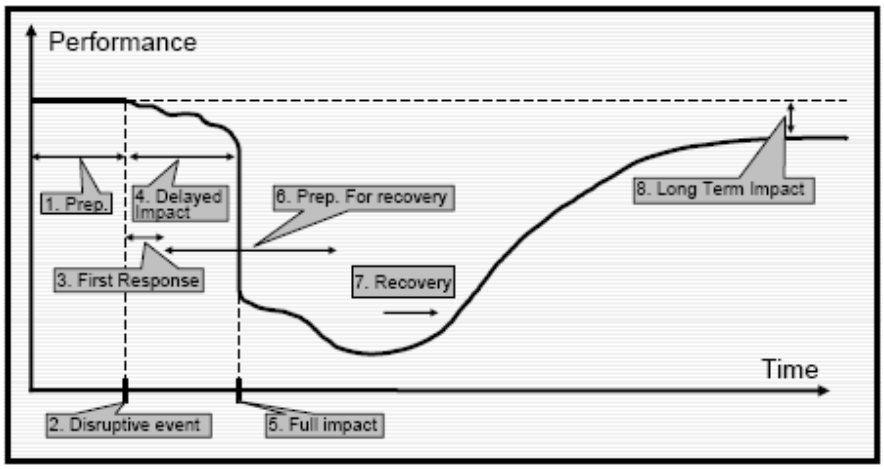


Figure 5 The process of supply chain disruption (Sheffi, Rice, 2005)

Stage 1. Preparation: in some cases, supply chain disruptions can be forecasted and prepared beforehand (such as the forecasting and preparation to the upcoming hurricane, flooding or earthquake; a labour strike which has already been announced by the union of labour). The impacts of supply chain disruptions could be minimized by the preparations.

[1] http://www.logistiek.nl/nieuws/id4753-Distributiemalaise_bij_CocaCola_duurt_voort.html

Stage 2. The Disruptive Event: this stage represents the moment that the event occurs. The examples are the aircrafts crashed into the World Trade Towers on September 11, the union of labour begins a strike or patients are found to be infected by SARS.

Stage 3. First Response: at this stage, immediate actions are taken in order to control the situation and minimize possible further damage. The example is the setting up of restrictive zones by Dutch government in order to prevent the spread of Avian Influenza.

Stage 4. Delayed Impact: some disruptions can take time to effect supply chains, especially those disruptions occurring in the upstream supply chain. Some disruptions can take time to affect a company, depending on factors such as the magnitude of the disruption, the available redundancy (such as safe store), and the inherent resilience of the organization and its supply chain.

Stage 5. Full Impact: whether immediate or delayed, once the full impact hits, performance often drops sharply. In general, initial impacts damage single link of supply chain, but bring more impacts to other links.

Stage 6. Recovery Preparations: before the performance can be recovered, companies make preparations and minimize the losses. The preparations are determining which parts are still available and which parts are not; finding alternatives (suppliers or transport modes); contact other links in the supply chain and formulate the recovery strategy and plan.

Stage 7. Recovery: carrying out recovery plan to restore the performance to the original or a desired state. The possible activities are running overtime/over capacity, sourcing from alternative supplier or using different transport route/modes, using similar spare part to replace the original one.

Stage 8. Long-Term Impact: some damages to supply chain processes are severe or even never to be restored. The examples are the company's image/reputation or the customer relationships. It takes a lone time and requires continual efforts to restore the reputations and customer relationships once they are damaged. The impact can last for a long term. Hendricks and Singhal (2005) indicate that the long term effects of supply chain disruptions include a decrease of long-term shareholder value, corporation profitability and an increase of share price volatility.

An example of Nokia and Ericsson provided by Peck (2003) can be used to illustrate these stages: *On the evening of March 17th 2000, a thunderstorm occurred in central New Mexico State of USA. A lightening bolt hit a power line, which caused a fluctuation in the power supply, which resulted in a fire in a local semiconductor plant owned by Dutch firm Phillips Electronics NV. The fire was brought under control in minutes, but a batch of trays containing enough silicon wafers for thousands of mobile phones were destroyed in the furnace. The damage to the factory from smoke and water was much more extensive than the fire itself, contaminating the entire stock of millions of chips. The suppliers immediately prioritized customers, according to the value of their business. Between them, Nokia and Ericsson accounted for 40% of the plant's output of the vital radio frequency chips, so these companies were put at the top of the supplier's list.*

Stage 1	*There was no preparation in this case.*
Stage 2	*The event was a fire caused by lightning in a thunderstorm.*
Stage 3	*First response was the efforts by the plant to put out the fire.*
Stage 4	*Initial impact was the damage of entire stock of millions of mobile phone chips and the production of the plant was stopped for a week.*
Stage 5	*Full impact was that main mobile phone manufacturers Nokia and Ericsson lost chips supply for their productions in the months immediately after.*
Stage 6	*- The recovery preparation of Nokia were:* • *Sent out engineers to America to investigate the situation* • *Enhanced monitoring of incoming supplies on a weekly to daily base* *- Ericsson was not aware of the severity of the event and did not prepare for the recovery.*
Stage 7	*- The recovery activities of Nokia were:* • *Forced Philips using any additional capacities in all other plants (other than the one burnt) to meet Nokia's requirement.* • *Sent out representatives to alternative suppliers in America and Japan for available supplies and persuaded them to start production immediately* • *Reconfigured its products to take slightly different chips from other sources* • *Reduced lead time to less than a week by negotiating with suppliers* *- No recovery activities were carried out by Ericsson until April. Ericsson had no alternative suppliers because of the strategy of single sourcing*
Stage 8	*- The long term impact to Nokia were:* • *The production level was restored and the supply of chips was consolidated* • *Market winner* *- The long term impact to Ericsson were:* • *Lost sales of USD 400 million*

Table 1 Stages of supply chain disruptions applied to the example of Nokia & Ericsson

2.6 What is resilience?

In material science, resilience is the physical property of a material which causes it to return to its original shape or position after a deformation that does not exceed its elasticity (Rice, Caniato, 2003). In business context resilience is an organization's ability to react to an unexpected disruption such as one caused by a terrorist attack or a natural disaster and resume normal operations (Coutu, 2002). Resilience implies the ability of a system to return to its original or desired state after being disturbed (Christopher, Peck, 2003). Enterprise resilience is the ability and capacity to withstand systemic discontinuities and adapt to new risk environments (Starr, Newfrock, Delurey, 2003). A definition of resilience used in this research is provided by Rice and Caniato (2003):

> ***Resilience is the ability to react to an unexpected disruption and restore normal supply network operations.***

A resilient organization effectively aligns its strategy, operations, management systems, governance structure, and decision-support capabilities so that it can uncover and adjust to continually changing risks, endure disruptions to its primary earnings drivers, and create advantages over less adaptive competitors (Starr, Newfrock, Delurey, 2003). Other authors mentioned organizational resilience as:

- The maintenance of positive adjustment under challenging conditions (Worline et al., 2004)
- The ability to bounce back from untoward events (Sutcliffe, Vogus, 2003)
- The capacity to maintain desirable functions and outcomes in the midst of strain (Bunderson, Sutcliffe, 2002; Edmondson, 1999)

Resilience capacity is a multidimensional construct at the organizational level that describes collective behaviours and attitudes (Lengnick-Hall, Beck, 2005). It is the unique blend of cognitive, behavioural, and contextual properties that increase a firm's ability to understand its current situation and to develop customized responses that reflect that understanding. The three components of resilience capacity are:

- **Cognitive resilience:** the organization has a deep understanding of what's happening around it. (Cognitive resilience is a conceptual orientation that enables an organization to notice, interpret, analyze, and formulate responses in ways that go beyond simply surviving an ordeal.)
- **Behavioural resilience:** the organization is capable to react in a systematic, proactive fashion when something unexpected occurs**.** (Behavioural resilience is the engine that moves an

organization forward. This property enables a firm to learn more about the situation and to fully use its own resources and capacities through collaborative actions.)

- **Contextual resilience[2]:** the organization has a good network relationship and thus has a knock for getting others' help to rapidly cope with and respond to changes. (Contextual resilience provides the setting for integrating and using cognitive resilience and behavioural resilience. It is composed of connections and resources.)

The trends of globalization, off shoring and outsourcing have made the supply chains more and more complex and vulnerable. On the other side, the vulnerability of logistics networks increased as a consequence of longer and more efficient (lean) supply chains. The direct result is that the even smallest disturbance could easily lay down the entire networks. This can lead to huge volume of trade loss, because of the possible withdraw of customer orders or could not attain the required customer service level. On the long term, it can even lead to a damage of corporate exist image or loss of market share. The same as that many risks within the supply chain, there are also several risks in the external surrounding to supply chains, such as storms or hurricanes. They normally are more difficult to prevent and make much more serious consequences, especially at the structure of the logistics network itself. A TNO research shows that the US business units of a large multinational manufacturing chemicals, fibres and plastics has a sleeping hurricane team that becomes active preceding the hurricane season (Eijkelenbergh et al., 2007). This team continuously checks inventory positions (both of own companies as those of suppliers) to prevent stand still of plants.

The core concept of supply chain resilience is that a business can keep on producing or distributing after an unexpected disturbance in the supply chain. By the concept, resilience strives to restore/recover the supply chain process against the possible disturbances. The main distinguish between security and resilience is that the former more focus on to preventing the disturbance, but the later more focus to quickly return to the original state or to a desired balance. Both are useful to reduce risks and have to

2 In this research, the respondents of the survey (see chapter 4) could indicate their cooperation/relationship with their direct supplier and their direct customer, but no more. For this reason, the survey can not get the information of the whole supply chain, but part of the supply chain (three stages: former stage-focal company-later stage). Second, the focal company can have many direct suppliers in the former stage and many direct customers in the later stage. In this situation (actually very often), the focal company is at the same time in many different supply chains, and the different supply chains have different structures and could be involved in different industries, the focal companies could be resilient in this supply chain but not in another one. They all make the measurements to the whole supply chain invisible. As an effect of this limitation, this research mostly focuses on Cognitive Resilience and Behavior Resilience.

be regarded as complimentary. In the vulnerability map which provided by Sheffi and Rice (2003, 2005), risks are measured in two dimensions; probability and impact (see the equation below).

Risk = probability * impact (Sheffi & Rice, 2003)

In this equation, risk is the multiple products of probability and impact. It will become smaller by reducing either probability through security measures or impact through resilience measures. Security aims to reduce the risk before supply chain disruptions have taken place. Resilience aims to develop a supply chain strategy that brings fewer losses after a disruption

It is commonly agreed that risk is the combination of chance and consequence. Security is the strategy to decrease the probability of a disturbance and resilience is the strategy to reduce the impact of disruption (strategy developed to limit the damages).

The figure below shows the drivers, the events and the consequences of supply chain disruptions (some examples are also provided). It also shows the different phases of security and resilience in the whole process. The items are explained in the following section.

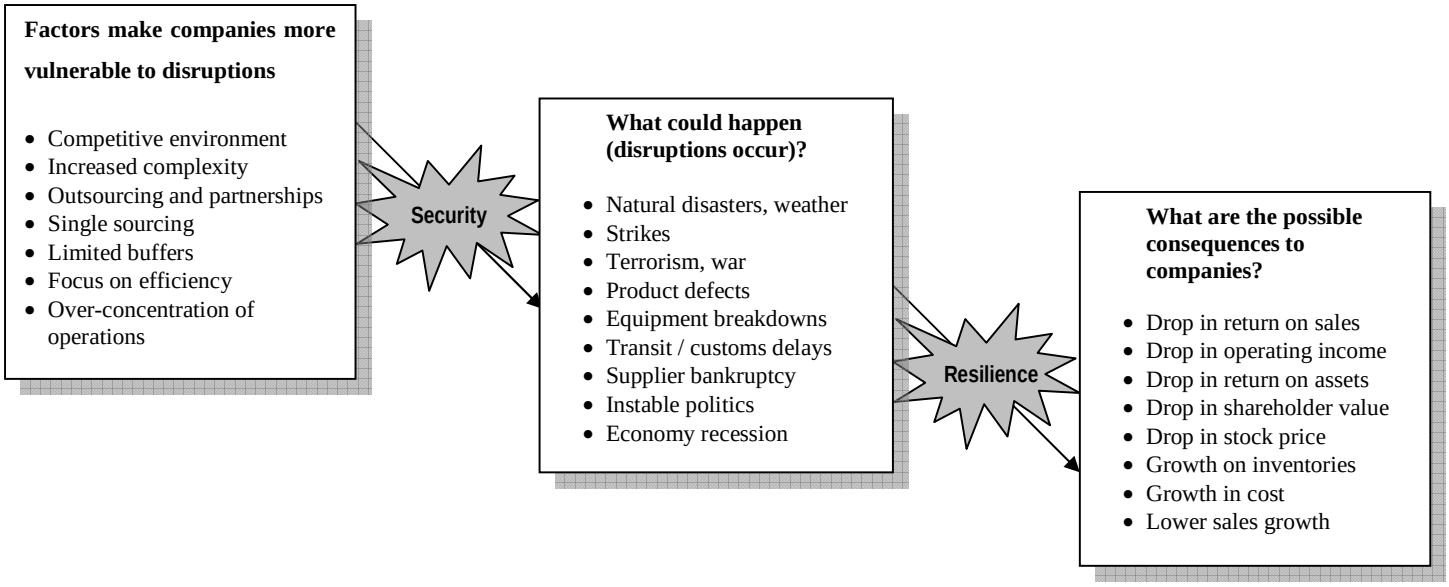


Figure 6 An overview of the driving factors, events and consequences of disruptions

In 2002, the survey 'Protecting Value Study' was conducted among Fortune 1000 firms by the National Association of Corporate Treasures, FM Global and Sherbrooke Partners. It was in the topic of supply

chain risks and disruptions. There were 199 Fortune 1000 companies that responded to the survey. Most of the respondents were in the positions of financial executives, risk managers and treasurers. The survey results (partially) were (www.protectingvalue.com):

- *More than 75% of the respondents said that a large disturbance in their top earning driver would either cause sustained damage to their firm's earnings or threaten its continuity of operations.*
- *Less than 25% of the respondents believed that their current risk management efforts sufficiently address key areas of contingency planning.*
- *More than 33% of the respondents answered that the senior managers of their business lacks understanding of the impact a major disruption would have on their company. The preparation for major disruptions is also missing.*

The results of this investigation show that companies are not really aware at the impacts/consequences of supply chain disruptions and can not respond efficiently once they occur. Their operations can be damaged by disruptions either to them or their supply chain partners. A good business continuity plan could help companies better prepare to supply chain disruptions. Several conceptual frameworks for supply chain resilience are provided by Christopher and Peck (2003), Sheffi and Rice (2005) and Cocchiara (2005). They will be discussed in detail in chapter 5.

Chapter 3 Research Design

In the previous chapter, the contexts of supply chain disruptions and resilience have been outlined. These contexts are the theoretical foundation of the empirical research: the survey and development of a resilience framework tested in a case study.

This chapter is organized as follows: first to state again the three research questions of this thesis and indicate how they can be answered. After that, the design of the questionnaire survey will be discussed. Finally, the outline for the developed resilience framework will be provided.

The first two research questions of the thesis are: *"what are the main causes of supply chain disruptions to Dutch companies?"* and *"what have Dutch companies done to overcome the disruptions?"* These two questions can be answered by conducting a questionnaire survey. The results will be provided in chapter 4. The third research question is: *"what can Dutch companies do to become more resilient to such disruptions?"* It is very difficult to answer this question because of the extreme complexity (large amount of Dutch companies and they are in various industries and businesses). However, this research tries to answer it through the development of a resilience framework as tested in a single case study. It is obvious that the results of the case study do not have the generality to Dutch companies. The results will be presented in chapter 5.

3.1 Design of a questionnaire

The objective of the questionnaire survey is to explore the state regarding supply chain disruptions in the Netherlands and the reactions of Dutch companies. The results of the questionnaire survey provide the answers of the first two research questions. The targeted population of the questionnaire survey is the manufacturing/trading companies and LSPs located in the Netherlands. It includes original Dutch based companies and the Dutch subsidiaries of international companies. The sampled companies are the members of national organizations TNO, EVO, TLN and NDL. The team Logistics is part of the business unit Mobility & Logistic at TNO, it provides consulting services in logistics to customers (such as the sampled companies). EVO is an association of Dutch manufacturing/trading companies. Compared with EVO, TLN is an association of Dutch transport and logistics companies. NDL is an organization of Dutch import/export and its members are also the members of EVO and TLN. The sampled companies have been contacted via the four organizations.

Different questionnaires are designed for Manufacturing companies and Logistics Service companies. The main reason is that these two groups have different risks and disruptions. For instance, manufacturing companies are exposed to the risk of production and many risks from their material suppliers. However, the pure logistics service companies normally don't (because their customers take the risks).

The questionnaire was designed into three blocks----background information, disruptions and resilience. The block of background information explores details of the responding companies. The detailed information includes industry, core business and main activities. The second block is in the form of open questions. The aim is to record significant disruption events of the responding companies. The questions includes the cause of the disruption, the period of the event, the first response activities, the long term recovery activities and the lesson learnt from the disruption. The last block explores the resilience performance of the responding companies[3]. The questionnaires include the awareness of resilience, the performance regarding to resilience and the willingness to improve company's resilience level and so on.

The contents of the two questionnaires are also different between manufacturing/trading companies and LSPs (mainly in the causes of disruptions). The detailed difference can be found in the formal questionnaires in the appendix.

The way of analysis is to group the supply chain disruptions by their causes. The cause can be a natural disaster, a fire or a bankruptcy of supplier. Based on the grouping, the consequences of the events are identified. For instance, the consequence of a fire can be a disruption in production (when the fire occurs at the factory) or a disruption in transport (when the fire occurs at the company who provides transport service). Finally, the responses of companies regarding these supply chain disruptions are indicated.

[3] The original idea of block three is to collect data in 5-points scale and analyze them via SPSS. However, the quantity of respondents (only 18 manufacturing/trading companies; 17 LSPs) is not sufficient to conduct a quantitative analysis (the results will not be significant). Due to this reason, block three will not be analyzed in this thesis.

3.2 Design of resilience framework and test in case study

The first two research questions report the facts regarding supply chain disruptions and recovery activities of Dutch companies. They require a collection of information from many different companies (divers in location, industry and business area) thus a survey is the best option. The third research question concerns the possible way of creating resilience in supply chains. The literatures in chapter 5 show several conceptual frameworks of resilience provided by experts such as Sheffi & Rice and Christopher & Peck. However, these conceptual frameworks only indicate the factors that influence supply chain resilience. Using the conceptual framework of Christopher and Peck as an example, it indicates that resilient supply chains can be achieved through supply chain (re)engineering. Companies may be aware that they should (re)engineer their supply chain, but it is still not precise. In order to answer the third research question (what can Dutch companies do?), the researcher designs a step-by-step approach regarding creating resilience based on the conceptual frameworks as available as available nowadays. This part of research is in cooperation with a large Dutch company; NXP semiconductors.

Chapter 4 Empirical Finding from Survey

This chapter first presents the general information (e.g. location, industry, business area) of the participating companies of the survey. After that, an analysis to the supply chain disruptions to these Dutch companies is provided. The supply chain disruptions are grouped by their causes (e.g. storm, fire or labour strike). Based on the grouping, the responding actions of these Dutch companies to the disruptions are also described. The first two research questions (what has happened regarding supply chain disruptions in the Netherlands and what have Dutch companies done) are answered by the analysis.

4.1 Data Description

On behalf of TNO (The Netherlands Organization of Applied Scientific Research), I conducted a survey among Dutch companies (I developed the questionnaires; the printing and delivery of the questionnaires were managed by TNO; EVO, TLN and NDL forward the questionnaires by email or put it at the VLM portal). 750 questionnaires were sent to Dutch companies which are the contact companies of TNO or members of EVO, TLN and NDL. 35 of them were returned in the following six weeks, 18 of them were manufacturing/trading companies and 17 were LSPs. The response rate was low (4.7%) and the main reason could be the complexity of the topic (this is indicated by the colleagues at TNO who have abundant experiences of doing surveys in similar topics to Dutch companies). In order to attract the attention of companies and increase the response rate, the questionnaires were printed on paper and sent out through the networks of TNO, EVO, TLN and NDL. Most of these questionnaires were filled out by logistics/supply chain managers, production managers; purchase managers and directors. They described 44 supply chain disruptions they experienced in the last 5 years. The industries of manufacturing/trading companies and the businesses of LSPs are showed in the Table 2. In the table, manufacturing/trading companies are coded from M1 to M18; and the LSPs are coded from L1 to L17.

Table 2

Code	Industries of Manufacturing /trading companies	Code	Businesses of LSPs
M1	Tobacco	L1	Terminal
M2	Chemical	L2	Transport
M3	Chemical	L3	Logistics
M4	Chemical	L4	Flower auction
M5	Press (books)	L5	Distribution (books)
M6	Foods	L6	Transport
M7	Electronics	L7	Express/transport/logistics
M8	Flower	L8	Logistics
M9	Chemical	L9	Cargo Care
M10	Fashion	L10	Logistics
M11	Electronics	L11	Logistics
M12	Electronics	L12	Transport
M13	Household	L13	Fashion Logistics
M14	Semiconductors	L14	Integrated Logistics
M15	Semiconductors	L15	4PL
M16	Metals	L16	Transport
M17	Wooden	L17	Logistics
M18	Paper		

The companies participating in the survey

These companies are located in different areas of the Netherlands. Figure 7 shows the locations of responding companies. In this figure, manufacturing/trading companies and LSPs are differentiated by colours.

Figure 7The companies participated in the survey

As showed in Figure 7, manufacturing/trading companies (marked in blue) and LSPs (marked in orange) are randomly spread over the Netherlands. The majority of these companies are more in the middle and west Netherlands other than north and east.

More information (includes industry, business area and assets/facilities) of these companies is provided in Table 3. In case that one company runs more than one business and owns multiple assets/facilities, the sum of each category are not equal to each other and they are all bigger than the number of companies (18-manufacturing/trading companies and 17-LSPs). For example, one LSP can have the business of transport and storage. As a result, this company is presented twice in the table.

Manufacturing/trading companies			
Categorization based on industries		**Categorization based on business areas**	
Electronics	5	Wholesale/trade	8
Chemical	4	Assembling	6
Pharmacy	3	Production (end product)	6
Non-food	3	Production (work-in-process)	6
Food	2	Production (raw materials)	4
Building/materials	2	Retail	3
Paper/packing	2		
Automobile	1		
Fashion	1		
Spare parts	1		
White and brown goods	1		
LSPs			
Categorization based on business areas		**Categorization based on assets/facilities**	
Transport	13	Truck	14
Storage	12	Warehouse	13
Value adding service	8	Train	4
		Vessel (sea transport)	4
		Barge (inland waterway)	4
		Aircraft	4
		Tank/silo	1

Table 3 Categorization of responding companies

The manufacturing/trading companies (4 companies M5, M9, M11 and M16 are trading companies, the rest (14 companies) are manufacturing companies) cover the major industrial areas such as: electronics, chemical, automotive, pharmaceutical, clothing, and foods & drink. Companies in the following three industries take up more than half of total: electronics (25%), chemical (16%) and pharmaceutical

(12%). They are active in several business areas such as: raw material supply, manufacturing semi-finished products, manufacturing for end products, retail and logistics. The most significant business areas are retail (33%), manufacturing end product (18%) and manufacturing semi-finished products (18%).

The LSPs are concentrated in the business areas of transportation (36%), warehousing (36%) and other value adding activities (27%). In order to provide logistics services to customers, these LSPs own or rent various facilities and assets: 32% of the LSPs own trucks, 30% of the LSPs operate at least one warehouse.

4.2 Causes of supply chain disruptions to Dutch companies

In the questionnaire survey, companies were asked to describe their supply chain disruptions by answering a series of open questions. The first three open questions concerned the cause, time and consequence of disruptions. By combining the answers of these questions, the rough story of these disruptions became clear. The cause of disruptions varied from a labour strike in Rotterdam harbour to a key supplier bankruptcy. The details of all supply chain disruptions are attached in the appendix. By grouping similar causes, it can be concluded that the supply chain disruptions to Dutch companies in the last five years were mostly caused by:

- Strike or unavailability of labour (21% of all disruptions)
- Bankruptcy or unreliability of supply chain partner (mainly supplier) (18%)
- Unavailability of infrastructures or transport (e.g. harbour, road, airport or tunnel) (14%)
- Legislation/regulation of government/authority/institution (11%)
- Natural disaster (e.g. storm, flood or SARS) (11%)
- IT system turns down or incompatible with existing operation (9%)
- Fire at the plant, warehouse or office (9%)
- No electricity supply to continue operation (7%)

Figure 8 provides an overview to the causes of supply chain disruptions in percentages. For example, labour strike/unavailability is the most frequent cause of disruptions and it caused 21% of disruptions mentioned in this survey.

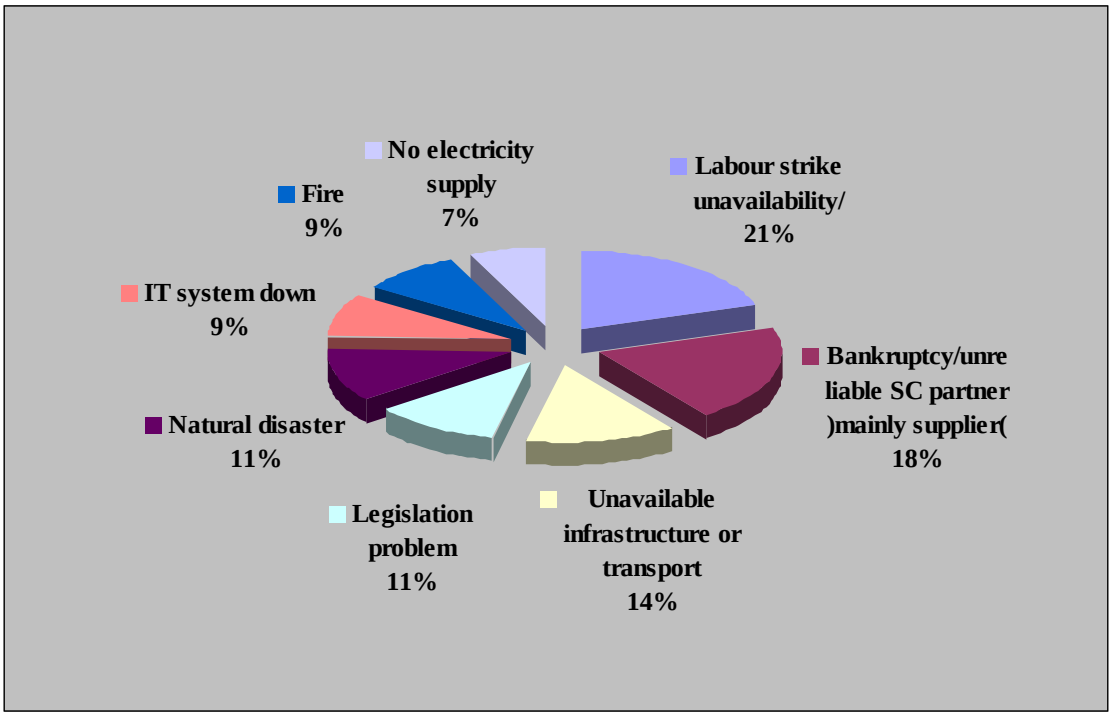


Figure 8 An overview to the causes of supply chain disruptions (N=44)

4.2.1 Labour strike and unavailability

Nine supply chain disruptions were caused by labour strike and unavailability (mentioned by LSP: L1 (2x), L7, L8, L13 and manufacturing/trading companies: M4, M10, M12, M18).

For LSPs, the primary cause was the unavailability of qualified truck drivers and order picking staffs in warehouse. It is difficult to recruit 'ready-to-use' employees directly from the labour market. The new employees need to be trained to become 'qualified' to the companies' information system (such as WMS) and working environment (such as the transport routes and schedule) before they can really start. The training can take up to several months. The consequences were that trucks and other facilities could not be used; on time delivery could not be ensured and quality of service was more difficult to realize. These LSPs responded to labour strike and unavailability by the following actions:

- Contact employment agencies (3x, L1, L8, L13)
- Hire temporary truck drivers (e.g. from Germany or Eastern Europe) (3x, L1, L8, L13)
- Enhance internal training (2x, L7, L8)
- Issue job advertisements (2x, L1, L8)
- Make use of charters (2x, L1, L8)
- Reward adjustment (partly fixed and partly flexible based on performance) (2x, L7, L13)

- Motivate employees by good corporate culture (2x, L1, L13)
- Better contact with education institutes (2x, L1, L7)
- Reallocate employees from other branches or departments within the company (1x, L13)

The second cause of disruptions to LSPs was a labour strike at a terminal. There was only one case in this survey. It was especially true to a large container terminal operator. Although the labour strike at the terminal only lasted several days, the consequences were large. The routine operations such as loading/uploading, container transport and storage were stopped. Vessels were waiting outside the terminal for days or switched to alternative ports. The terminal operator responded to the disruption by the following activities:

- Negotiate with labour union or other social parties at the terminal (1x, L1)
- Contact alternative terminals (1x, L1)

For manufacturing/trading companies, the reported supply chain disruptions caused by labour strike and unavailability mainly occurred at their suppliers or contracting LSPs. The labour strike at the supplier of a company (M18) led to supply chain disruptions in the failure of supply. Disruption in transport occurred at the French railway operator (M4), ECT Delta terminal (M12) and Rotterdam harbour (M10). Although the failure modes were different, the consequences to manufacturing/trading companies were more or less the same. Due to a strike at the supplier, the company (M4) lost the supply of raw materials and had to shut down operations in extreme circumstances. The reported consequences also included large loss of sales and damage of customer royalty (M10, M12). The actions carried out by manufacturing/trading companies were:

- Contact alternative supplier/LSP (3x, M4, M10, M18)
- Multiple sourcing/transport route (2x, M4, M18)
- Make use of safety stock (2x, M10, M12)
- Adjust production equipment/technique/process in order to use similar raw materials/spare parts (1x, M12)

4.2.2. Bankruptcy or unreliability of supply chain partners (mainly suppliers)

Eight supply chain disruptions were caused by bankruptcy or unreliability of supply chain partners (mentioned by manufacturing/trading companies: M2 (2x), M7, M8, M9, M14 and LSPs: L10, L13).

The supply chain partners mainly included key suppliers, B2B customers and LSPs (of manufacturing/trading companies).

Two manufacturing companies (M9, M14) reported supply chain disruptions by bankruptcy of suppliers. The supplier the company (M14) was taken over by another company. In another case, the supplier of the company (M9) went bankrupt. The long term contact/relationship with the management team became useless in both cases. In the first case, the management team was changed after the company was taken over. After that, the supplier even quit the business because the new venture had a new mission statement and industry/business reorientation. The direct consequence was a failure in supply. In the case of the company (M14), the supplier suddenly went bankrupt. As a result, the production of the company (M14) was disrupted in the period 2005 – 2006. Customer demand could not be fulfilled timely and orders were missed. The two manufacturing/trading companies were hurt severely by the disruptions because they did not anticipate the disruptions and thus no preparations were done in advance. A Manufacturing company (M2) outsourced its global delivery activities to a shipping company which was one of the biggest in the world. The manufacturing company was totally depended on the shipping company for the transport of hazardous goods. In 2006, this shipping company merged with another top shipping company and decided it does not longer serve the manufacturing company. The manufacturing company was not able to reach the desired world wide customer service level for half a year. The main reactions of manufacturing/trading companies were:

- Redundant supply chain partners identified (4x, M2, M7, M9, M14)
- Make use of standardize materials/components (2x, M9, M14)
- Make use of inventory (2x, M7, M9)
- Establish advanced supplier selection criteria (1x, M14,)
- Continually checking the financial states of suppliers (1x, M14)

A LSP (L10) reported that it lost a major B2B customer which took 30% of its total turnover. The customer switched sourcing to another logistics company which was 18% cheaper in price. As a result, the company (L10) had to shut down its capacity up to 60%. Another LSP (L13) suddenly lost the cooperation with a partner because it (the partner) was taken over by another company. The company (L13) lost a large amount of import and export (250.000 – 500.000 euro a year). These LSPs overcame the disruptions by:

- Measure potential disruption in advanced (2x, L10, L13)

- Look for alternatives (2x, L10, L13)
- Customer differentiation/diversification (looking for customers in multiple industries, businesses and countries) (1x, L10)

4.2.2 Unavailability of infrastructures and transport (e.g. harbour, road, airport or tunnel)

The significant infrastructures such as harbour, airport or highway are easily to be damaged by nature disasters or terrorist attack. The reconstruction of infrastructure normally requires a long period. The usages of these infrastructures can be affected by the intervention of government. There were 5 disruptions caused by unavailability of infrastructure and transport reported by manufacturing/trading companies (M2, M8, M10, M11, and M15) and 1 reported by LSP (L2).

A manufacturing company (M11) described a disruption that was caused by the unavailability of an airport. In 2004, Bangkok International Airport was extra busy during the flower peak season. A large amount of flowers needed to be delivered in a short time in order to keep fresh. The flights for flowers took up a big amount of transport capacity of the airport. It led to a delay to other deliveries. As a result, the company (M11) had to wait for its goods for an additional three weeks. It brought extra logistics cost. Another large manufacturing company (M15) mentioned that due to the opening up of a new Thailand international airport in 2006, their air deliveries were delayed for a period of two weeks. The third case was provided by flower trading company (M8). It stated disruptions as delayed flights, changed flights, no cooling during transport and storage of flowers occurred frequently in the period of 2006 and 2007. Therefore flowers arrived in a lower condition at airports. The companies had the following responding actions:

- Close contacts with airport authorities (2x, M10, M15)
- Cooperate with organizations that have local knowledge regarding transport (1x, M10)
- Be more aware of the peak season and thus avoid the transport capacity bottleneck (1x, M11)
- Make use of express deliveries (1x, M11)

Although the availability of transport infrastructures was very important to the activities of LSPs, there was only one LSP (L2) that reported the disruption. There was a serious downburst occurred in 2007 and it destroyed the warehouse of the company (L2). All the stocked goods in the warehouse were lost. Reconstruction of the warehouse took several months and storage was not possible during the period. The LSP had done:

- Build up expertise regarding emergency such as downburst of a building (1x, L2)

4.2.3. Legislation/regulation of government/authority/institution

This cause of supply chain disruption mostly comes from the interventions of government and (international) organizations. Recall the example of Storteboom in chapter 1. The transport of eggs and live chickens were totally not allowed by the government in order to prevent the spread out of Avian Influenza to other areas of the country. It directly resulted in a disruption to their chicken processing activities. This was a typical example of this cause of disruption. In the survey, there were 4 disruptions caused by legislation/regulation of government or other (international) organizations mentioned by manufacturing/trading companies (M10 (2x), M17 (2x)) and 1 disruption mentioned by a LSP (L16).

A manufacturing company (M17) chops down trees in the Netherlands. It consumes a big amount of wood each year as raw materials. Some significant production activities were forbidden or constrained by the new flora and fauna legislations of Dutch government in order to protect forest. The disrupted productions were moved to Germany. The company M17 spent 4 months to move all the equipments to Germany, as there was no production possible in the relocation area in the Netherlands. A global clothing company (M10) produces largely in China and sells the products in its shops in Europe. It mentioned that there were several agreements between China and EU on import/export quota to protect European products for certain fashion categories in the year of 2005, 2006 and 2007. As a result, the possibilities to source specific fashion from China were limited. These manufacturing companies have the obligations to follow these legislations and thus their supply chains were disturbed. They replied these legislations in the ways of:

- Reallocate forbidden production activities (2x, M10, M17)
- Sourcing from different countries (2x, M10, M17)

There was one LSP (L16) claimed that government legislations were unreliable and there is no clear vision on long-term regulations. Too many inspections were conducted by different organizations. There were much double working activities and moreover often without notice in advance. The LSP (L16) had not any reaction to these interventions from government and other organizations.

4.2.4. Natural disaster (e.g. storm, flood or SARS)

The possible natural disasters in the Netherlands are storm, heavy snowfall, flooding due to heavy rain showers and diseases (such as Avian Influenza). Both the type and frequency of natural disasters are relatively low in the Netherlands. From a supply chain perspective, Dutch companies are also affected by the natural disasters that occur outside the Netherlands. There were 3 disruptions mentioned by manufacturing/trading companies (M10, M15, and M17) and 2 disruptions mentioned by LSPs (L14, L17) were caused by natural disasters.

A manufacturing company (M15) mentioned that a large amount of its deliveries were delayed due to the SARS outbreak in Asia 2003. The disaster disturbed the import/export between Asia and Europe. The disruption lasted for a period of 2 months. Another manufacturing company (M17) chops down trees. It mentioned that a storm made a huge damage to the forest in July 2006. It resulted in a collapse at the wood market and the prices of wood largely went down. This market condition directly impacted the production of this company (its production cost became too high because the sale price went down). These manufacturing companies conducted the following activities:

- If possible, adjust sourcing/production schedules to avoid the period/season in which the nature disasters occur frequently (e.g. storms are more often in winter) (1x, M17)
- Make use of alternative infrastructure (1x, M15)
- Build up business continuity plan regarding emergency (1x, M15)

A LSP (L14) stated that one of its office/DC was hit by a flooding due to heavy rain showers in 2003. Its electricity was switched off for a period of 2 days as transformer facilities were flooded and thus all IT facilities were shifted down. The disruption lasted for 3 days. As a result there were losses to dock levellers, stocked goods and the offices were damaged. Another LSP (L17) mentioned that in the winter time of 2004/2005, 2005/2006 and 2006/2007, there were heavy snowfalls in the Netherlands. Roads were heavily congested and thus traffic was disrupted for full nights. The full loaded trucks of the LSP were stuck on the highway and thus could not get to customers in the right time. They responded the natural disasters by:

- More aware about weather forecasting/disaster alarm (2x, L14, L17)
- Make business continuity plan (1x, L14)
- Protect fix assets through insurance (1x, L14)

4.2.5 IT system turns down, Fire and No electricity supply

The above mentioned five causes are the major causes of supply chain disruptions in the Netherlands. They together cover more than 76% of the disruptions that are reported in the survey. Beside these main causes, there were also other minor causes reported by these companies. They were: IT system turns down or incompatible with existing operation (4 disruptions reported by M5, M12, M14 and L2); fire at the plant, warehouse or office (M6, M18 and L9, L14); and no electricity supply to continue operation (M13 and L6, L14). In general, fire and no electricity supply can be prevented by enhancing safety and security measures. For instance, companies can use automatic fire alarms and install a back up power supply. In the survey, IT system turns down included a failure in the communication network (company L2); switched to a new WMS (warehouse management system) (company M14); and unavailability of the online order system (company M5). The results were incorrect delivery (incorrect products were delivered to the customer or in a wrong quantity) (company L2); new WMS was not compatible to the existing operations (company M14); and loss of sales because customers could not order via the internet booking system (company M5).

The response of companies to IT system problems included:

- Make use of multimedia communication (1x, L2)
- ICT relative measures (1x, M14)
- More contact with the provider of IT system/internet/cable (1x, L2)
- Copy significant data/information (1x, M14)

The responses of companies to electricity supply included:

- Contact electricity supplier to deliver back-up power unit (1x, M13)
- Purchase of back-up power unit (1x, L6)
- Hired a back-up power unit during peak hours (1x, L14)

The responses of companies to fires included:

- Improve safety and security inspections regarding fires (4x, M6, M18, L9, L14)

Chapter 5 Resilience Frameworks and Case Study NXP-ITEC

This chapter first reviews three existing resilience frameworks and discusses their strengths and weaknesses. Secondly, it provides the new resilience framework designed by the researcher and two colleagues of TNO. Thirdly, this chapter also provides the results of the case study at NXP-ITEC. At last, it states the lesson learnt out of this case study.

5.1 Review of conceptual frameworks for supply chain resilience

This section describes three conceptual frameworks of supply chain resilience. These frameworks aim at indicating the factors that influence supply chain resilience.

5.1.1 Conceptual framework by Christopher and Peck

Christopher and Peck (2003) suggest creating resilience by better managing supply chain risks. They categorize supply chain risks as supply risk, process risk, demand risk, control risk and environmental risk. Supply risk relates to potential or actual disturbances to the flow of product or information upstream of the focal firm. Demand risk is the downstream equivalent of supply risk. Supply risk and demand risk are external to the focal company but internal to the supply chain. Process risk relates to disruptions in product conversion and value addition. Control risk arises from the application or misapplication of rules, procedures or management systems. Process risk and control risk are internal to the focal company. Environmental risk concerns the events outside the scope of the supply chain such as natural disasters, governmental policy and economic regression. They indicate that a resilient supply chain considers risk reduction and business continuity as one of the most significant management objectives. A conceptual framework ‘creating the resilient supply chain’ is provided to minimize the five supply chain risks.

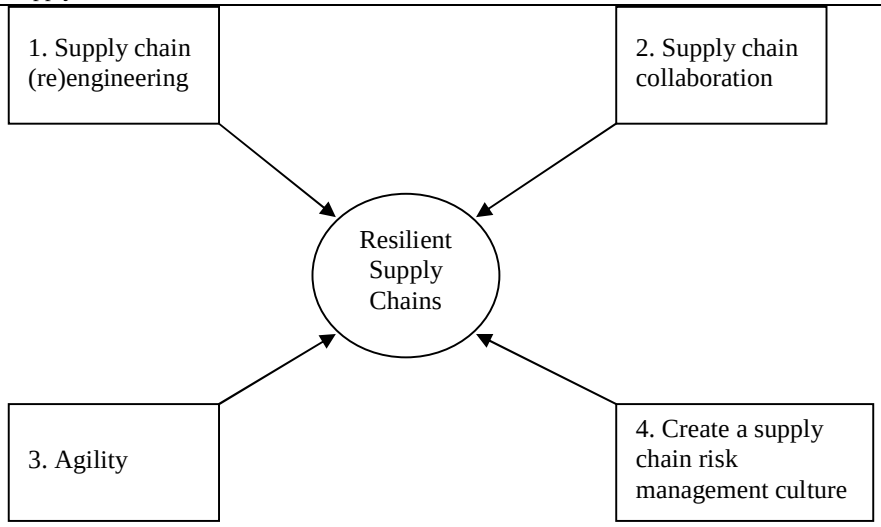


Figure 9 Adapted conceptual framework of Christopher and Peck (2003)

Supply chains are normally designed to minimize cost or maximize/optimize customer service, rarely to minimize risk. The framework shows four factors toward resilient supply chains (see Figure 9).

Factor one – Supply chain (re)engineering

Companies can redesign/reengineer their supply chains by embedding the risk management concept. The main activities are building up supply chain understanding (mapping critical processes and register main risks in these processes); establishing supply base strategy (multiple sourcing and supplier selecting criteria); and designing principles for resilience (flexible or redundant supply chain).

Factor two – Supply chain collaboration

Supply chain collaboration includes collaborative planning (a plan to create a condition that allows different participants cooperating smoothly) and supply chain intelligence (sharing knowledge and information through advanced information system).

Factor three – Agility

Agility is the ability to respond rapidly to unpredictable changes in demand or supply. It can be achieved by scanning/intervening supply chain statues such as the upstream and downstream inventories, demand and supply conditions. Increasing the speed of operations and reduce lead time are also creating supply chain agility.

Factor four – Create a supply chain risk management culture

Creating a supply chain risk management culture also increases resilience (build up risk management committee and factor risk considerations into decision making).

This framework advocates creating resilient supply chains by categorizing, assessing and managing supply chain risks. It indicates what companies can do to reduce supply chain risks from suppliers, customers, environment and internal to the companies. However, it does not show what the supply chain disruptions are and how companies can respond to them properly. The following framework of Sheffi and Rice for supply chain resilience focuses on supply chain disruptions.

5.1.2 Conceptual framework by Sheffi and Rice

Sheffi and Rice (2005) start directly from the assessment of supply chain disruptions (refer to Figure 4 The Vulnerability Framework in section 2.2). Companies can identify supply chain disruptions with high likelihood – high impact (e.g. loss of key supplier) and low likelihood – low impact (e.g. workplace violence). There are also many disruptions with low likelihood – high impact (e.g. IT system failure) and high likelihood – low impact (e.g. transportation link disruption). Although there are various disruptions, their impacts occur only in a few patterns: delay or unavailability in supply, transportation, production (internal), communication/information system and human resource. To each of these supply chain disruptions, Sheffi and Rice (2005) indicate several possible reactions. They emphasize building up flexibility and redundancy in the supply chain as the main responsive strategies.

In the conceptual framework, Sheffi and Rice (2005) advocate companies first to assess supply chain disruptions by their likelihood (low – high) and impact (low – high); and then identify the possible impacts (supply, transport, production, communication/information system or human resource) generated by these disruptions. The next step is to select proper strategies based on the matrix: create flexibility[4], make scenario exercises and conduct crisis management and so on are the options to low likelihood – high impact disruptions; create redundancy[5], make contingency planning and conduct crisis management are the options to high vulnerable disruptions; create redundancy, make contingency

[4] Flexibility entails creating capabilities in the company to respond by using existing capacity that can be redirected or relocated. It comes from investments in infrastructure and capability long before the flexibility is needed (Sheffi and Rice, 2003, 2005).

[5] Redundancy entails maintaining capacity in the company to respond, largely through investments in capital and capacity prior to the point of need. An important distinction with flexibility is that the additional capacity may or may not be used – it is the additional capacity that would be used to replace the capacity loss of a disruption (Sheffi and Rice, 2003, 2005).

planning are the options to high likelihood – low impact disruptions. No actions are necessary to the low impact disruptions. As an example, loss of a key supplier is a high impact disruption. The possible impacts are unavailability of supply. Creating redundancy is recommended to the companies that are vulnerable to this disruption. The figure below shows the conceptual framework of Sheffi and Rice:

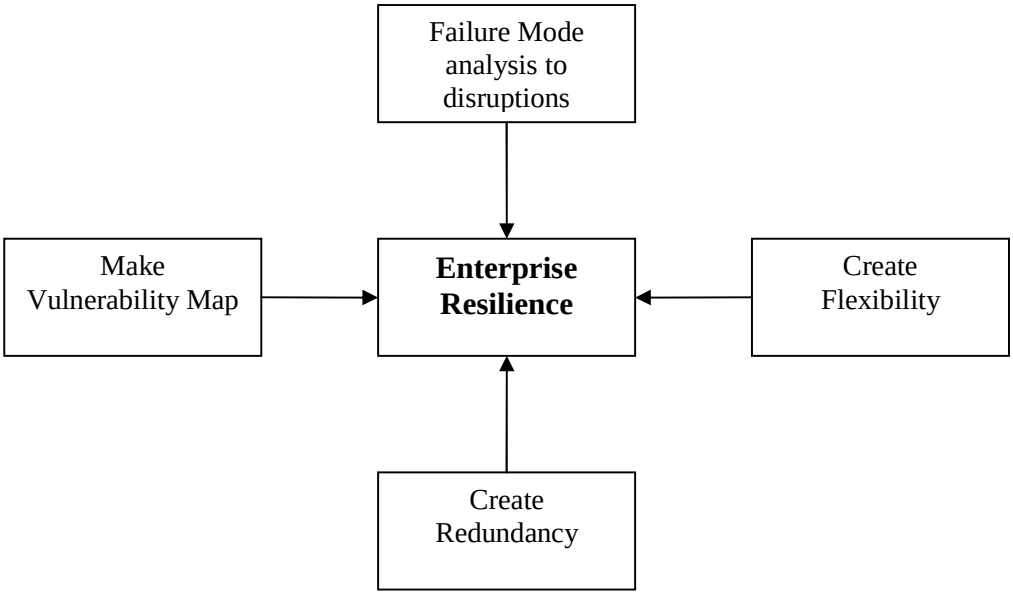


Figure 10 Adapted conceptual framework of Sheffi and Rice (2005)

This conceptual framework allows companies to assess their vulnerability by classifying supply chain disruptions in two dimensions (likelihood and impact), what the proper strategies are and which actions they can take (the advantages and disadvantages of each strategy is also provided, see Appendix 1 – Supply Chain Resilience Responses by Failure Mode (Rice, 2003)). The main results of their research are: 1) identification of supply chain disruptions – the most frequent supply chain disruptions can be grouped by five failure modes (supply, transportation, production, communication and human resource); 2) measurement of supply chain disruptions – the vulnerabilities of companies can be identified by assessing the likelihood and impact of supply chain disruptions; 3) treatments/solutions for supply chain disruptions – companies can reduce/mitigate the likelihood/impact of supply chain disruptions by creating flexibility, redundancy, making business continuity plans, conducting crisis management and scenario analysis. However, the results are based on the research among 20 American companies (most of them are shippers) and the supply chain disruptions they have experienced before. The results do not have a high generality especially to the situations outside America and/or other type of companies (such as Logistics Service Providers). The reason is that the 20 America companies have a similar business environment, governmental regulations and natural environment which can very different with other parts of the world. For instance, hurricanes are more frequent in America, while floods are the

most significant natural disaster in China; the custom or governmental regulations are different between EU and America. The recommended framework/strategies may not fit to Dutch companies and the possible supply chain disruptions in the Netherlands (see the survey results in chapter 4) could be different with those in America. A new resilience framework is designed by the researcher and its usefulness will be discussed based on the case study; NXP-ITEC pilot.

5.1.3 Conceptual Framework by Cocchiara

Cocchiara (2005) was the Chief Technology Officer for business resilience at IBM. In his article 'Beyond disaster recovery: becoming a resilient business. An object-oriented framework and methodology', he stated that a business resilience framework should be objective oriented and cover the areas of:

Strategy*: the strategies used by the business to complete day-to-day activities while ensuring continuous operations.*

People*: the structure, skills, communications and responsibilities of employees.*

Processes*: the critical business processes necessary to run the business, as well as the IT processes used to ensure smooth operations.*

Applications and data*: the software necessary to enable business operations, as well as the method used to develop that software.*

Technology*: the systems, network and industry-specific technology necessary to enable applications and data.*

Facilities*: the buildings, factories and offices necessary to house organization, production or service technologies.*

The objective is to create resilience within all these areas (for example, by availability of disaster recovery strategies; people having multiple skills; flexible processes; backup IT system and critical data are available; knowledge/technology are documented; and facilities are safe and secured). Cocchiara (2005) provided his conceptual framework to help companies achieve this objective (see Figure 11 below):

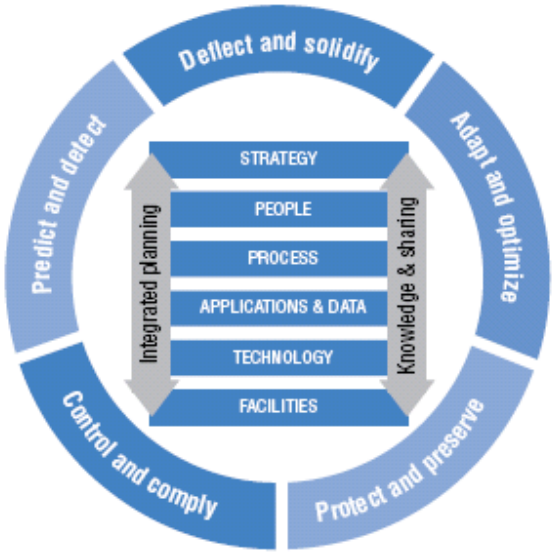


Figure 11 Conceptual framework by Cocchiara (2005)

In this conceptual framework, "Control and comply" imply to anticipate, evaluate and control risks and to comply with the regulations of industry and government; "Predict and detect" imply to predict, detect, estimate, measure and report disruptions in order to ensure security and enable business continuity. "Deflect and solidify" imply to create flexibility to deflect problems and ensure continuity of operations through reliability, redundancy. "Adapt and optimize" imply to ensure adaptable, efficient and integrated risk mitigation strategies, technologies and processes. "Protect and preserve" imply to ensure that the business is preserved and protected against accidental and intentional damage, alternation or misuse.

Compared with the conceptual framework of Christopher, Peck (2003) and Sheffi, Rice (2005), this conceptual framework does not start from the assessment of supply chain risks or disruptions, but the companies' objectives. In the first conceptual framework, Christopher and Peck (2003) suggest companies to assess supply chain risks (risks of supply, demand, process, control and environment) and reduce the probabilities. In the second conceptual framework, Sheffi and Rice (2005) advocate companies to recover normal operations against supply chain disruptions (disruptions in supply, transportation, production/facilities, communications and human resources) and mitigate the impacts. In the third conceptual framework, Cocchiara (2005) suggested companies to (re)orient their objectives (in the aspects of strategy, people, process, application & data, technology and facilities) regarding resilience. Although the above mentioned experts made their conceptual frameworks individually, they came up with similar conclusions/recommendations. For example, all of them suggested companies to

optimize supply chain networks and (re)design corporate strategies regarding resilience. Both the second and the third conceptual frameworks suggested companies to create flexibility and redundancy. Both the first and the third conceptual framework advocated companies to create agility in order to efficiently respond to demand changes.

5.1.4 Strengths and weaknesses of existing conceptual frameworks

This last section reviews the existing three resilience frameworks; the section describes the strengths and weaknesses to each of them.

- Resilience framework of Christopher and Peck

Strength

The framework of Christopher and Peck focuses on supply chain risks and aims to create supply chain resilience through a better management of risks. The strength of this framework is that it leads management to consider how, where, when and why supply chains may be vulnerable at each level of the landscape (the level including (a) internal to the focal company, (b) external to the focal company but internal to the supply chain network, (c) external to the network). It helps management to identify the sources of risk in each level (Process risks and Control risks in level (a), Demand risks and Supply risks in level (b), Environment risks in level (c)).

Weakness

However, too much focus on risk management is also the weakness or limitation of this framework. Its recommendations to companies are all risk relevant. In principal, the essential of risk is the probability of something's occurrence. Supply chain risks in this case are the probability of the occurrence of supply chain disruptions. Supply chain process are a continued flow of goods and information; it always exposes to supply chain disruptions. This framework focuses on eliminating the probability of disruptions other than to restore the supply network to the original state after being disrupted. Supply chain resilience especially focuses on high impact and low probability risks. These risks are easy to be ignored in risk management because of low probability. Furthermore, the probability of many high impact and low probability disruptions (e.g. storm or hurricane) can't be eliminated through risk management. The low effectiveness to high impact and low probability disruptions is the weakness of this framework.

- Resilience framework of Sheffi and Rice

Strength

Rather than focusing at supply chain risks, the framework of Sheffi and Rice focuses on the failure modes of supply chain disruptions. While there are many different types of risk, there are only a limited set of potential outcomes or impacts from any of the various risks. Failure modes (disruption in supply, transport, production, communication and human resource) are used to represent the few ways that the system could fail, regardless of the actual cause of the disruption (each failure mode could be generated by different causes, but the effect on the supply network is nearly the same). Sheffi and Rice indicated the strength of their resilience framework as: it allows companies to exploit the similarity between traditional and new threats, leveraging existing tools to both assess risk exposure and reduce the vulnerability; it has a strong power of synthesis – despite the high number of threats, the relevant failure modes are just a few, and they will probably remain the same even if new threats appeared. I consider its strength as it looks at the impacts of supply chain disruptions and indicates the possible response strategies and actions which help companies to restore their supply chain performance.

Weakness

However, the weakness of this resilience framework is that it only assesses two dimensions of disruptions (probability and consequence). It does not consider the difficulty of remedial actions to the disruptions. The difficulty of remedial actions is related to the expected efforts a company should take in case of a disruption and to return to its original state of supply chain network operations. For example, this framework considers a high probability and high consequence disruption as a main threat to a company. However, if the disruption is very easy to be remedied by the company, even though both the probability and consequence are high, it should not be considered as a main problem to this company (at least the company should be aware of it). The missing measurement of remedial actions of disruptions is the weakness of this resilience framework.

- Resilience framework of Cocchiara

Strength

The resilience framework of Cocchiara advises companies creating resilience by integrated planning of their strategy, people, process, applications & data, technology and facilities. The strength of this framework is that it links resilience to enterprise resources (such as people, technology and facility) which are familiar by managers. There are various supply chain risks and sources of disruptions, and it

is difficult to handle them all. Instead of assessing supply chain risks or disruptions, this framework advises companies to conduct a resilience scan to internal resources. Trying to improve business continuity through "Control and comply" (see section 5.1.3), "Predict and detect", "Deflect and solidify", "Adapt and optimize" and "Protect and preserve". In another word, Christopher and Peck advised companies to manage risks; Sheffi and Rice advised companies to anticipate disruptions; Cocchiara advised companies to ensure the continuity of internal resources. Compared with the first two resilience frameworks, this framework integrates creating resilience with other business objectives.

Weakness

The weakness of this resilience framework is that it only indicates the enterprise resources (e.g. people and facility) which should be protected against disruptions and the recommended activities (e.g. "Control and comply"), but it does not elaborate on how to prioritize them. Companies should be able to prioritize their activities and make resilience plans based on their specific situations.

5.1.5 Conceptual framework by Li, Lammers and Eijkelenbergh

As mentioned in previous sections, the objective of this study was to build a step-by-step approach that can guide companies to improve their resilience. The approach is also the answer of research question three: what can companies do to improve resilience? As indicated in section 2.6, companies can improve their resilience by creating resilience capacity: cognitive resilience, behaviour resilience and contextual resilience. As companies creating their resilience capacity, they interpret uncertain situations more creatively (cognitive resilience) and therefore is better able to conceive of both familiar and unconventional activities (behaviour resilience) that take advantage of relationships and resources (contextual resilience). Based on the analysis to the pros and cons of existing resilience frameworks and the concepts of resilience capacity, Li, Lammers and Eijkelenberg develop a new resilience framework (figure 12).

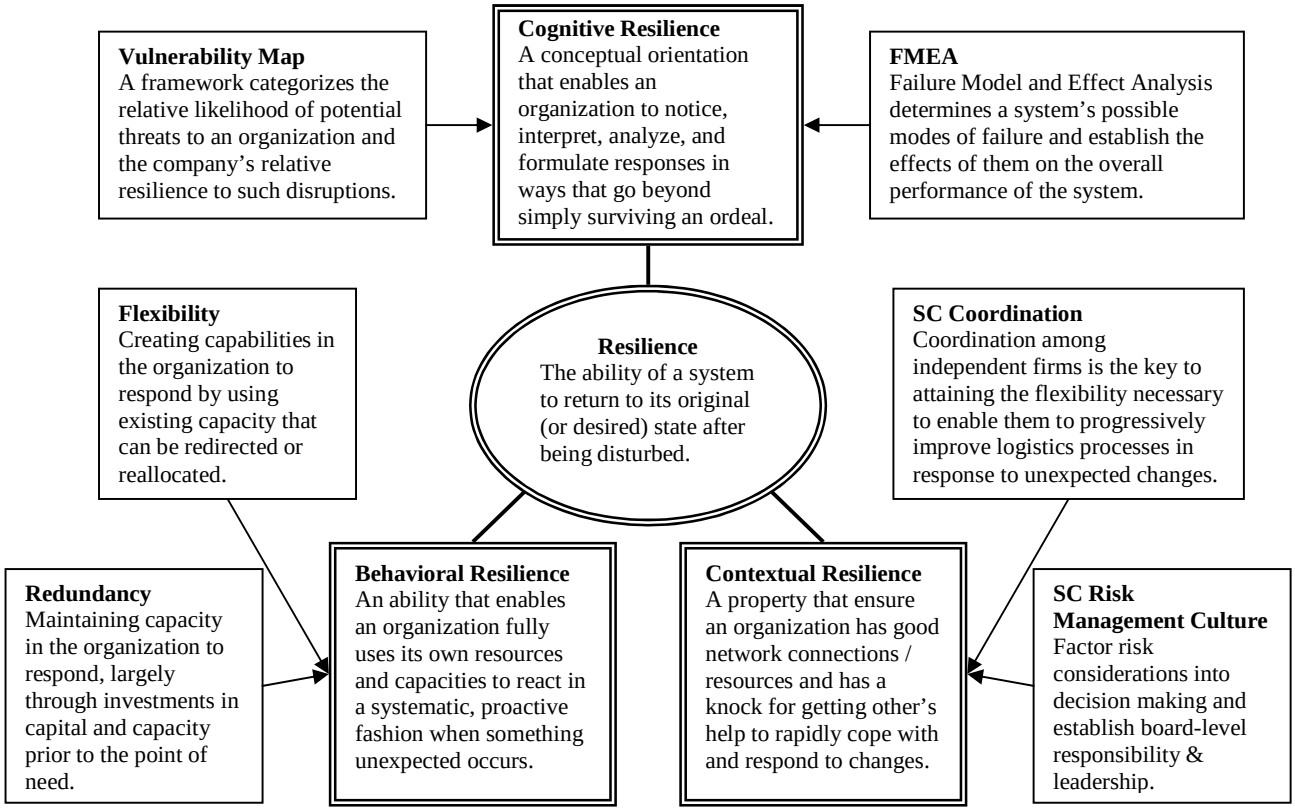
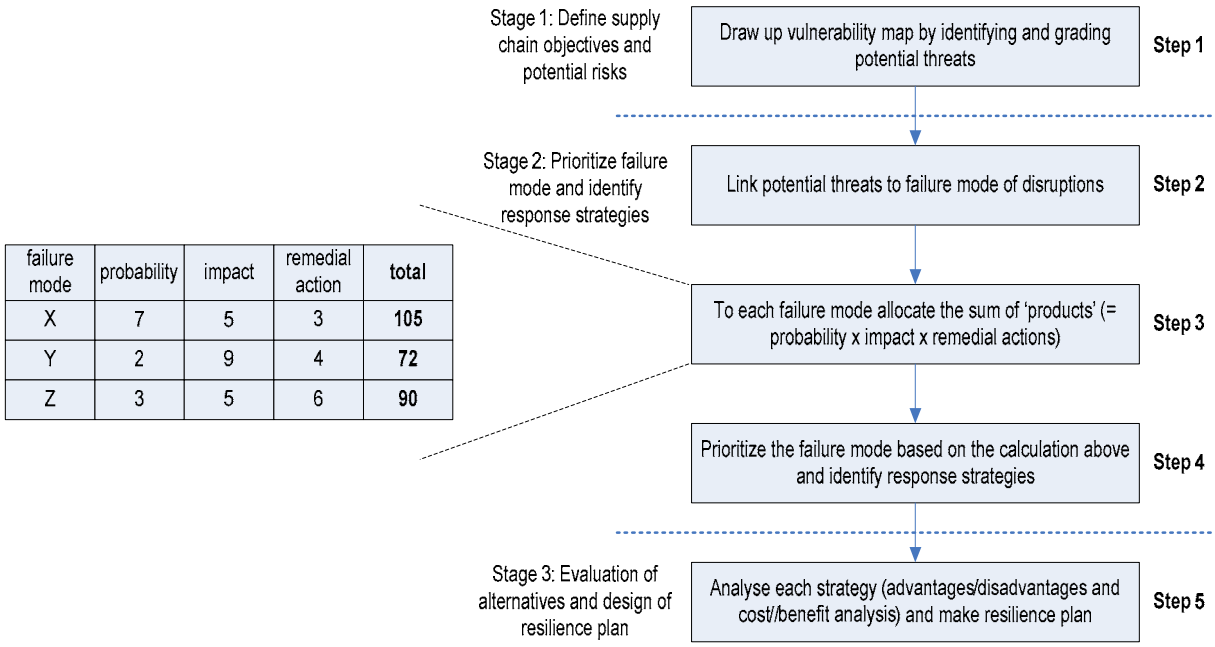


Figure 12: Resilience framework by Li, Lammers and Eijkelenberg

This framework indicates the methods and strategies of building up the three resilience capacities. After this framework, the researchers further developed a step-by-step approach which is pilot tested in real business. The approach is based on the Failure Mode and Effect Analysis (FMEA) methodology. FMEA is a tool that makes it possible to determine a system's possible mode of failure, and then to establish the effects of those failures on the overall performance of the system. FMEA is widely used as a quality improvement tool that can also be used for identifying and ranking supply chain risks. The researchers adopted the FMEA framework and applied it to the resilience theory. The new approach consists of five steps (as described in Figure 13).



failure mode	probability	impact	remedial action	total
X	7	5	3	105
Y	2	9	4	72
Z	3	5	6	90

Figure 13: Step-by-step approach of resilience

1 The first step aims to draw up a vulnerability map. Breaking down the supply chain (or the selected part) into component parts and brainstorming about each individual threat gives an overview of the potential supply chain disruptions.

2 After that the effects of each individual potential disruption are established. For each threat a ranking on a scale of one to 10 to indicate the threat in terms of its probability (one equal's low probability; 10 equal's high probability) is given, consequences are defined (one equal's low severity; 10 equal's high severity) and priority for remedial actions[6] is established (one equals easy; 10 equals difficult).

3 Calculate the product of the ranking to establish the criticality or Risk Priority Number (RPN) of the threat.

4 Rank the calculated RPN based on the calculation above and identify response strategies for each individual potential supply chain disruption.

5 At last, analyze each response strategy (advantages/disadvantages and cost/benefit analysis) and make a resilience plan.

6 The remedial actions are related to the expected efforts a company should take in case of a disruption. The higher the value will be, the more difficult it will be to return to its original state of supply chain network operations. It does not indicate anything on the effort of actions a company should take to prevent supply chain disruptions in advance, e.g. by defining a business continuity plan.

5.2 Case study

The aim of the case study at NXP-ITEC is to explore if the new conceptual resilience framework really work effectively and see if it is better than the existing resilience framework(s). The researcher also expects to find out the limitations and the possible way of further improvement. The case study was conducted by the researcher in close cooperation with TNO.

5.2.1 Company brief

- NXP Semiconductors

NXP Semiconductors was founded on 29 September 2006 from Philips Semiconductors, a division of the Royal Philips Group. It became a separate legal entity called NXP Semiconductors and is owned by a consortium of private investment companies (Kohlberg Kravis Roberts and Co., Bain Capital, Silver Lake Management Company, Apax Partners Europe Managers, AlpInvest Partners, and some other investors) and Royal Philips Electronics. Royal Philips Electronics retained a 19.9% minority stake in NXP. It is one of the World's leading semiconductor manufacturers. In 2006, NXP had total sales of EUR 5 Billion, 37,000 employees, and sales offices in 60 countries and 20 manufacturing plants in Europe, the USA and Asia. According to industry analysts Gartner, NXP ranked 11th in 2006 for the overall semiconductor market. It is a leading supplier of application specific system solutions and components to the Home Consumer Electronics, Mobile and Personal handsets, Automotive & Identification and Multi Market Semiconductor device markets. Over 70% of its total sales go to the top 50 accounts. NXP values the customers as partners and align roadmaps and future plans via the strong key-account relations.

Philips Semiconductors moved forward as NXP Semiconductors. The official announcement was made to the global media early on Friday, 1st, September 2006. The move marks a milestone in the company's 53-year history as the company became independent from Royal Philips. In order to emphasize the rich heritage that NXP gained from 53 years as part of Royal Philips, the NXP name is supported by the tagline "Founded by Philips".

NXP intends to expand on, or to achieve leading market shares in the mainstream markets for Mobile and Personal, Home, Automotive, Identification and Multi Market Semiconductors. This will further

improve its ability to shape the applications and markets which NXP plays in and will allow the company to achieve the scale required to be able to fund the development of system solutions in advanced process nodes. NXP's leadership in system solutions for the target application markets is based on in-depth systems know-how obtained through the long-standing relations with market shaping customers and through product performance and price leadership.

- NXP-ITEC

NXP-ITEC develops, manufactures, sells and services leading edge equipment for assembly and testing of (discrete) semiconductors. This equipment has allowed the Business Unit Multi Market Semiconductors to gain a leading position on cost and quality. The NXP-ITEC products are Die bonders, Wire Bonders, Moulding equipment, Testers (electrical final test) and Tapers / Die sorters. Products are sold within NXP. To maintain the product portfolio at benchmark level and have sufficient flexibility, the NXP-ITEC organization mainly focuses on development and service, while manufacturing is fully subcontracted. Customers of NXP-ITEC are mainly NXP Assembly Plants in the world for back-end production, like Assembly Plant Guangdong (China), Hong Kong, Malaysia, Philippine, Jilin (China), etc.
NXP-ITEC is the essential solution provider by creating exclusive best in class industrial solutions enabling Multi-Market Semiconductors (MMS) growth and cost leadership. NXP-ITEC acts as an exclusive in-house supplier of equipment and production systems for MMS. NXP-ITEC excels in realizing inventive, state of the art and reliable solutions for low-cost, high-volume needs, resulting in lowest Die Free Package Cost. NXP-ITEC is committed to stay well ahead of the competition by managing the technical competencies. A strategic company rule has been made that NXP-ITEC is not allowed to supply the external market, but only act as an in-house equipment supplier for NXP-ITEC.

The mission of NXP-ITEC is briefly that ITEC supports NXP backend assembly by providing best in class equipment, production concepts and associated information technology. Business strategy of NXP-ITEC is to create added value by:

- lowering costs via upgrading & low cost solutions;
- flexibility via enabling ramp up;
- quality via in depth knowledge of processes & equipment;
- though clear understanding of Business Line's roadmaps in order to align the equipment roadmaps.

In alignment with the business strategy of NXP-ITEC, ITEC has made a strategic decision to outsource all of its production capacities to qualified suppliers since 1990's. This strategic decision has made NXP-ITEC more focused on technological design and innovative R&D, and additionally more dependable on the performance of suppliers. Therefore, it is critically important for NXP-ITEC to manage its suppliers well and build up a long-term collaborative relation with them. The NXP-ITEC organization (90 staff) consists of:

- a development group for product creation;
- product teams for each product with focus on product improvement, application development and customer support;
- a supply group, for order fulfilment, logistical support, supply chain management, service coordination and supply of mature products and spare parts.

The NXP-ITEC organization structure is presented in Figure **Error! Reference source not found.**.

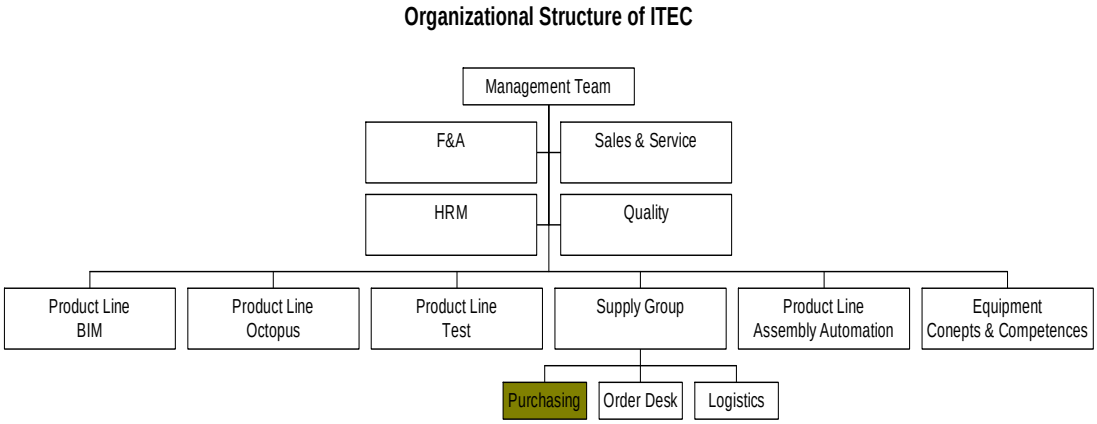


Figure 14: Organizational structure of NXP-ITEC

5.2.2 Identifying and grading potential disruptions

The first stage of the resilience framework is the assessment of the potential risks in the supply chain of NXP-ITEC[7]. To identify those risks results of a survey on resilience are used. In that survey NXP-ITEC has indicated one of their major disruptions was a bankruptcy of a supplier. As a result own planning was disrupted and customer demand could not be fulfilled timely and orders were missed. This section presents an overview of potential supply chain disruptions at NXP-ITEC, one of the five failure modes as described in section 2.4.

[7] Due to the cooperating person to this research was the purchasing manager of NXP-ITEC, the information used in this case study was focused on the supply aspect (out of the whole supply chain) and the risks were mostly concerned supply risks.

By means of a brainstorm with NXP-ITEC purchasing manager and a literature review of the most common supply chain disruptions in industry, an overview has been created including potential disruptions to the supply chain of NXP-ITEC. This list includes 28 potential disruptions and is mostly supply oriented:

- bankruptcy of 2-tier supplier;
- single sourcing for critical components;
- suppliers located at vulnerable regions;
- limited knowledge transfer between supplier and NXP-ITEC;
- importance of NXP-ITEC to financial performance supplier;
- functional specifications are not well documented;
- critical components not available in requested quantity;
- low quality of critical components;
- difficult to monitor strategic supplier;
- difficult to monitor bottle-neck supplier;
- difficult to monitor lever supplier;
- difficult to monitor routine supplier;
- no visibility over supplier technical capacity;
- language and/or cultural barriers at supplier level;
- poor supplier relationship;
- mergers & industry consolidation;
- no alternative design available in case of single sourcing;
- technical problems at supplier;
- bankruptcy of strategic supplier;
- wrong delivery of materials due to not well documented functional specifications;
- functional specifications do not provide alternatives;
- long life-time of machinery (product);
- necessity of spare parts;
- weak supplier selection process;
- dependent on a small number of key suppliers with few alternatives;
- long supplier lead time;
- disruptions due to climatologic circumstances;
- legal difficulties with supplier.

5.2.3 Selecting and clarifying top 15 potential disruptions

A list of 15 most important disruptions, identified by the purchasing manager, has been clarified and sent to other four NXP-ITEC managers (include a supply chain manager, a logistics manager and two product development managers). A top-15 was selected by the purchasing manager to limit the time of filling out the questionnaire and to focus only at major potential supply chain disruptions.

	Risk factor	Clarification
1	Functional specifications are not well documented	Difficult to change (switch) between supplier
2	Bankruptcy of strategic supplier	Loss primary supply and the connection with up-stream suppliers
3	Weak supplier selection process	No thoughts about alternative suppliers in case of manufacturing prototypes
4	Necessity of spare parts	Supplier is not able to deliver spare parts after the last machine has been produced
5	No alternative design available in case of single sourcing	An alternative design can support the exchange (switching) of machinery components
6	Functional specifications do not provide alternatives	Due to absence of alternatives it will be more difficult to change (switch) to alternative supplier
7	Long supplier lead time	A long lead time implies a sensitivity to disruptions
8	Long life-time of machinery (product)	As the average life time is long (e.g. 20 years), the chance disruptions at supplier level happen increases
9	Difficult to monitor strategic supplier	As the connection to up-stream suppliers, monitoring strategic supplier is essential of supply chain supervision
10	Bankruptcy of 2-tier supplier	Loss supply from the 2-tier supplier (the alternative supplier is possible to be found)
11	Single sourcing for critical components	'Single sourcing' increase possibility of disruption, 'Critical components' increase consequence of disruption
12	Mergers & industry consolidation	Due to trends of global consolidation the risk increases contracts are not guaranteed
13	Dependent on a small number of key suppliers with few alternatives	Less flexibility to disruptions and lower bargain power to these suppliers
14	Critical components not available in requested quantity	Production can not follow the schedule and back-order is required
15	Difficult to monitor bottle-neck supplier	As the connection to up-stream suppliers, monitoring strategic supplier is essential of supply chain supervision

Table 4 Top 15 supply chain risks ranked by the purchasing manager

5.2.4 Ranking top 15 potential disruptions by five managers together

The managers have been asked to apply the FMEA-analysis and identify for each item a ranking on a scale of one to 10 to indicate the threat in terms of its probability (one equals low probability; 10 equals

high probability), consequences (one equals low severity; 10 equals high severity) and priority for remedial actions (one equals easy; 10 equals difficult)[8]. Based on the results the product of the ranking is calculated to establish the criticality or Risk Priority Number (RPN) of the threat. The table below presents the results, based on an average RPN, corrected for the fact that one of the respondents rated the risk priority number in average much higher compared to its colleagues.

New priorities made by 5 managers	Risk factor	Clarification
1	Single sourcing for critical components	'Single sourcing' increase possibility of disruption, 'Critical components' increase consequence of disruption
2	Functional specifications do not provide alternatives	Due to absence of alternatives it will be more difficult to change (switch) to alternative supplier
3	Bankruptcy of strategic supplier	Loss primary supply and the connection with up-stream suppliers
4	No alternative design available in case of single sourcing	An alternative design can support the exchange (switching) of machinery components
5	Critical components not available in requested quantity	Production can not follow the schedule and back-order is required
6	Functional specifications are not well documented	Difficult to change (switch) between supplier
7	Long supplier lead time	A long lead time implies a sensitivity to disruptions
8	Long life-time of machinery (product)	As the average life time is long (e.g. 20 years), the chance disruptions at supplier level happen increases
9	Difficult to monitor strategic supplier	As the connection to up-stream suppliers, monitoring strategic supplier is essential of supply chain supervision
10	Weak supplier selection process	No thoughts about alternative suppliers in case of manufacturing prototypes
11	Bankruptcy of 2-tier supplier	Loss supply from the 2-tier supplier (the alternative supplier is possible to be found)
12	Dependent on a small number of key suppliers with few alternatives	Less flexibility to disruptions and lower bargain power to these suppliers
13	Necessity of spare parts	Supplier is not able to deliver spare parts after the last machine has been produced
14	Difficult to monitor bottle-neck supplier	As the connection to up-stream suppliers, monitoring strategic supplier is essential of supply chain supervision

[8] The detail data and calculation in FMEA is excluded in the text for confidential reason

New priorities made by 5 managers	Risk factor	Clarification
15	Mergers & industry consolidation	Due to trends of global consolidation the risk increases contracts are not guaranteed

Table 5 The overview of top-15 supply chain risks ranked by five managers together

5.2.5 Comparison of the two ranks

There are several differences between the priorities of the purchasing manager and the average priorities of the five managers. The significant differences are the priorities of the following five risks (the differences of priorities are equal or bigger than 5):

- Single sourcing for critical components – new priority 1 and previous priority 11
- Critical components not available in requested quantity – new priority 5 and previous priority 14
- Functional specifications are not well documented – new priority 6 and previous priority 1
- Weak supplier selection process – new priority 10 and previous priority 3
- Necessity of spare parts – new priority 13 and previous priority 4

The purchasing manager indicated that the differences between his rank and the new rank didn't surprise him. However, as showed above the priorities of the 15 supply chain risks are significantly different in the two ranks. The differences might be made by the different perspectives of the five managers (who come from different functions, positions within the company and experience level and thus have different understanding and sense to supply chain risks). For example, the purchasing manager considers the probability of single sourcing for critical components as low and thus he ranked this supply chain risk as the 11^{th} priority. He has paid great efforts in the past to avoid single sourcing for critical components and thus he believes it is not likely to happen. The product development manger must consider the availability of critical components when products are still in the developing phase. He might be more sensitive about single sourcing to critical component and doesn't know the efforts made by the purchasing manager (to avoid single sourcing) and thus rank it with a high priority.

5.2.6 Managing supply chain risks

Before defining strategies to manage and reduce supply chain risks, the most important disruptions to the supply chain of NXP-ITEC are clustered into categories (see Table 6). This was done, as some of the risk factors are to some extent overlapping and therefore could be combined. For each category of

supply chain risk this chapter presents some tools to overcome a disruption. This chapter described those tools in more detail (split into existing tools and some (out-of-the-box thinking) ideas of the researcher and a colleague at TNO.

Nr.	Risk factor	Supply risk category
2	Functional specifications do not provide alternatives	Functional specifications are not well documented
6	Functional specifications are not well documented	
3	Bankruptcy of strategic supplier	Loss of supplier
11	Bankruptcy of 2-tier supplier	
10	Weak supplier selection process	Weak supplier selection process
9	Difficult to monitor strategic supplier	Difficult to monitor supplier
14	Difficult to monitor bottle-neck supplier	
8	Long life-time of machinery (product)	Necessity of spare parts
13	Necessity of spare parts	
1	Single sourcing for critical components	Single sourcing without back-up supply
3	No alternative design available in case of single sourcing	
12	Dependent on a small number of key suppliers with few alternatives	
7	Long supplier lead time	Long supplier lead time
15	Mergers & industry consolidation	Mergers & industry consolidation
5	Critical components not available in requested quantity	Critical components not available in requested quantity

Table 6 Categorization of supply chain risks

- Functional specifications are not well documented

Existing tools

An easy exchange between suppliers can also be guaranteed by specifying the production technology (machinery and production process) as used by integrators (the most important suppliers of NXP-ITEC). NXP-ITEC obliges major suppliers contractually to document all relevant information and in some cases this information need to be shared with competitors (e.g. by training). On the other hand, it also expects from the integrator that an open communication dialogue (share information related to

purchase price, added value, etc.) takes place. In this way NXP-ITEC tries to reduce supply chain risks, as they are not dependent on a single supplier, although it should be mentioned that in reality sharing private information can be very difficult (especially for bottleneck suppliers).

New ideas according to researcher and TNO

To avoid the risk that it is too difficult to change between suppliers, a correct documentation of functional specifications is necessary. Functional specifications are not only related to component level, but also to production technology as applied by suppliers. A good documentation of components implies that (at least) 80% of the functional specifications are documented correctly. The quality can be guaranteed by means of a kind of co-readership, in which the co-reader checks if the documented functional specifications meet a minimum quality level (to be defined by NXP-ITEC). Such a mechanism need to be less time consuming. By minimum effort the organization can be brought at a higher level.

- Loss of supplier

Existing tools

One of the major risks in an international business environment is the loss of a key supplier due to bankruptcy or mergers & acquisition. Strict monitoring of key suppliers therefore will be necessary. NXP-ITEC uses a system in which key suppliers financial status is audited yearly. A (self-assessment) audit questionnaire is used for that. Moreover, NXP-ITEC organizes every 3 months face-to-face meetings with major suppliers and integrators to become more aware about the current performance.

New ideas according to researcher and TNO

An alternative to close monitoring of key suppliers can be the creation of more product flexibility. This implies that the component itself can be produced at more than one supplier. To realize this it is very important that those that are responsible for developing a component prototype keep those alternatives in mind when defining and testing it. The problem although is that when engineers are designing machinery, the only thing normally in their mind is the performance of the machine. They would often not think about cost/benefit, market, source of supply, customer satisfaction and so on. They prefer to make their products unique, which will reduce (suppliers) flexibility.

- Weak supplier selection process

Existing tools

Moreover, when selecting and establishing the relationships with (potential) suppliers, considering the 'power balance' is a significant factor. Important questions are:

- Is the development direction (regarding market segment and/or technical standard) of this supplier in line with NXP-ITEC's?
- Is this supplier (financially) dependent on NXP-ITEC?
- Is NXP-ITEC one of the company's major customers?

NXP-ITEC needs to assess this information and maintain the supplier's relationship accordingly. A continuous review of the current power balance and the deviation from its optimum is necessary. And more important, in case of big deviations, managers need to take the correct actions to correct the power balance.

New ideas according to researcher and TNO

When defining and selecting suitable suppliers it is important to make use of the correct selection criteria. Not only component prices are important, but also supply chain related parameters need to be incorporated. Examples are lead times (normally not more than a couple of weeks), reliability, flexibility (possibility to upscale production when demand is increasing) and technical know-how. A good supplier selection process framework, in which each of the aspects/factors is assigned a weight by the relative importance (the rate could be at a 10 point scale or in percentage), is useful. These framework rates are the fix parts of the assessment framework. There is also a flexible part; it includes the individual suppliers' rate to these aspects/factors. The cumulative average value of each supplier can be counted by means of such a framework. NXP-ITEC already started with the development of such a framework. A simpler alternative to this could be a standard list of mind joggers that can be used during the supplier selection process. In this way the company's sourcing awareness level can be increased and the suppliers' selection process can be improved.

Further more, in order to spread risks, it is important to spread suppliers over different areas, serve different customers, compete in different markets, provide different kinds of products, use different kinds of transportation modes, have different specifications, etc. Diversification guarantees that in case of one single event in a specific location, market, industry of product, the impact can be limited in case

the organisation has a diversified structure. The impact or loss in one specific area could be compensated by other areas.

At last, as stated in the previous section, to increase resilience levels it is important to think about alternative suppliers when purchasing components or developing prototypes.

- Difficult to monitor supplier

Existing tools

Suppliers have different supply chain risk and vulnerability awareness and take different countermeasures. It is not surprising that they are exposed to certain supply (chain) risks and that disruptions could happen in anytime. Regularly checking the up-to-date statues of suppliers is one of the core activities of ITEC's purchasing department. Having a clear overview of all suppliers regarding supply chain risks and vulnerabilities helps to benchmark among suppliers and build up NXP-ITEC's standard of supply (chain) risks.

In general, NXP-ITEC's suppliers are required to participate in a yearly (self-assessment) audit. This method is applied to lower tier suppliers or major suppliers that perform best. By means of a questionnaire NXP-ITEC gets insight into the current performance, which can be compared with historical data. Questions addressed are:

- What is the current number of employees?
- What is the expected turnover?
- What is the realized turnover? (can be compared with the expected turnover)
- What is the expected profit?
- What is the realized profit? (can be compared with the expected profit)
- Who are the top-10 customers (preferably with ranking)? (can be used to assess if NXP-ITEC is a key customer)
- What is the plan of investments and their payback period?
- What is the direction of future expanding?
- Organize every 3 months face-to-face meetings with major suppliers and integrators.
- Yearly monitoring of suppliers' financial status by using (self-assessment) audit questionnaires which are sent to major suppliers and integrators.

Moreover, NXP-ITEC organizes quarterly face-to-face meeting with key suppliers. During those meeting managers discuss the current situation and developments over the past quarters. Also an outlook for the upcoming period is discussed. As for all key suppliers their turnover is largely dependent on NXP-ITEC, all of them are willing to share critical information such as financial ratios, business plans or market strategies).

- Necessity of spare parts

New ideas according to researcher and TNO

One of the important threats to NXP-ITEC's performance is related to the product life cycle. NXP-ITEC provides a quality guarantee to its customers (i.e. a 10 year product guarantee period, including spare part availability). Because of some external reasons (especially technological revolution) the product life cycle of machine components can be shorter. One example is a keyboard with PS2 connector. As most keyboards have a USB connection nowadays, it is very important to specify what is needed. Otherwise, a non compatible component will be delivered. To avoid this, one can think about long-term framework contracts regarding the supply of spare parts, although it should be mentioned that this (or alternatives like keeping a limited inventory of critical components) can be cost intensive. Moreover, suppliers need to agree that they will continue to produce/store the same machine or spare parts for a longer period (could be 10 to 20 years after the last component has been produced).

An alternative could be the use of standard components instead of customer made one's or apply a redundancy strategy. In this was easy exchange can be stimulated, although engineers should avoid making machinery specific (see section on 'lose supplier'). Further more, NXP-ITEC can redesign and test critical components regularly (upgrading of machines is not required). In this way it can be guaranteed that alternatives are available quickly in case a specific supplier is not able to deliver the required spare parts.

- Single sourcing without back-up supply

Existing tools

In general single sourcing without a back-up should be avoided, as it implies that the supply chain is vulnerable and moreover it reduces the bargain power. NXP-ITEC aims to spread the supply chain risk by looking for alternative suppliers for each (key) component. As stated earlier if one company wants to be the preferred supplier of NXP-ITEC, it has to promise that it will train another company and

guarantee that it can provide the same component to NXP-ITEC. The knowledge on how to produce the component has to be documented and shared with back-up suppliers and NXP-ITEC. As compensation, NXP-ITEC pays for the Intellectual Property Rights. An alternative to this strategy would be to redesign components regularly. In this way NXP-ITEC becomes less vulnerable as a back-up solution is available.

When NXP-ITEC decides, maybe for good reasons, to apply a single sourcing strategy, strict monitoring (see section on 'difficult to monitor supplier') of those suppliers is necessary. Also one should think about whether this single source is able to accommodate higher market demand and is therefore reliable in all circumstances.

- Long supplier lead time

New ideas according to researcher and TNO

In case of a long supplier lead time various strategies can be applied. First of all one can think about keeping a limited inventory of critical components, although this can be cost intensive. Also the use of another transportation mode (i.e. air instead of sea) can be useful to reduce supplier's lead time. An alternative could be to select local suppliers. Sometimes it is cheaper to source in Central and Eastern European countries than in Asia, as hidden costs of those suppliers are often higher (i.e. congestion at ports creates loss of sales or higher inventory) (Stalk and Waddell, 2007). At last one can make more use of pipeline stock, in other words some inventory is shipped by slower transportation modes, or a hybrid transport network (making more use of different transport modes, in stead of one single mode) can be applied.

- Mergers & industry consolidation

New ideas according to researcher and TNO

Due to a global consolidation trend by mergers and acquisition the risk increases that contracts with original contact persons become useless. Therefore, previous arrangements can not be guaranteed. To overcome those barriers several alternative strategies can be applied (already discussed earlier):

- Yearly monitoring of suppliers' financial status by using (self-assessment) audit questionnaires which are sent to major suppliers and integrators.
- Organize every 3 months a face-to-face meeting with major suppliers and integrators.

- Training of competitors to make them also aware of the production technology and process. Especially for bottleneck suppliers this is difficult to realize.
- Select multiple suppliers and avoid single sourcing.
- Use standard components instead of custom made one's to stimulate easy exchange.
- Redesign critical components regularly, so alternatives are available in case a specific supplier is not able to deliver the required components.
- Keep limited inventory of critical components.

- Critical components not available in requested quantity

New ideas according to researcher and TNO

To guarantee that critical components are available in the requested quantity several options are possible. These measures are a combination of those that have been discussed before:

- Keep limited inventory of critical components.
- Select multiple suppliers and avoid single sourcing.
- Use standard components instead of custom made one's to stimulate easy exchange.
- Redesign critical components regularly, so alternatives are available in case a specific supplier is not able to deliver the required components.
- To accommodate higher market demand one should create production flexibility when defining contracts. Especially in case of single sourcing this is important, as the selected supplier should be reliable in all circumstances.

5.2.7 Measure potential supply chain disruptions in the method of Sheffi & Rice

Besides the method designed by the researcher, this case study also used the method of Sheffi & Rice to measure the potential supply chain disruptions to NXP-ITEC. The results are presented in a vulnerability map, indicating whether or not the identified supply chain disruption can be classified as low probability - high impact, it can be concluded that four factors (out of the Top 15) are located in the upper-left section. These threats are: functional specifications do not provide alternatives, bankruptcy of strategic supplier, difficult to monitor strategic supplier and long supplier lead time. Seven factors can be classified as high probability, high consequences: single sourcing for critical components, no alternative design available in case of single sourcing, critical components not available in requested quantity, functional specifications are not well documented, weak supplier

selection process, single sourcing for critical components and critical components not available in requested quantity. Four threats in lower left section, they are: long life-time of machinery (product) cause unavailable of spare parts, mergers & industry consolidation, dependent on a small number of key suppliers with few alternatives and difficult to monitor bottle-neck supplier.

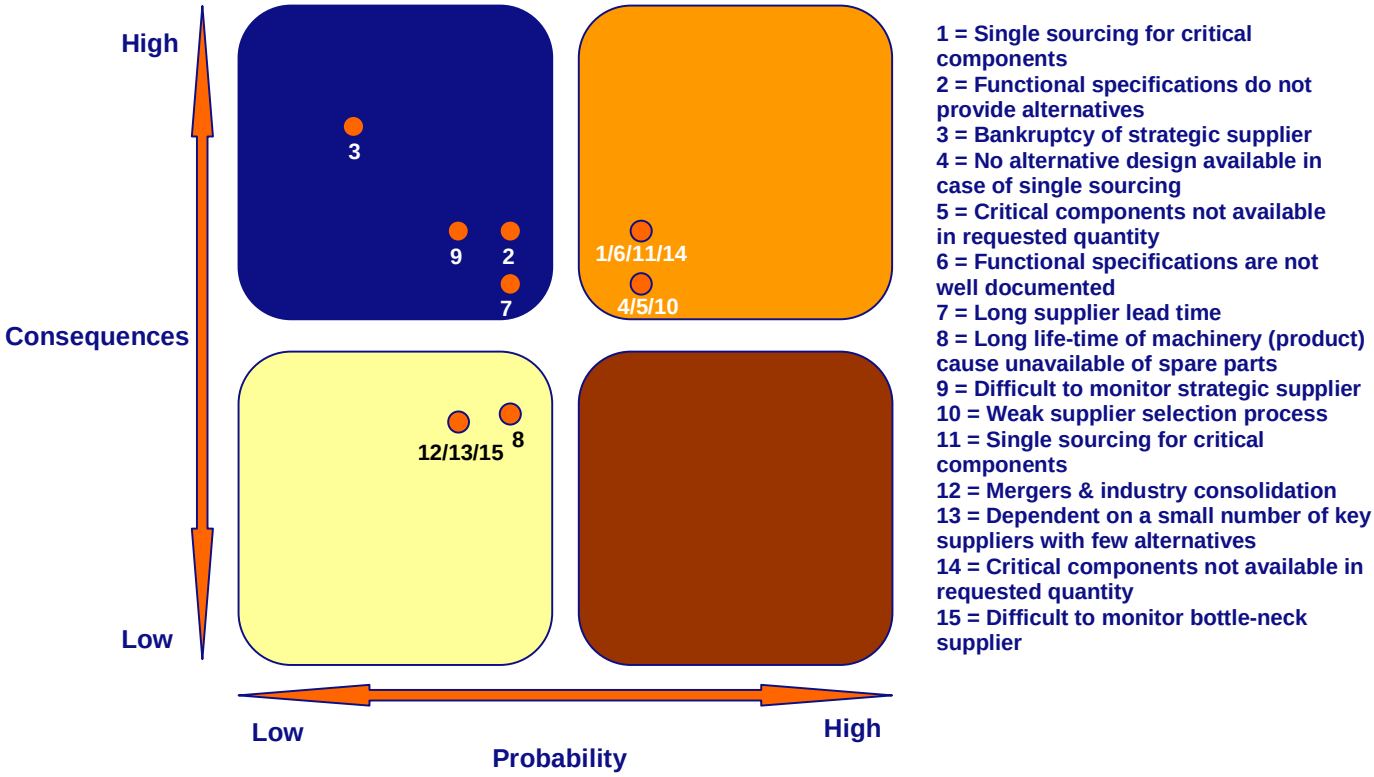


Figure 15: Vulnerability map

It is advised to NXP-ITEC that when defining operational strategies (based on that what has been discussed in this chapter) to become more resilient, the focus should first be at the high probability, high consequences disruptions. This in contradiction to the framework of Sheffi & Rice, who strive to focus on low probability – high impact disruptions. The reason for this is that it should be verified first if NXP-ITEC is at this stage aware of those high probability – high impact disruptions and if the organization is flexible enough to overcome potential disruptions. An organization should have already measures/strategies in place to overcome those threats; given the characteristics of the disruptions (both probability and consequences are high). After that NXP-ITEC should focus at low probability, high impact disruptions. As most companies are not aware of the consequences of those disruptions there is a risk that in case such an event happens, the company does not know how to react. Therefore the impact of the disruption will be enlarged and performance drops often sharply.

5.2.8 Conclusions of case study and recommendations to NXP-ITEC

- Conclusions

In this study, FMEA-analysis has been used to measure supply chain risks and assign a Risk Priority Number. The pilot has shown that using FMEA is of added value compared to more traditional two dimensional analyses, in which resilience is defined as low probability high impact supply chain disruptions. Adding the difficulty of remedial actions to overcome after the disruption has happened to the framework gives benefit to the overall approach, as this element indicates whether or not the consequences of a disruption can be overcome soon or not and which effort it will need.

Moreover, the pilot has shown that the framework can contribute to internal discussions on resilience and increase the awareness level. Positive remarks were received from the five NXP-ITEC managers. Therefore, the researcher also thanks NXP-ITEC for their contribution to this case study. The weakness of the framework although is that it is only useful at a more strategic level and not at an operational one. It indicated some high level strategies to overcome or prevent supply chain disruptions, but does not tell an organization how to implement it in a real-world.

- Recommendations

It is recommended to NXP-ITEC to use the results of this case study for internal meetings and discuss together how the supply chain can be made more resilient. It is important that the results of those discussions are documented and where necessary corporate supply chain strategies should be adopted at a tactical and operational level.

Chapter 6 Conclusion

This chapter reviews the findings of the research, including literature review, survey and a case study; draws up conclusions and provides recommendations to further research.

6.1 Conclusion

The objective of this research is to provide an easy-to-use guideline for Dutch companies to make them less vulnerable to supply chain disruptions. The guideline is what I call the step-by-step approach in chapter 5. In general, it is difficult to make such an approach that fits for all Dutch companies and thus the approach does not have a high generality. However, I tried to make it based on an observation of 35 Dutch companies (which provided 44 examples of supply chain disruptions in the Netherlands), and it was consolidated through a deep case study of NXP semi-conductors (although only a single case study does not allow a generalization to all Dutch companies). The research questions are discussed one by one in the remainder of this section.

1. ***What are the main causes of supply chain disruptions to Dutch companies?***

The results of a survey show that the main causes of supply chain disruptions to Dutch companies are: Strike or unavailability of labour, Bankruptcy or unreliability of supply chain partner (mainly supplier), Unavailability of infrastructures, Legislation/regulation of government/authority/institution, Natural disaster, IT system turns down or incompatible with existing operation, Fire at the plant, warehouse or office, No electricity supply to continue operation. Kleindorfer and Saad (2005) categorize them by events of operational contingencies, events of natural hazards and events of terrorism attack and political instability. The survey results show that the majority of supply chain disruptions to the responding companies are caused by events of operational contingencies (such as strike, supplier bankruptcy and failure of infrastructure). Natural hazards like storm and flood are a minor cause. Obviously the Netherlands has a good natural environment and little terrorism activities.

2. ***What have Dutch companies done to overcome the disruptions?***

Sheffi and Rice (2003) defined failure modes of supply chain disruptions as failure in supply, failure in transport, failure in production, failure in communication and failure in human resource. In chapter 4, it has been shown that Dutch companies have taken various actions to overcome the disruptions and restore the lost performance. By synthesizing the actions, it can be found that the companies responded to the disruptions by increasing flexibility and redundancy. The responding companies increased their flexibility by training multi-skilled employees, making use of standard components so that suppliers can be changed without affecting production, creating flexible production processes to accommodate demand change and requiring volume flexibility from suppliers. They also increased the redundancy of their critical materials/components, supply chain partners (mainly suppliers) and communication/information system. The strategies were for instance: make use of inventory, alternative supplier and back-up information system. In general, building up redundancy (e.g. inventory) requires big investments for a long time; there is a trade-off between redundancy and efficiency (Sheffi and Rice, 2005).

3. What can Dutch companies do to become more resilient to such disruptions?

As mentioned before, it is very difficult to answer this question in general. However, the case study of the Dutch manufacturing company NXP, department ITEC, provides an example of such an approach (see Figure 12 in chapter 5). This research investigated how NXP-ITEC could create supply chain resilience through the use of a step-by-step approach. The approach might not fit other Dutch companies, but it can still provide insights for companies who want to make their own resilience plan. The conceptual frameworks provided by Christopher and Peck (2003), Sheffi and Rice (2003, 2005) and Cocchiara (2005) indicate the factors that influence supply chain resilience. This step-by-step approach is formulated based on these existing conceptual framework using their individual strengths and indicates the actions of creating supply chain resilience. These actions have been investigated at NXP-ITEC and have received positive remarks from the five managers (a purchasing manager, supply group manager, logistics manager and two product development managers). The results of the case study (including the potential supply chain disruptions and corresponding actions to prevent as a result of the step-by-step approach) will be used at the internal meeting of NXP semi-conductors and put into consideration when making corporate/supply chain strategies.

6.2 Limitation

This research has several limitations. The first is the small number of responding companies in the survey. This limitation is mentioned in the beginning of chapter 4. The recommendation to further research in this topic is avoid using open questions in questionnaires. One possibility is to use 5-points scales questions instead of open question, and structure questions directly based on the failure mode of supply chain disruptions (Sheffi and Rice used to make a survey in the year of 2003). In this way, the response rate may be increased. Another limitation relates to the case study of NXP-ITEC. The step-by-step approach is developed to help Dutch companies become less vulnerable to supply chain disruptions. It can not be done by doing research in only one company. The recommendation is to make multiple case studies in different companies. Trying to cover the main industries in the Netherlands and to design the step-by-step approach specialized to different industries (it can be adapted by the characteristics of industries).

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Appendix A Table of Supply Chain Resilience Responses by Failure Mode

Table Supply Chain Resilience Reponses by Failure Mode

Resilience to Disruption in….	Action	Advantages	Disadvantages
Supply	Use multiple and/or local sources in different locales. [111]	Spreads risk across two firms, two locations; local source protects against international supply constraints.	Higher cost to qualify supplier, lower volume leverage, no assurance additional supplier is more resilient.
	Use single source.	Known supplier, high supplier commitment, leveraged volume.	Vulnerable to disruption unless supplier has multiple flexible sites, backup plans.
	Contract for supplier flexibility.	Contract obligates supplier in advance.	Potentially higher cost per unit, may entail fixed costs for "take or pay" committed volume. [112]
	Modify inventory levels.	"Right" parts inventory and risk pooling may reduce inventory costs.	Requires periodic analysis by item as conditions change.
	Modify product to use standard parts.	Reduces part and inventory cost, complexity.	Costly to modify existing materials standards.
Trans portation	Prepare for, use multiple modes and carriers.	Pre-disruption relationship ensures support in crisis.	May need to commit volume to the alternate modes to get access in a disruption.
	Use spot market for capacity.	Efficient transaction with no upfront or lasting commitment.	Unknown carrier means added risk, potential for exceptional high pricing.
	Use logistics providers to source transportation.	Providers may have greater leverage and access.	Requires commitment (volume, cost) and relationship with logistics provider
Production Facilities	Use multiple sites, each making multiple products.	Enables shifting production around locations.	Requires standardization in production operations, additional capital for additional facilities. [113]
	Modify inventory levels and policies.	"Right" FGI levels and risk pooling may reduce inventory costs.	Requires periodic analysis, potential redesign of supply network.
	Modify product to use standard processes.	Leverages common capabilities for lower cost, easier backup available.	Costly to modify product and production processes.
	Contract backup production facilities	Committed back up assured, potential to co-locate at supplier or customer	Not dependable without contingency contract for the facilities in disruption. [114]
Communications	Use range of media. [115]	Communication in nearly any event.	Must maintain range of old and new technology.
	Back up data.	Protects against data loss.	Still requires physical system in event of system loss.
	Contract backup system.	Provides for near-term availability.	Potential delay in response to massive disruption.
	Set up and operate parallel or mirrored IT system.	Affords immediate system availability.	Requires cost to build, operate, and maintain separate system in protected environment
Human resources	Cross-trained workers.	Shift employees to best use as needed	Must cross-train, modify work system.
	Modify production process for unskilled labor.	Allows rapid increase or decrease in capacity.	Requires simplification of production process (not always feasible).
	Back up knowledge.	Best practices captured and documented	Requires significant investment to capture and maintain knowledge in useful form.

Appendix B Questionnaire to Manufacturing/trading companies

Supply Chain Resilience

Deze vragenlijst is ontwikkeld door TNO, in samenwerking met EVO, TLN, NDL en de Erasmus Universiteit, in het kader van het TRANSUMO project PROTECT. Het doel is beter inzicht te krijgen in de huidige stand van zaken met betrekking tot supply chain resilience in Nederland. Resilience wordt gedefinieerd als de veerkrachtigheid van ketens om verstoringen op te vangen en de ontstane, maar ongewenste situatie, te herstellen in een (eventueel nieuw) economisch en logistiek evenwicht. Vooral Amerikaanse bedrijven hebben voor het jaar 2007 resilience tot topprioriteit benoemd, wijs geworden door o.a. 9/11, blokkades van de havens aan de Amerikaanse westkust in 2002 en de gevolgen van de orkaan Katrina. Het ligt in de lijn der verwachting dat dit gaat overwaaien naar Nederland.

De informatie wordt gebruikt om een kennis over resilience over te dragen aan Nederlandse bedrijven en een resilience raamwerk op te stellen. Op die manier kunnen Nederlandse bedrijven problemen in logistieke ketens voorkomen of de impact van mogelijke ongeregeldheden beperken. Alle verzamelde gegevens worden vertrouwelijk behandeld: alleen geaggregeerde en anonieme resultaten worden bekend gemaakt.

De vragenlijst dient bij voorkeur beantwoord te worden door de logistiek of operationeel manager van uw bedrijf of door medewerkers die betrokken/bekend zijn met dit onderwerp. Het invullen van de vragenlijst neemt naar schatting 15 minuten in beslag. Als dank voor uw bijdrage ontvangt u de resultaten van het onderzoek, waardoor u de mogelijkheid hebt om uw antwoorden te vergelijken met de gehele steekproef.

De vragenlijst is opgedeeld in drie blokken:
- Sectie A – *Achtergrondinformatie*
- Sectie B – *Verstoringen*
- Sectie C – *Resilience*

Bij voorbaat dank voor uw deelname!

Met vriendelijke groet,

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Sectie A – Achtergrondinformatie

A1. Wat is de naam van uw bedrijf? In welk land is het hoofdkantoor gevestigd? Hoeveel medewerkers heeft uw bedrijf? (deze informatie is alleen bestemd voor intern gebruik, bedrijfsnamen worden niet gepubliceerd)

Bedrijfsnaam	_____
Adres	_____
Vestigingsland hoofdkantoor	_____
# Medewerkers NL	_____

A2. Naam van de medewerker die de vragenlijst heeft ingevuld (deze informatie is alleen bestemd voor intern gebruik, namen van medewerkers worden niet gepubliceerd)

Naam	_____
Functie	_____
E-mail	_____
Telefoon	_____

A3. Welke functie vervult uw bedrijf binnen de keten? *(doorhalen wat niet van toepassing is)*

Producent grondstoffen	ja / nee
Producent halffabricaten	ja / nee
Producent eindproducten	ja / nee
Detail- / groothandel	ja / nee
Retail	ja / nee
Logistieke dienstverlening	ja / nee

A4. In welke productsegment is uw bedrijf actief? *(doorhalen wat niet van toepassing is)*

Elektronica	ja / nee
Kleding	ja / nee
Levensmiddelen	ja / nee
Automotive	ja / nee
Papier / verpakking	ja / nee
Spare parts	ja / nee
Chemie	ja / nee
Farmacie	ja / nee
Non-food	ja / nee
Wit- en bruingoed	ja / nee
Bouw / materialen	ja / nee
Overig, namelijk	_____

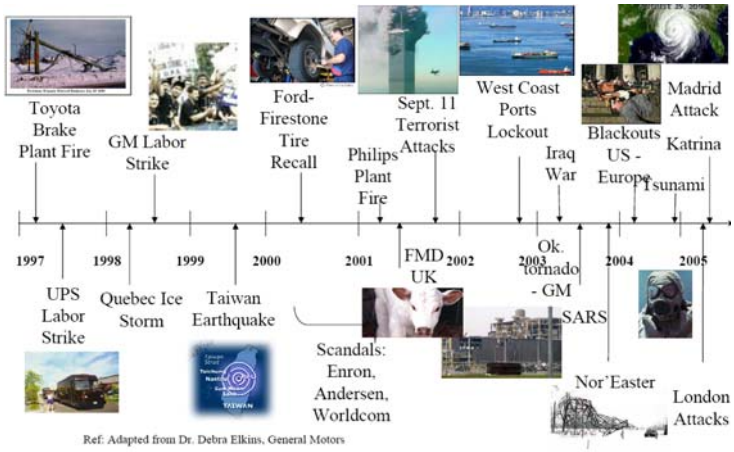
A5. In welke gebieden is uw bedrijf actief *(doorhalen wat niet van toepassing is)*

	inkoop vanuit	productie in	verkoop in
Nederland			
België en Luxemburg			
Duitsland			
Overige Europese landen			
Noord Amerika			
Zuid Amerika			
Azië Pacific			
Midden Oosten en Afrika			

Sectie B – *Verstoringen*

Herinnert u zich het capaciteitstekort bij ECT? Of hebt u recent te maken gehad met een faillissement van één van uw toeleveranciers/opdrachtgevers? Vermoedelijk hebt u toen zelf ervaren hoe kwetsbaar uw logistieke netwerk is. Een aantal opeenvolgende trends, zoals het wereldwijd inkopen en uitbesteden van activiteiten, het beperken van het aantal toeleveranciers en de centralisatie van distributiefaciliteiten middels Europese distributie centra's, hebben bijgedragen aan de gevoeligheid van vele supply chains. Het is dan ook aangetoond dat de grootste risico's niet liggen binnen uw bedrijf zelf, maar juist in de breedte van het netwerk van belangrijke toeleveranciers en klanten.

Indien al beschikbaar, richten vele bedrijven op dit moment vooral de aandacht op het garanderen van de bedrijfscontinuïteit door de risico's binnen het eigen bedrijf te beperken. Doordat de complexiteit van logistieke netwerken echter toeneemt, onder andere als gevolg van uitbesteding van bedrijfsactiviteiten die geen directe waarde toevoegen, de globalisering en de onvoorspelbaarheid van de markt, neemt de kans op verstoringen toe. Bovendien is de kwetsbaarheid van logistieke netwerken toegenomen als gevolg van langere en efficiëntere supply chains, waardoor de kleinste verstoring het gehele proces lam kan leggen. Dit kan leiden tot omzetverlies, doordat klanten orders terugtrekken of doordat servicegraden niet meer behaald kunnen worden. Op de lange termijn kan dit voor uw bedrijf zelfs leiden tot imagoschade of verlies van het marktaandeel. Hoewel vele risico's binnen de supply chain dus afstammen van de externe omgeving, bijv. oorlogen, epidemieën of aardbevingen, is er een groeiend bewijs dat de gevolgen ervan vooral te wijten zijn aan de structuur van het logistieke netwerk zelf.



De belangrijkste oorzaken van verstoringen in supply chains zijn hieronder opgesomd. In de meeste gevallen betreft het hier de directe aanleiding die leidt tot een verstoring.

Gebeurtenissen binnen de bedrijfscontext	Gebeurtenissen in ketenperspectief
0. Geen	0. Geen
1. Verlies van essentiële bedrijfsdata	1. Faillissement toeleverancier
2. Grootschalige problemen met ICT (bijv. werking ERP-pakket)	2. Juridische problemen met toeleverancier
3. Grootschalige brand	3. Staking bij toeleverancier
4. Bedrijfsstakingen	4. Grootschalige brand bij toeleverancier
5. Grootschalige diefstal	5. Verstoringen door fusies en overnames bij toeleveranciers
6. Grootschalige technische storing binnen eigen productie	6. Technische problemen bij toeleveranciers
7. Niet beschikbaar zijn van vervoer op het moment dat dit essentieel is	7. Onvoldoende (productie)capaciteit bij toe-leverancier om marktvraag op te vangen
8. Problemen met vinden van geschikte nieuwe medewerkers	8. Verstoring door aardbeving in gebied waar toeleverancier opereert
9. Grootschalige elektriciteitsstoringen	9. Ernstige sneeuwval in gebied waar toeleverancier opereert
10. Foutieve vraag- en productievoorspelling	10. Verstoringen door orkanen of tornado's in gebied waar toeleverancier opereert
11. Structurele problemen met toeleveringen	11. Verstoring door burgeroorlog in gebied waar toeleverancier opereert
12. Overige gebeurtenissen	12. Politieke instabiliteit in gebieden waar u actief bent
	13. Overstromingen in gebieden waar u actief bent
	14. Verscherpte wet- en regelgeving in gebieden waar u actief bent
	15. Terrorisme
	16. Overige gebeurtenissen

B1. Beschrijf in onderstaand figuur kort en bondig de belangrijkste verstoring(en) die u het afgelopen vijf jaar heeft meegemaakt. Onder belangrijk verstaan wij een verstoring die niet behoort tot de normale fluctuatie binnen uw bedrijf of anderzijds gekenmerkt kan worden als onverwacht, een lage kans op, maar aanzienlijke impact.

Verstoring I

Oorzaak	
Jaartal	
Gevolgen	
Genomen maatregelen om snel te herstellen	
Tijdsduur van de verstoring	
Leerervaringen n.a.v. deze verstoring en genomen structurele maatregelen	

Verstoring II (indien van toepassing)

Oorzaak	
Jaartal	
Gevolgen	
Genomen maatregelen om snel te herstellen	
Tijdsduur van de verstoring	
Leerervaringen n.a.v. deze verstoring en genomen structurele maatregelen	

Verstoring III (indien van toepassing)

Oorzaak	
Jaartal	
Gevolgen	
Genomen maatregelen om snel te herstellen	
Tijdsduur van de verstoring	
Leerervaringen n.a.v. deze verstoring en genomen structurele maatregelen	

Sectie C – *Resilience*

Een algemeen, door MIT (Massachussets Institute of Technology) research group opgestelde en aanvaarde, definitie van resilience is (Sheffi, et al. 2003):

In de materiaalkunde is resilience de fysieke eigenschap van een materiaal om na het buigen of indeuken terug te schieten in de oorspronkelijke vorm. Binnen organisaties kan resilience gedefinieerd worden als de mogelijkheid om na een onverwachte verstoring in de supply chain weer terug te keren naar de oorspronkelijke situatie (bijv. het weer op gang brengen van leveringen). Het gaat hier dus om het reduceren van de impact van de verstoringen en niet om het terugdringen van de kans op een gebeurtenis.

C1. Hebt u het gevoel dat het onderwerp 'resilience' leeft binnen uw bedrijf (bijv. bewustwording binnen management, een resilient strategie of het voorbereid zijn op mogelijke verstoringen)? *(op een vijfpuntschaal doorhalen wat niet van toepassing is)*

Helemaal niet 1 2 3 4 5 Voldoende bewustzijn

C2. Bent u, op basis van uw antwoorden zoals gegeven in sectie B, van mening dat resilience belangrijk is / zou moeten zijn voor uw bedrijf? *(op een vijfpuntschaal doorhalen wat niet van toepassing is)*

Helemaal niet mee eens 1 2 3 4 5 Helemaal mee eens

C3. Is uw bedrijf bereid inspanningen te doen om de effecten van potentiële verstoringen te reduceren door goede voorbereidingen vooraf? *(op een vijfpuntschaal doorhalen wat niet van toepassing is)*

Helemaal niet 1 2 3 4 5 Zeker wel

C4. Veronderstel dat uw bedrijf besluit om een resilience strategie te integreren in de bedrijfsvoering, waardoor u beter kunt reageren op potentiële verstoringen in de supply chain. In hoeverre bent u bereidt hierin te investeren? *(op een vijfpuntschaal doorhalen wat niet van toepassing is)*

Helemaal niet 1 2 3 4 5 Zeker wel

C5. Veronderstel dat uw bedrijf relaties met belangrijke toeleveranciers en klanten versterkt, waardoor u meer resilient wordt en dus beter kunt reageren op potentiële verstoringen in de supply chain. In hoeverre bent u bereidt hierin te investeren? *(op een vijfpuntschaal doorhalen wat niet van toepassing is)*

Helemaal niet 1 2 3 4 5 Zeker wel

Afsluitende vraag

Hoe kan TNO bedrijven het beste ondersteunen om meer resilient te worden (meerdere antwoorden mogelijk)? *(doorhalen wat niet van toepassing is)*

Workshops	ja / nee
Samenvatten van beschikbare literatuur	ja / nee
Beschrijven van succesvolle voorbeelden	ja / nee
Directe ondersteuning van bedrijf	ja / nee
Raamwerk om meer resilient te worden	ja / nee
Anders, namelijk	_____

Hartelijk dank voor uw medewerking!

Wilt u niet vergeten de vragenlijst aan ons terug te sturen;

Wilt u niet vergeten de vragenlijst aan ons terug te sturen;

per e-mail: bart.lammers@tno.nl

of per post:
TNO Bouw en Ondergrond, business unit Mobiliteit en Logistiek
Bart Lammers
Postbus 49
2600 AA Delft

Appendix C Questionnaire to LSPs

Supply Chain Resilience

Deze vragenlijst is ontwikkeld door TNO, in samenwerking met EVO, TLN, NDL en de Erasmus Universiteit, in het kader van het TRANSUMO project PROTECT. Het doel is beter inzicht te krijgen in de huidige stand van zaken met betrekking tot supply chain resilience in Nederland. Resilience wordt gedefinieerd als de veerkrachtigheid van ketens om grootschalige verstoringen op te vangen en de ontstane, maar ongewenste situatie, te herstellen in een (eventueel nieuw) economisch en logistiek evenwicht. Vooral Amerikaanse bedrijven hebben voor het jaar 2007 resilience tot topprioriteit benoemd, wijs geworden door o.a. 9/11, blokkades van de havens aan de Amerikaanse westkust in 2002 en de gevolgen van de orkaan Katrina. Het ligt in de lijn der verwachting dat dit gaat overwaaien naar Nederland.

De informatie wordt gebruikt om een kennis over resilience over te dragen aan Nederlandse bedrijven en een resilience raamwerk op te stellen. Op die manier kunnen Nederlandse bedrijven problemen in logistieke ketens voorkomen of de impact van mogelijke ongeregeldheden beperken. Alle verzamelde gegevens worden vertrouwelijk behandeld: alleen geaggregeerde en anonieme resultaten worden bekend gemaakt.

De vragenlijst dient bij voorkeur beantwoord te worden door de logistiek of operationeel manager van uw bedrijf of door medewerkers die betrokken/bekend zijn met dit onderwerp. Het invullen van de vragenlijst neemt niet meer dan 15 minuten in beslag. Als dank voor uw bijdrage ontvangt u de resultaten van het onderzoek, waardoor u de mogelijkheid hebt om uw antwoorden te vergelijken met de gehele steekproef.

De vragenlijst is opgedeeld in drie blokken:
- Sectie A – *Achtergrondinformatie*
- Sectie B – *Verstoringen*
- Sectie C – *Resilience*

Bij voorbaat dank voor uw deelname!

Met vriendelijke groet,

TNO Bouw en Ondergrond, business unit Mobiliteit en Logistiek
Bart lammers
Postbus 49
2600 AA Delft

Vragen? Bel Bart Lammers op 06-22230527 of mail via bart.lammers@tno.nl

September 2007

Sectie A – Achtergrondinformatie

A6. Wat is de naam van uw bedrijf? In welk land is het hoofdkantoor gevestigd? Hoeveel medewerkers heeft uw bedrijf? (deze informatie is alleen bestemd voor intern gebruik, bedrijfsnamen worden niet gepubliceerd)

Bedrijfsnaam	_____
Adres	_____
Vestigingsland hoofdkantoor	_____
# Medewerkers NL	_____

A7. Naam van de medewerker die de vragenlijst heeft ingevuld (deze informatie is alleen bestemd voor intern gebruik, namen van medewerkers worden niet gepubliceerd)

Naam	_____
Functie	_____
E-mail	_____
Telefoon	_____

A8. Welke diensten levert uw bedrijf? *(omcirkelen wat van toepassing is)*

Transport	ja / nee
Warehousing	ja / nee
Value added activities (bijv. assemblage of verpakken)	ja / nee
Anders, namelijk	_____

A9. Welke modaliteiten / faciliteiten gebruikt uw bedrijf voor het aanbieden van bovenstaande diensten? *(omcirkelen wat van toepassing is)*

Vrachtauto	ja / nee
Trein	ja / nee
Binnenvaart	ja / nee
Zeevaart	ja / nee
Luchtvaart	ja / nee
Warehouse	ja / nee
Tank / silo opslag	ja / nee
Anders, namelijk	_____

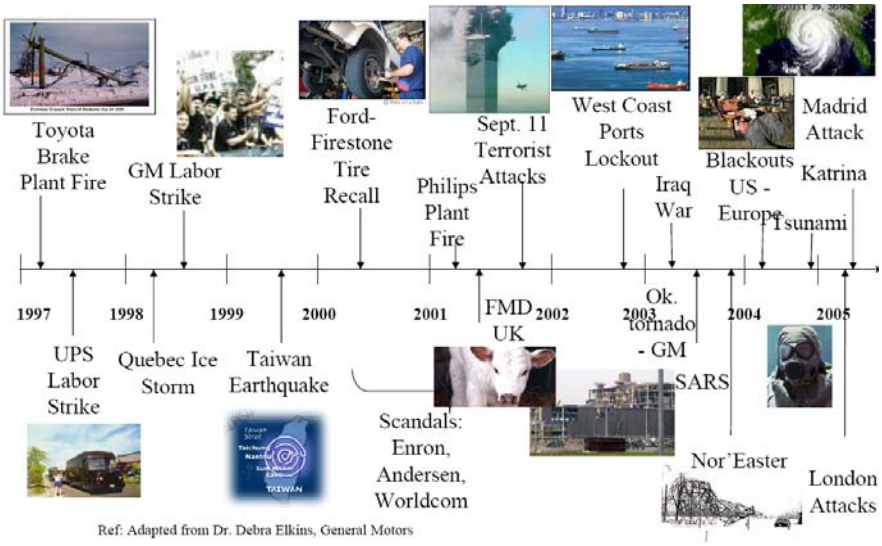
A10. In welke gebieden is uw bedrijf actief *(omcirkelen wat van toepassing is)*

	Door uw eigen bedrijf	**Via samenwerkings-partners**
Nederland	ja / nee	ja / nee
België / Luxemburg	ja / nee	ja / nee
Duitsland	ja / nee	ja / nee
Frankrijk	ja / nee	ja / nee
Polen	ja / nee	ja / nee
Italië	ja / nee	ja / nee
Overige Europese landen	ja / nee	ja / nee

Sectie B – *Verstoringen*

Herinnert u zich het capaciteitstekort bij ECT? Of hebt u recent te maken gehad met een faillissement van één van uw grote opdrachtgevers? Of hebt u te maken gehad met een andere langdurige verstoring? Vermoedelijk hebt u toen zelf ervaren hoe kwetsbaar uw logistieke netwerk is. Een aantal opeenvolgende trends, zoals het wereldwijd inkopen en uitbesteden van activiteiten, het beperken van het aantal toeleveranciers en de centralisatie van distributiefaciliteiten middels Europese distributie centra, hebben bijgedragen aan de gevoeligheid van vele supply chains. Het is dan ook aangetoond dat de grootste risico's niet liggen binnen uw bedrijf zelf, maar juist in de breedte van het netwerk van belangrijke toeleveranciers en klanten.

Indien al beschikbaar, richten vele bedrijven op dit moment vooral de aandacht op het garanderen van de bedrijfscontinuïteit door de risico's binnen het eigen bedrijf te beperken. Doordat de complexiteit van logistieke netwerken echter toeneemt, onder andere als gevolg van uitbesteding van bedrijfsactiviteiten, de globalisering en de onvoorspelbaarheid van de markt, neemt de kans op grootschalige verstoringen toe. Bovendien is de kwetsbaarheid van logistieke netwerken toegenomen als gevolg van langere en efficiëntere supply chains, waardoor de kleinste verstoring het gehele proces lam kan leggen. Dit kan leiden tot omzetverlies, doordat klanten orders terugtrekken of doordat servicegraden niet meer behaald kunnen worden. Op de lange termijn kan dit voor uw bedrijf zelfs leiden tot imagoschade of verlies van het marktaandeel. Hoewel vele risico's binnen de supply chain dus afstammen van de externe omgeving, bijv. oorlogen, epidemieën of aardbevingen, is er een groeiend bewijs dat de gevolgen ervan vooral te wijten zijn aan de structuur van het logistieke netwerk zelf.



Ref: Adapted from Dr. Debra Elkins, General Motors

De belangrijkste oorzaken van grootschalige en vaak langdurige verstoringen in supply chains zijn hieronder opgesomd. In de meeste gevallen betreft het hier de directe aanleiding die leidt tot een grootschalige verstoring. Dit overzicht is indicatief, met andere woorden u wordt uitgenodigd ook verstoringen met een andere oorzaak in uw gedachte mee te nemen.

Gebeurtenissen binnen de bedrijfscontext	**Gebeurtenissen in ketenperspectief**
13. Geen 14. Verlies van essentiële bedrijfsdata 15. Grootschalige problemen met ICT (bijv. werking ERP-pakket) 16. Grootschalige brand 17. Bedrijfsstakingen 18. Niet beschikbaar zijn van vervoer op het moment dat dit essentieel is 19. Problemen met vinden van geschikte nieuwe medewerkers 20. Grootschalige elektriciteitsstoringen 21. Grootschalige diefstal 22. Overige gebeurtenissen	0. Geen 17. Faillissement belangrijke klant / samenwerkingspartner 18. Juridische problemen met belangrijke klant 19. Staking bij belangrijke klant 20. Grootschalige brand bij belangrijke klant 21. Wegblokkades (bijv. Frankrijk) 22. Verstoring door klimatologische omstandigheden (bijv. aardbeving, ernstige sneeuwval, orkanen) in gebied waar belangrijke klant opereert 23. Verstoring door burgeroorlog in gebied waar belangrijke klant opereert 24. Politieke instabiliteit in gebieden waar belangrijke klant actief is 25. Overstromingen in gebieden waar belangrijke klant actief is 26. Verscherpte wet- en regelgeving in gebieden waar belangrijke klant actief is 27. Terrorisme 28. Boycot 29. Overige gebeurtenissen

B2. Beschrijf in onderstaand figuur kort en bondig de belangrijkste verstoring(en) die u het afgelopen vijf jaar heeft meegemaakt. Onder belangrijk verstaan wij een verstoring die niet behoort tot de normale fluctuatie binnen uw bedrijf of anderzijds gekenmerkt kan worden als onverwacht, een lage kans op, maar aanzienlijke impact.

Verstoring I

Oorzaak	
Jaartal	
Gevolgen	
Genomen maatregelen om snel te herstellen	
Tijdsduur van de verstoring	
Had u van te voren nagedacht over deze mogelijke verstoringsoorzaak en had u reeds maatregelen genomen?	
Leerervaringen n.a.v. deze verstoring en genomen structurele maatregelen	

Verstoring II (indien van toepassing)

Oorzaak	
Jaartal	
Gevolgen	
Genomen maatregelen om snel te herstellen	
Tijdsduur van de verstoring	
Had u van te voren nagedacht over deze mogelijke verstoringsoorzaak en had u reeds maatregelen genomen?	
Leerervaringen n.a.v. deze verstoring en genomen structurele maatregelen	

Verstoring III (indien van toepassing)

Oorzaak	
Jaartal	
Gevolgen	
Genomen maatregelen om snel te herstellen	
Tijdsduur van de verstoring	
Had u van te voren nagedacht over deze mogelijke verstoringsoorzaak en had u reeds maatregelen genomen?	
Leerervaringen n.a.v. deze verstoring en genomen structurele maatregelen	

Sectie C – *Resilience*

Een algemeen, door MIT (Massachussets Institute of Technology) research group opgestelde en aanvaarde, definitie van resilience is (Sheffi, et al. 2003):

In de materiaalkunde is resilience de fysieke eigenschap van een materiaal om na het buigen of indeuken terug te schieten in de oorspronkelijke vorm. Binnen organisaties kan resilience gedefinieerd worden als de mogelijkheid om na een onverwachte verstoring in de supply chain weer terug te keren naar de oorspronkelijke situatie (bijv. het weer op gang brengen van leveringen). Het gaat hier dus om het reduceren van de impact van de verstoringen en niet om het terugdringen van de kans op een gebeurtenis.

C6. Hebt u het gevoel dat het onderwerp 'resilience' leeft binnen uw bedrijf (bijv. bewustwording binnen management, een resilient strategie of het voorbereid zijn op mogelijke grootschalige verstoringen)? *(op een vijfpuntschaal omcirkelen wat van toepassing is)*

Helemaal niet 1 2 3 4 5 Voldoende bewustzijn

C7. Bent u, op basis van uw antwoorden zoals gegeven in sectie B, van mening dat resilience belangrijk is / zou moeten zijn voor uw bedrijf? *(op een vijfpuntschaal omcirkelen wat van toepassing is)*

Helemaal niet mee eens 1 2 3 4 5 Helemaal mee eens

C8. Is uw bedrijf bereid inspanningen te doen om de effecten van potentiële grootschalige verstoringen te reduceren door goede voorbereidingen vooraf? *(op een vijfpuntschaal omcirkelen wat van toepassing is)*

Helemaal niet 1 2 3 4 5 Zeker wel

C9. Veronderstel dat uw bedrijf besluit om een resilience strategie te integreren in de bedrijfsvoering, waardoor u beter kunt reageren op potentiële grootschalige verstoringen in de supply chain. In hoeverre bent u bereidt hierin te investeren? *(op een vijfpuntschaal omcirkelen wat van toepassing is)*

Helemaal niet 1 2 3 4 5 Zeker wel

C10. Veronderstel dat uw bedrijf relaties met belangrijke klanten / samenwerkingspartners versterkt, waardoor u meer resilient wordt en dus beter kunt reageren op potentiële grootschalige verstoringen in de supply chain. In hoeverre bent u bereidt hierin te investeren? *(op een vijfpuntschaal omcirkelen wat van toepassing is)*

Helemaal niet 1 2 3 4 5 Zeker wel

Afsluitende vraag

Hoe kan TNO bedrijven het beste ondersteunen om meer resilient te worden (meerdere antwoorden mogelijk)? *(omcirkelen wat van toepassing is)*

Workshops	ja / nee
Samenvatten van beschikbare literatuur	ja / nee
Beschrijven van succesvolle voorbeelden	ja / nee
Directe ondersteuning van bedrijf	ja / nee
Raamwerk om meer resilient te worden	ja / nee
Anders, namelijk	_____

Hartelijk dank voor uw medewerking!

Wilt u niet vergeten de vragenlijst aan ons terug te sturen;

per e-mail: bart.lammers@tno.nl

of per post:
TNO Bouw en Ondergrond, business unit Mobiliteit en Logistiek
Bart Lammers
Postbus 49
2600 AA Delft

Appendix D Survey results of manufacturing/trading companies

Code	Disruption	Measures	Lessons leant
M1	N/A	N/A	N/A
M2	Wrong project planning of outsourcing activities of sea transport bookings. Employees were already dismissed or were departed, whereas the process was still ongoing and not working in the correct way. As a result booking should be done manually and was often too late The disruption happened in 2006 and covered a period of half a year.	Much work done manually and working overtime by remaining employees.	Better and well-thought time planning. Having available an emergency plan.
	In 2006 and 2007 shortage of ADR road transport. Therefore it was not possible to supply our goods in time (or sometimes even not all) to customers.	Accepting longer lead times for the transport of goods.	Be more flexible regarding transport lead times.
	Merge of Nedlloyd and Maersk in 2006 resulted in a rejection of our containers at ships. Therefore this manufacturer was not able to supply various customers world-wide. The company realized that it was totally dependent on Nedlloyd for the transport of hazardous goods. The disruption lasted for half a year.	Training and introduction of the company's products at various (different) carriers.	Not working with only one carrier.
M3	N/A	N/A	N/A
M4	Strikes of mainly French railway operators, which interrupted the supply of manufacturing locations in the south of France regularly.	Shortage of raw material which results (in extreme circumstances) to the shut down of production and therefore no supply to final customer.	Making use of several rail vans to transport raw materials to overcome a period of strikes.
M5	Each year at least once internet facilities are not available. As a result customers are not able to enter orders in the booking system. The distribution assignment could not be replenished. As a result speed deliveries are necessary at the moment internet is available. Think about direct link between customers who orders via internet at online retailer, who is responsible for forwarding the order online to distribution system. Customer and publisher have overview of current data.	N/A	No structural measures taken. Dependent on availability internet provider / cable operator.
M6	Due to arson the production had to be stopped in 2005 for a period of 2 weeks. 30% available capacity in week 3, 4, 5. 60% available capacity in week 6, 7, 8. 100% available capacity after 3 months.	Insurance inspections. First week clearing, next week reinstallation, reconstruction.	Improved security requirements and close of industrial zone.
M7	Supplier unavailable to deliver products for a period of 3 months due to technical problems. Therefore, for	Redistribution of decentralize countries and making use of wholesaler's stock to limit the consequences.	Always knowing which alternatives are available for processes and suppliers.

	a period of 2 months (very) difficult to supply.	Looking for alternative supplier.	
M8	Delayed flights, changed flights, no cooling during flights. Therefore flowers arrived not cooled at airports. This happened frequently in the period 2006 and 2007.	People at location were managed by local employees of the company.	Full chain should be checked on cooled storage and transport. Data loggers are used to follow the supply chain from beginning till end.
	Arrival of incomplete deliveries in the period 2006-2007. As a result production could be influenced negatively for a period of 1 to 7 days.	Investments in pallets disposure.	Full orders should be sent by means of full pallets. At once entering of goods and after that transport to production.
M9	Within our company we need several articles to analyze samples from world-wide customers in a correct way. We have a supplier that contacts several other suppliers to deliver the requested goods. One of those suppliers went bankrupt in 2007 and therefore the requested products could not be delivered. As a consequence in specific circumstances we were not able to meet response times of providing sample results.	The company looked for other suppliers that were able to deliver substitutes. Due to specific conditions, delivery times, etc. this is a time consuming process and took at least 2 weeks. It is increased as the company is a laboratory and has outsourced those activities. Finally, an alternative supplier was found. Some times later the bankrupt supplier made a start up again and problems have been solved.	Being more aware that those things happen and an own inventory could be useful. In that way it will be possible to create a timing buffer and use that for ordering products at alternative suppliers. Moreover, looking for alternative suppliers for critical products in beforehand. In that way it will be possible to switch faster in case such a bankruptcy happens.
M10	Shifting sourcing to Bangladesh. Bangladesh is instable at multiple levels: political, infrastructure and climatology. Delayed delivery and lower quality of delivered products. Disruption happened in 2006-2007.	Cooperating with organizations that have local knowledge and are 'accepted' at governmental level.	Do not limit sourcing to only one country and guarantee easy switching.
	In 2006 congestion at Rotterdam harbor, strikes at hauling organization and customers happened for a period of several weeks. Therefore delay in supplies and as a result delays in supply of customers and own shops.	Rerouting to other harbors, although alternatives are limited as special agreements have been arranged with customers.	N/A
	Agreements between China and EU to introduce quota to protect European products for certain fashion categories. Applicable for the period 2005/2006/2007. As a result the possibilities to source specific fashion from China were limited.	Sourcing in other countries than China.	Do not limit sourcing to only one country
M11	In 2004 products were stucked for a 3 week period at Bangkok International Airport during the flower peak season. This was done by the regular carrier. Reserved capacity was sold to other companies that offered a higher price. As a result deliveries to customers were delayed; additional costs have to be paid for express deliveries with alternative carriers. Additional costs domestic express deliveries.	Express deliveries were sent via other carriers.	During peak seasons more lead-time should be included, smaller quantities should be sent so that offload has not such high impact anymore. Recently PAN-European agreements with expeditor, in which it is indicated that different carriers and schedules should be used.
M12	Strikes ECT Delta terminal, strikes Smit Tak (April 2006). Therefore containers were not timely available	N/A	As a manufacturer those strikes could not be influenced.

	and therefore could not be sold in a specific month or quarter. Impacted financial results for a specific time period. Loss of sales.		
	Computer disruption at ECT Delta terminal (May 2006), although last years there are multiple reasons why disruptions happen at ECT Delta terminal. Therefore containers were not timely available and therefore could not be sold in a specific month or quarter. Impacted financial results for a specific time period. Loss of sales.	As a manufacturer it is not possible to influence the availability of containers. The barge operator can be characterized as victim. As lead times should be reduced all transport is done by truck.	ECT operation cannot be influenced by manufacturer. Cargo is distributed as much as possible between Amsterdam and Rotterdam, although offering from China to Amsterdam is limited.
M13	In 2005 the power supply was lost. Therefore the company's processes stopped for a one day period.	The electricity supplier was contacted to deliver back-up power, although this was not successful.	Arrangement of back-up power facilities for ICT.
M14	Due to SARS in 2003 various deliveries were delayed. The disruption lasted for a period of 2 months.	Take other flight connections.	Making contingency planning.
	Problems with ICT when transferring to new warehouse operator. As a result delivery was delayed and sometimes the incorrect product was delivered. The disruption happened in 2005 and lasted for a period of one month.	Containment actions: tightly following daily planning, prioritizing, and ICT measures.	Slow, step by step, start-up in case of a transfer.
	In 2006 the new Thailand airport was operational. For a period of 2 weeks deliveries were delayed.	Close contacts with airport authorities and logistics service provider.	Build up of stock levels.
M15	Bankruptcy of supplier. Therefore structural problems with supply. Unsatisfactory production capacity at suppliers to meet market demand. As a result own planning was disrupted in the period 2005 - 2006 and customer demand could not be fulfilled timely and orders were missed. The disruption lasted 2 - 3 months.	Second sourcing. Redesign at component level.	Spreading of risks. Adjusting selection criteria of suppliers.
M16	N/A	N/A	N/A
M17	Too less transport availabilities, in combination with peak months (approx. 4 months). Due to flora and fauna legislation should be transferred to Germany. As a result costs will increase.	N/A	Develop activities in Germany
	Due to legislation it was not possible to work anymore in the Netherlands for a 4 months period and all equipment had been transported to Germany.	Purchasing wood in Germany.	N/A
	Storm. Huge losses in forest. Wood market collapse and prices go down. Stocks become less valuable. Such a disruption happens every 4 years approximately. Last one happened July 2006.	Limit contractual losses in advance	When sourcing in specific months, taking into account certain months in which storms occur more often.
M18	Big fire at major supplier. Therefore in 2004 we did not receive for half a year products from that supplier.	The company searches for alternatives. Tested them and implemented it (partially of the shelf products).	More awareness on the need of multiple sourcing, preferably at the supplier.

	In 2006 major strike at Finish paper industry. Rapidly increasing delivery times in the chain. Sometimes, already produced stock was not available anymore. The total disruption lasted for a period of 1 month.	Search for alternative suppliers (sometimes found). Although sometimes customers had to be contacted to mention the increase of delivery times.	It is still very difficult to anticipate to those disruptions. Although import of cardboard from China is started nowadays.

Appendix E Survey results of LSPs

Code	Disruption	Measures	Lessons leant
L1	3 days company strike (internal). Direct loss of sales as customers' accommodates capacity (temporarily) in other harbors. Also less trust of customers that this terminal operator is a "reliable partner"	N/A	Better contacts with social partners (not only within CAO negotiations). Better involvement of own personnel.
	Since 2004 difficulties to find new and qualified employees. As a result nowadays less qualified resources available for production and maintenance.	Advertising campaign; better contacts with education institutes. Forum organized industry Rotterdam harbor. Hiring contractors	Besides measures already taking, making more use of foreign employees.
L2	Due to a technical disruption in 2006 the company was 1 day not contactable for truck drivers and customers.	Contacting intermediary who arranges our telephones and subscription. Switching telephones to mobile, so the company could be reached.	If the same disruption would happen, the same measures would be taken
	Due to a downburst (A downburst is created by an area of significantly rain-cooled air that, after hitting ground level, spreads out in all directions producing strong winds.) in 2007 the roof of the warehouse was destroyed. Moreover stocked goods had losses. Supply chain disruptions take place for several months.	Involve an expert. Executing contra-expert opinion at the moment we had the feeling the insurance company would reject the claim.	Importantly of getting involved experts to carry out contra expertise.
L3	N/A	N/A	N/A
L4	N/A	N/A	N/A
L5	N/A	N/A	N/A
L6	In 2006 electricity supply failed for a period of 3 hours. Therefore no communication and administration was possible.	Used batteries to get light as soon as possible. Servers had already automatic back-up functionality.	Purchase of back-up power unit.
L7	Non availability of transport at the moment it is essential.	N/A	N/A
	Difficulties with finding qualified new employees	N/A	N/A
L8	In 2007 the company had too few qualified employees for a period of 6 months. As a result trucks could not be used.	Several employment agencies contacted, internal training, job advertisements, making use of charters, using German truck drivers.	Long term planning should be available. Making decisions immediately.
L9	In 2005 a fire happened at the server room. As a result the company had for a period of 2 days only a virtual central computer. For one day the company could only be contacted by phone.	After one day a replacement of the computer / server was available.	Emergency plans should be available. More serious training of BHV. Identifying clear guidelines. Backing of management team necessary to succeed.
L10	Due to large tender procedure the company lost a major customer (30% turnover) since 1 October 2006, as a German logistics service provider was 18% cheaper compared to the current conditions. As a result 60% of the activities should be stopped.	Via customer requested to cooperate with new logistics service provider. He was a little bit skeptical, although in a later stage happy with this support.	More customer differentiation, although this is more difficult than it looks like. Structural measures taken like better involvement of MT and mid-layer employees. Moreover more critical to customers; now always saying "yes", also indicating "no" in an early stage.

L11	N/A	N/A	N/A
L12	N/A	N/A	N/A
L13	From 2000 to 2001 and also in 2007 lack of qualified employees. Strengthened by large changes in employee portfolio. As a result growth was reduced and quality of service was more difficult to realize. As a result the optimal prices could not be charged. Moreover not fully qualified personnel hired, although the results were not satisfactory in forehand.	Own employment agency introduced which mediates between people from Eastern Europe and our (other) companies. Reward adjusted, partly fixed and partly flexible (based on performance). Employees who do not fit in the companies cultures were requested to leave.	Partly outsourcing activities. Labor costs should be in line with increase of turnover. Possibility to made workers redundant (via employment agency).
	Sudden stop of cooperation by partner, which represented largest import and export (250.000 - 500.000 Euros a year). Partner was in 1999 taken over by another company. Return on investment was according to board of directors too low. Current management was replaced. Relationships became useless, as new MT and other ideas.	Try to set up new cooperation with other companies. This attempt was not successful as we as company were a niche player with only a limited number of suppliers for each country. Our former partner was prepared, although we were not.	Always thinking about alternatives. Be prepared of a potential change. Try to contact as much as possible those who are responsible for making decisions.
L14	In 2006 and 2007 power supply failed for a period of 2.5 hours. As a result the production stopped and for a period of 36 hours there were difficulties regarding the start up of the mechanical order collection system.	During peak hours the company hired a back-up power unit	Probably the company will install a permanent back-up power unit, as the impact of the disruption is more than only the 2,5 hours of production loss
	In 2003 one of the offices / DC was hit by a flooding due to heavy rain showers. As a result there were losses to dock levelers, stocked goods (limited loss), cleaning of office floors, walls and doors, electricity switched of for a period of 2 days as transformer facilities were flooded, all IT facilities were shifted down. The disruptions covered a period of 3 days.	Salvage (the act of saving or rescuing a ship or its cargo) company involved via insurance company.	A business continuity plan was created to overcome those types of calamities and limit the loss and be operational as soon as possible.
	In the year 2005 short-circuit in ups of IT equipment happened. As a result (toxic) smoke development inside the company and the company workers had to be evacuated. All IT equipment had to be shut down and therefore the operational process was disturbed. All equipment had to be cleaned by a special company due to toxic and corrosive steam that turned down on equipment.	UPS (uninterruptible power supply) shut down and by means of back-up power unit IT equipment was restarted soon.	Facilities for exchanging computers / servers are examined.
L15	N/A	N/A	N/A
L16	Government laws are unreliable; no clear vision. Too many inspections by different organizations. Much double working activities and moreover often without reporting in advance.	N/A	N/A
L17	In 2004 internal theft with a total value of 25.000 Euro. As a result agitation at employees; who is responsible? Police investigation for several months. Potential perpetrators have left the company in the meantime.	Various inspections of outgoing goods, extension of scanning. Entry controllers and cameras.	Also make clear that measures be taken to overcome theft are maintained.
	Heavy snowfall in the Netherlands (November 2005 and	No measurement was available to overcome	Too much traffic at the roads?

	winter 2006/2007). Roads are heavily congested. Cars get stuck for a full night.	those problems.	