On Managing Disruption Risks in the Supply Chain - the DRISC model

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Lund, September 2007

Ulf Paulsson

Abstract

Background
Today's modern, industrialized society is based on globalization, specialization and mass-production. It is a society dependent upon highly integrated supply chain flows. Disruptions in those flows may cause devastating negative consequences, both for the individual company, for the supply chain, and for the society at large.

Purpose and objectives
The *purpose* of the thesis is *to contribute to the knowledge on how to manage disruption risks in the supply chain*. There are two objectives. The *first* is to "*to identify, structure and summarize the state of the art on supply chain disruption risks*". The *second* is "*to develop and test a generic, aggregate model for managing disruption risks in the supply chain*".

Method
The first objective is fulfilled with the help of a *search* in literature within the areas of risk, risk management, supply chain management, and supply chain risk. The results from the literature review are then complemented with *empirical* material, and the existing knowledge within each area is summed up and analysed. Finally conclusions are drawn and suggestions for new research are presented.

The identified research need is used as starting point for the fulfilment of objective two. A model, called the *DRISC model* (Disruption Risks In Supply Chains), dealing with the risks of disruptions in the product flow in the supply chain from raw material to end market, is developed. The usability of the complete DRISC model is *tested* through application on a *real case* and through a *survey* among risk managers.

Results

The state of the art review revealed that supply chain risk management can be described as a new area under rapid development with several interesting "islands of theories" but yet without any common, solid foundation of basic concepts and generic models.

The DRISC model covers, as seen from the angle of an individual company/unit in the supply chain, all potential product flow-related disruption risks in the total supply chain. These risks are classified into 15 different classes that are assessed and summarized into a total expected consequence value. The model further assists in finding new and better ways to handle those risks.

The test of the DRISC model on a real case, Brämhults, showed that the model was of value for identifying, structuring and estimating the supply chain risks and for giving an overall picture of the risk exposure situation. The survey of risk managers confirmed that.

Summary

BACKGROUND

Two hundred years ago, supply chains basically had just one link, e.g. the farm. Today the supply chain from natural resources to end market could easily consist of ten sequential links or more. The chain of transport and storage activities from the first supplier to the end market has also changed character over the years and gradually developed from a step-wise chain via a logistical chain into a supply chain — a supply chain that today is in rapid change. For many products, no single company[1] has control of more than just a small portion of the total value adding process. As a consequence, today more *focus* is *on the supply chain* and less on the individual company in the chain. It is, however, only the individual company that can take actions, but those actions must now be taken with a supply chain perspective.

With competition shifting from companies to supply chains, it has become very important for the individual company to be a "member" of a competitive supply chain that gives the company a fair share of its surplus. It has therefore become essential for the individual company in the supply chain to find out what consequences different supply chain design and management alternatives have for the competitiveness of the supply chain and of the company, and to actively promote alternatives with high competitiveness.

Many firms that earlier realised that the biggest *opportunities* to increase their competitiveness did not lie in improving their internal efficiency but in supply chain design and integration are now realizing that the biggest *risks* to the company are not within the company itself but in *its dependency on the supply chain*. The conclusion that many seem to draw today is that when dealing with supply chain issues, increased attention has to be devoted to risk aspects.

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[1] or organization or authority or other relevant unit. Only the word “company” will be used in the Summary, but the application area is much broader than that.

Today's modern, industrialized society is based on globalization, specialization and mass-production, just to mention a few of the relevant trends. Almost no company makes the whole product any longer, unless it is a very uncomplicated product. It is a society based on highly integrated supply chain flows. Disruptions in those flows can rapidly have severe negative consequences for the individual company, the supply chain and for society. On the other hand, the possibilities to handle disruptions of different kinds are much greater today than before. But to be able to grasp those possibilities you need to have knowledge of the risks and how to handle them.

PURPOSE AND OBJECTIVES

The *purpose* of this thesis is *to contribute to the knowledge on how to manage disruption risks in the supply chain*.
There are two objectives:

- *to identify, structure and summarize the state of the art on supply chain disruption risks; and*
- *to develop and test a generic, aggregate model for managing disruption risks in the supply chain.*

STRUCTURE AND METHOD

The thesis consists of *four* conceptually different sections where the first section includes an introductory chapter and a methodological chapter.

The *second section* deals with the fulfilment of the first objective. It starts with a *general search* in literature within the areas of risk, risk management, supply chain management, and supply chain risk. Included in the last is a *comprehensive search* for scientific articles; the articles found are stored in a database, which is then analysed from different angles. After supplementing the results from the literature review with some *empirical* material, the existing knowledge within the areas is summed up and analysed. Finally conclusions are drawn concerning the need for new research.

The *third section* deals with the fulfilment of the second objective. The identified need for new knowledge through research is here one starting point. A model dealing with disruption risks in the product flow of a generic total supply chain is developed. The model is called the *DRISC model* (Disruption Risks In Supply Chains). It has three important theoretical influences: a risk definition by Kaplan (1997), a risk management model from International Electrotechnical Commission (IEC 1995), and a supply chain risk structure model from Peck et al. (2003). The model is a step-by-step approach for assisting in risk management of supply chains. First the overall structure for the DRISC model is presented and then the initial part of the model – the framework for description and analysis – is developed. After that the different partial models for the risk management process are developed and, finally, integrated into the complete DRISC model. The usability of the DRISC model is then tested in two different ways: through application on a *real case* (Brämhults) and through a *suvey* among some risk managers. At the end of the section, conclusions are drawn and comments made concerning the developed DRISC model.

In the *fourth section* finally the results of the study are summed up, some final remarks about the area and of the study itself are made, and areas for further studies are proposed.

RESULTS

The *purpose* of the study was to contribute to our knowledge on how to manage disruption risks in the supply chain and has been fulfilled by the achievement of the two objectives.

The state of the art review

In all the presented cases there are supply chain flow-related risks, but the risk sources are of different kinds and the disruptions have more or less serious consequences. The ways the risks are handled also differ a great deal, as well as the degree to which the company is acting proactively. The rapidly increased importance of analysing how risks easily spread and amplify up and down the supply chain, so called integrative risks, does not seem to have been matched by an equal increase in risk awareness, and definitely not in risk handling actions. The focus appears to be mainly on separate, limited risks within a single plant, and they are handled with traditional risk handling methods. This behaviour is also supported by the tendency to split the risk responsibility between many different individuals and departments within each company. Hence there is a need for a better understanding of integrative risks and for collaborative risk handling processes.

Risk and *risk management* seem to be *theoretical areas* within which there is solid knowledge within a number of applied fields. There could be rather large differences between the different fields, but within each there is a consensus about how to define, identify, assess and manage the risks. Risk management *in organizations* has of tradition mainly concentrated on individual, separate risks, and suitable methods for dealing with each risk have been developed. But interest in integrative risks and collaborative risk handling has grown over time, and theories covering such risks have now been developed. *Supply chain management,* which stresses integration between the different links in the chain, is a rather new but currently well-established theoretical area within which there exist a number of separate "islands" of knowledge as well as a core of established knowledge. Within the theoretical area of *supply chain risks,* separate and clearly definable risks are still very much in focus. However, an increasing interest can be noticed in studying the changes in risk due to the increased integration in today's society, not least in the supply chains. Finally we have *supply chain risk management,* which can be seen as a new, theoretical area under rapid development with several interesting "islands of theories" but yet without any common, solid foundation of basic concepts and generic models for description and decision support.

A *need for better knowledge through research* is present in many of the above areas, but what seems to be especially important is the present lack of frameworks for decision support within supply chain risk management. There exists a clear need for models that are *general* and *proactive* and that with *limited efforts* can provide a picture of the risk situation in the *total supply chain* as well as assist in *finding new solutions* to the main risk problems.

The DRISC model

The DRISC model developed covers, as seen from the angle of an individual (focal) company in the supply chain, all product flow-related disruption risks in the total supply chain from natural resources to the delivered final product, and makes it possible to classify them into *15 different risk exposure boxes*, of which 3 include known result impacts and 12 expected result impacts. It also gives the possibility to summarize them into a total result impact figure. The model further assists in finding new and better ways to handle those risks. The DRISC model intend to be a *holistic* and *generic model* for managing disruption risks in the product flow of the supply chain that helps to treat supply chain risk issues systematically. It can be employed in a number of different ways and by different users as well.

The DRISC model is *positioned* vis-à-vis a number of other models dealing with supply chain disruption risk issues with the help of the two dimensions “supply chain scope” and “risk/opportunity scope”. It turns out that the research contributions that have most similarities with the DRISC model are Peck et al. (2003), Norrman & Jansson (2004), Gaudenzi (2005), and Kleindorfer & Saad (2005). A closer look at each of these reveals that the DRISC model explicitly includes more types of flow-related disruption risks in the total supply chain than the other models do, and that the DRISC model presents a partly new structure for risk analysis and risk evaluation of supply chain flow risks and how to manage them.

The *test* of the DRISC model on the Brämhults *case* showed that the model was of value for identifying, structuring and estimating the supply chain risks and for giving an overall picture of the risk exposure situation. The *survey* of risk managers confirmed that. It seemed that the respondents, although they had some criticisms e.g. of the use of certain concepts, all agreed that the DRISC model was an understandable model that could be useful for different kinds of risk audits.

The DRISC model developed here underlines the integrative risks in the supply chain and stimulates the individual link in the chain (the focal unit) to pay attention to and act in the best interests of the total supply chain, and to find and implement risk-handling solutions in co-operation with its supply chain partners while simultaneously looking after its own welfare. The model helps to make risk management holistic, structured and explicit, and is thereby hopefully *contributing to a more efficient and effective managing of supply chain disruption risks.*

Sammanfattning

BAKGRUND

Fokus riktas allt mer mot försörjningskedjan och allt mindre mot det enskilda företaget i takt med att konkurrens mellan enskilda företag[2] ersätts av konkurrens mellan försörjningskedjor. Det är emellertid endast det enskilda företaget som kan fatta beslut och vidta åtgärder, men dessa beslut och åtgärder måste idag ske utifrån ett kedjeperspektiv.

Med *ökat fokus på försörjningskedjan* har det blivit allt viktigare för det enskilda företaget att tillhöra en slagkraftig kedja vilken ger företaget en rimlig del av kedjans överskott. Det har därför blivit väsentligt för det enskilda företaget i försörjningskedjan att undersöka vilka konsekvenser olika design på kedjan och dess styrning har för kedjan, och för företaget, samt att aktivt stödja alternativ med hög konkurrensförmåga.

Många företag som tidigare ansåg att deras största potential för att öka sin konkurrensförmåga inte låg i att förbättra den interna effektiviteten utan i att förbättra försörjningskedjans design och integration anser nu att *de största riskerna* för företaget inte finns inom företaget själv utan *i dess beroende av kedjan*. Den slutsats som många drar är att när man hanterar frågor som har med försörjningskedjan att göra, så måste ett ökat intresse ägnas åt riskaspekterna.

Dagens moderna industrialiserade samhälle är baserat på globalisering, specialisering och massproduktion – för att bara nämna några av de aktuella trenderna. Nästan inget företag gör en hel slutprodukt längre, såvida det inte är en mycket enkel produkt. Det är ett samhälle baserat på högt integrerade flöden av råvaror, halvfabrikat och färdiga produkter. Avbrott i dessa flöden kan snabbt få allvarliga negativa konsekvenser, både för det enskilda företaget, för försörjningskedjan och för samhället. Å andra sidan är möjligheterna att hantera dessa avbrottsrisker klart

[2] eller organisationer eller myndigheter eller annan relevant enhet. Endast begreppet företag kommer dock att användas här i sammanfattningen men tillämpningen är mycket bredare än så.

större än tidigare. Men för att kunna gripa dessa möjligheter behövs kunskap om vilka riskerna är och hur de kan hanteras.

SYFTE OCH MÅL

Avhandlingens *syfte* är *att bidra till ökade kunskaper om hur avbrottsrisker i flödeskedjor kan hanteras.*
Avhandlingen har två mål:

- *att identifiera, strukturera och summera upp kunskapsfronten för området avbrottsrisker i försörjningskedjor*
- *att utveckla och testa en generisk, aggregerad modell för hantering av avbrottsrisker i försörjningskedjor.*

STRUKTUR OCH METOD

Avhandlingen består av fyra konceptuellt olika sektioner där den *första sektionen* innehåller ett introduktionskapitel och ett metodkapitel.

Den *andra sektionen* handlar om uppfyllandet av det första målet. Det börjar med ett generellt sökande efter litteratur inom områdena risk, risk management, supply chain management och supply chain risk. Inom det senare området görs även en omfattande sökning efter vetenskapliga artiklar; artiklarna lagras i en databas vilken sedan analyseras utifrån olika aspekter. Efter att ha kompletterat litteratursökningen med en del empiriskt material så summeras kunskapsfronten inom respektive område upp och kommenteras. Slutligen identifieras behovet av ny forskning.

Den *tredje sektionen* handlar om uppfyllandet av det andra målet. Det identifierade behovet av ny forskning är här en viktig utgångspunkt. Stegvis utvecklas en modell som behandlar avbrottsrisker i flödet i hela försörjningskedjan. Modellen kallas DRISC-modellen (Disruption Risks In Supply Chains). Den har tre viktiga teoretiska inspirationskällor; en riskdefinition av Kaplan (1997), en risk management modell från International Electrotechnical Commission (IEC 1995) och en ”supply chain risk structure” modell från Peck et al. (2003). Först presenteras den övergripande strukturen för modellen och därefter utvecklas den inledande delen av modellen kallad ”the framework for description and analysis”. Efter det utvecklas de olika partiella modellerna för risk management-processens olika delar och slutligen binds delarna ihop till den fullständiga DRISC-modellen. DRISC-modellens användbarhet testas sedan på två olika sätt; dels genom applikation av modellen på ett verkligt case (Brämhults), dels genom en enkät till risk managers. I slutet av sektionen görs kommentarer av den utvecklade DRISC modellens användbarhet och slutsatser dras.

Slutligen i den *fjärde sektionen* summeras studiens resultat upp, och några avslutande kommentarer ges om det studerade området och om själva studien.

RESULTAT

Kunskapsfronten

I samtliga presenterade *case* finns risker relaterade till flödet i försörjningskedjan, men riskkällorna varierar och avbrotten har mer eller mindre allvarliga konsekvenser. Sättet att hantera riskerna varierar också en hel del, liksom graden av proaktivt agerande. Den snabbt ökande betydelsen av risker som sprids och förstärks längs kedjan, s.k. integrativa risker i försörjningskedjans flöde, tycks inte ha matchats av en lika stor ökning i riskmedvetandet och definitivt inte i vidtagna riskhanteringsåtgärder och i risk management. Fokus tycks huvudsakligen vara på separata, begränsade risker, och de hanteras med traditionella riskhanteringsmetoder. Detta beteende understöds också av tendensen att dela upp riskansvaret på många olika individer och avdelningar.

Risk och *risk management* tycks vara teoretiska områden där det finns en solid kunskap inom ett antal applikationsområden. Det kan finnas klara skillnader mellan olika områden, men inom varje applikationsområde finns en konsensus om hur man definierar, identifierar, värderar och hanterar riskerna. *Risk management i organisationer* har av tradition huvudsakligen koncentrerats på individuella, separata risker och lämpliga metoder för att hantera respektive risk har utvecklats. Men ett intresse för integrativa risker och riskhantering som samordnas mellan kedjans parter har uppstått med tiden, och teorier som täcker detta har utvecklats. *Supply chain management,* vilket betonar integrationen mellan de olika leden i försörjningskedjan, är ett ganska nytt men idag väl etablerat teoretiskt område inom vilket det finns ett antal separata "kunskapsbitar" och även en kärna av etablerad teori. Inom området *supply chain risks* är det de enskilda och klart identifierbara riskerna som fortfarande står i fokus. Emellertid kan ett ökat intresse för att studera riskkonsekvenserna av den ökade integrationen i dagens samhälle, inte minst bland försörjningskedjorna, skönjas. Området *supply chain risk management*, slutligen, kan ses som ett nytt teoretiskt område under snabb utveckling med flera intressanta "öar av teorier" men ännu inte med någon gemensam, solid bas av grundläggande begrepp och modeller att stå på.

Behov av ny forskning finns inom många av de ovan nämnda områdena men vad som är speciellt framträdande i nuläget är bristen på grundläggande teoretiska begrepp och strukturer inom supply chain risk management. Där finns det ett klart behov av modeller som är generella och proaktiva och som med begränsade resurser kan bidra till att ta fram en bild av risksituationen i hela försörjningskedjan samt hjälpa till med att finna nya lösningar på de viktigaste riskproblemen.

DRISC-modellen

Den utvecklade DRISC-modellen omfattar, sett utifrån ett enskilt (fokalt) företags synvinkel i försörjningskedjan, alla produktflödesrelaterade avbrottsrisker i hela försörjningskedjan från naturresurser till levererad slutprodukt, och gör det möjligt att klassificera riskerna i *15 olika riskexponeringsboxar*, av vilka 3 omfattar känd resultatpåverkan och 12 förväntad resultatpåverkan. Den skapar också möjlighet att summera ihop dem till en enda siffra för resultatpåverkan. Vidare kan man med modellens hjälp lättare hitta nya och bättre sätt att hantera dessa risker. DRISC-modellen är en *holistisk* och *generisk* modell för hantering av avbrottsrisker i försörjningskedjans produktflöde vilket underlättar en systematisk behandling av försörjningskedjans riskfrågor. Modellen kan användas på många olika sätt och likaså av många olika slags användare.

DRISC-modellen positioneras gentemot ett antal andra modeller, vilka också behandlar riskfrågor relaterade till avbrott i försörjningskedjan, med hjälp av de två dimensionerna "försörjningskedjans omfattning" och "risk/möjlighet omfattning". Det visar sig att de forskningsbidrag som bäst överensstämmer med DRISC-modellen är Peck et al. (2003), Norrman & Jansson (2004), Gaudenzi (2005), och Kleindorfer & Saad (2005). En närmare granskning av dessa visar att DRISC-modellen explicit inkluderar fler flödesrelaterade avbrottsrisker i hela försörjningskedjan än vad de andra modellerna gör och att DRISC-modellen presenterar en delvis ny struktur för riskanalys och riskvärdering av flödesrelaterade avbrottsrisker i försörjningskedjan och för hur dessa skall hanteras.

Testen av DRISC-modellen på caset Brämhults visade på att modellen var av värde för att identifiera, strukturera och estimera riskerna i försörjningskedjan och för att ge en översiktlig bild av riskexponeringen. Enkäten till risk managers bekräftade detta. Det föreföll som om respondenterna, även om de hade en del kritik t.ex. på användningen av vissa begrepp, alla var överens om att DRISC-modellen var en begriplig modell som kunde vara användbar vid olika typer av riskgenomgångar.

DRISC modellen betonar de integrativa riskerna i försörjningskedjorna och stimulerar den enskilda länken i kedjan (det fokala företaget/enheten) att ägna uppmärksamhet åt samt agera för hela kedjans bästa, och för att finna och implementera riskhanteringslösningar i samarbete med sina partners i försörjningskedjan samtidigt som den ser till sitt eget bästa. Modellen kan användas som ett stöd för att göra riskhanteringen holistisk, strukturerad och explicit, och kan därmed förhoppningsvis bidra till en mer effektiv hantering av avbrottsriskerna i försörjningskedjor.

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Figures and Tables

Figures

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List of Definitions

(in the order they appear in the thesis)

- **Risk – general definition**: *Risk means being exposed to the possibility of a bad outcome.* (Place: Section 1.1.2. Source: Borge, 2001, p. 4).
- **Risk management**: *The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence*. (Place: Section 1.1.2. Source: Risk: Analysis, Perception and Management, 1992, p. 5).
- **Supply chain**: *A set of relationships among suppliers, manufacturers, distributors, and retailers that facilitates the transformation of raw materials into final products.* (Place: Section 4.1.3. Source: Beamon, 1998, p. 292).
- **Supply chain management**: *The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole.* (Place: Section 4.1.3. Source: Christopher, 1998, p. 18).
- **Supply chain risk management:** *To, collaboratively with partners in a supply chain or on your own, apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources in the supply chain.* (Place: Section 5.1. Source: Definition by the author in Brindley (ed), 2004, p. 80, developed from Norrman & Lindroth, 2002).
- **Product:** *Something one gets paid to deliver.* (Place: Section 8.1.1. Source: Definition by the author).
- **Focal unit**: *The individual unit in the supply chain from the perspective of which the supply chain flow risk issues are seen, interpreted and acted upon*. (Place: Section 8.1.1. Source: Definition by the author).
- **Focal product**: *The individual product or product group that the focal unit chooses to study.* (Place: Section 8.1.1. Source: Definition by the author).

- **Supply chain disruption:** *An interruption in the continuity of the normal supply chain flow with a negative impact.* (Place: Section 8.1.2.1. Source: Definition by the author developed from WordNet (2007) and from Svensson (2002)).
- **Negative consequence – definition in the DRISC model:** *A consequence of a disruption in the supply chain product flow that in comparison with the normal result created by the normal product flow has a negative result impact.* (Place: Section 8.1.2.1. Source: Definition by the author).
- **Expected outcome – definition in the DRISC model:** *The product of likelihood and consequence.* (Place: Section 8.1.2.2. Source: Definition by the author).
- **Risk – definition in the DRISC model:** See Figure 8.22 (Place: Section 8.4.3.3. Source: Definition by the author developed from Kaplan, 1997).

SECTION I

1 INTRODUCTION

First the background to the study is given. Then the research challenges are identified, the purpose presented, the objectives set and the potential contributions of the study for different target groups discussed. After that some theoretical areas of special relevance for the study are presented. Finally the basic methodological design and chapter structure are presented and their links to the objectives clarified. [3]

1.1 BACKGROUND

1.1.1 Transportation and storage in a historical context

Going back a century and a half in history we will find that in Sweden, as in most of today's other highly industrialized countries, the local farm was the basic economic and social unit on which the society was built. About 80–90 % of the population had agriculture as their occupation and lived on a farm. Almost everything that the inhabitants on the farm consumed was also produced at the same farm including food, water, clothing and housing. Transports were short and local – mainly to and from the farm's own fields. Storing was also local, usually in the farm’s own barns. While consumption was spread over the whole year, production was more discontinuous. Foodstuffs were mainly produced during the summer half of the year. It was therefore necessary for the farmers to have filled up their barns with foodstuffs like crops to survive

[3] Italics are used for chapter overviews, citations in text, separate citations, figure texts and table texts. Italics are also used for words, concepts and short sentences that the author finds important to emphasize.

the winter. For example, a hailstorm that destroyed the crops could have fatal consequences, as the possibilities to get foodstuffs from other parts of the country or from abroad were very limited.

Today's modern, industrialized society is based on globalization, specialization and mass-production, just to mention a few of the relevant trends. Almost no company or production unit makes the whole product any longer, unless it is a very uncomplicated product. The company is just one link in a supply chain where each link adds a part of the total value of the final product. A *supply chain* can briefly be described as a network of all the individual enterprises that collaborate to produce a product that satisfies customer needs.

Storing, which earlier was regarded as absolutely necessary to survive the winter, is today more regarded as something that should be avoided. The individual family has often just stored enough food for a couple of days' consumption, and companies also try to minimise storage. Both families and companies are therefore dependent on more or less continuous replenishment.

Two hundred years ago there was basically just one link in the supply chain – the farm. Today the supply chain from natural resources to end customer could easily consist of ten links or more. The chain of transport and storage activities from first supplier to end customer has also changed character over the years and gradually developed from a step-wise chain via a logistical chain into a supply chain (Cooper, Lambert & Pagh, 1997) — a supply chain that today is in rapid change. For many products, no single company has control of more than just a small portion of the total value adding process. Therefore competition no longer tends to be between different companies, but between different chains of companies (Christopher, 1998, p. 16). As a consequence, more *focus* is today *on the supply chain* and less on the individual company in the chain. It is, however, only the individual company that can take actions, but those actions have today to be taken with a supply chain perspective.

> *"The rapid development of transport systems, information technology, and just-in-time schemes leads to a high degree of*

integration and coupling of systems and the effects of a single decision can have dramatic effects that propagate rapidly and widely through the global society".
(Rasmussen & Svedung, 2000, "Proactive Risk Management in a Dynamic Society", p. 10)

Today's society is a society based on highly integrated supply chain flows. Disruptions in those flows might easily rapidly spread and amplify up and down the supply chain, so called *integrative risks*, and have severe negative consequences, both for the individual company, for the supply chain, and for society. On the other hand the possibilities to handle disruptions of different kinds are much greater today than before. But to be able to grasp those possibilities you need to have knowledge of the risks and how to handle them.

1.1.2 Increased focus on how to manage company risks

Risk, according to Borge*, "means being exposed to the possibility of a bad outcome"* (Borge, 2001, p. 4). This definition will be used in this study as a *general* **definition**[4] of the concept risk. Risk can thus be characterized as an event with negative consequences. To be able to come to grips with risks, risk management is needed.

The same source describes risk management in the following way: *"Risk management means taking deliberate action to shift the odds in your favour"* (Borge, 2001, p. 4). But here another source for the definition will be chosen, and that is The Royal Society in Britain. It **defines** *risk management* as *"the process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence"* (Risk: Analysis,

[4] The word defined in bold (**defined**) indicates that this definition of the concept will be used as a basis in the study, and that the definition can be found in the list of definitions presented at the beginning of the thesis just after the table of contents.

Perception and Management, 1992, p. 5). So you could say that risk management is dealing with risk issues in a systematic and rational way.

Company risks of different kinds have received increasing attention during the last decade, both in media (Simons, 1999) and as a research topic. For instance a number of major electricity blackouts in recent years in Europe and North America have underlined the vulnerability of our modern society and of its flows of material and information. In some countries new legislation has been introduced making it compulsory to include risk assessment information in the annual report. The tragic events of September 11 have further stressed the vulnerability of today's society (Greenberg, 2002). Added to this is an increasing awareness that mankind might be at the threshold of a period of extreme weather conditions like flooding and hurricanes, and e.g. Business Week has had cover stories like "The next big one" [5] .

> *"Compared to the stable conditions of the past, the present dynamic society brings with it some dramatic changes of the conditions of industrial risk management".*
> (Rasmussen & Svedung, 2000, "Proactive Risk Management in a Dynamic Society", p.10)

With competition shifting from companies to supply chains it has become very important for the individual company to be a "member" of a competitive supply chain that gives the company a fair share of its surplus. It has therefore become essential for the individual company in the supply chain to find out what consequences different supply chain design and management alternatives have for the competitiveness of the supply chain and of the company, and to actively promote alternatives with high competitiveness. (Beamon, 1998; Christopher 2005),

So far, short-term operational efficiency issues seem to have dominated this design work. But every supply chain design alternative also includes risks of different kinds, and many supply chains tend to be increasingly vulnerable. Many firms that earlier realised that the biggest

[5] Nussbaum, Bruce (2005) "The next big one". Business Week, European edition, September 19, 2005.

opportunities to increase their competitiveness did not lie in improving their internal efficiency but in supply chain design and integration are now realizing that the biggest *risks* to the company are not within the company itself but in *its dependency on the supply chain*. (Kajüter, 2003, p. 322).

A number of *severe company events* caused by supply chain disruptions have occurred during recent years, illustrating the fact that disruptions in one link of the chain could easily spread to other links in the chain (domino effects). (Bartholomew, 2005; Sheffi, 2005).

One example is Ericsson and the Albuquerque event in 2000. A minor fire caused by lightning in a production cell, a so-called clean room, at a sub-supplier's (Philips) plant in Albuquerque, New Mexico (USA), affected the delivery of electricity, causing overheating, which started a fire. The fire was extinguished in less than ten minutes, but it made the production room unclean and destroyed the production equipment. From a plant perspective the impact was low, but for Ericsson it was huge because the needed component – a radio frequency chip for their new mobile telephone T 28 – was single sourced. At that time there was a general lack of capacity for that kind of component all over the world, and still after 6 months the production of chips in the Albuquerque plant was only 50 % of normal production. Ericsson therefore lost many months of production of the T 28 model, which had just been very successfully launched, and was not able to meet market demand. For a considerable period of time, sales were lost and so were market shares. The accident also had an impact on Ericsson's decision to stop operating on the mobile phone terminal market on their own (Norrman & Jansson, 2004; Sheffi, 2005).

In his presentation of the half-year result for the period 1/1 – 30/6 2000 Kurt Eriksson, the managing director of Ericsson, said that if it hadn't been for the missing components the mobile telephone division would have presented a profit; now it was a loss of 1,8 billion SEK (Sydsvenska dagbladet, 22 July 2000, p. A10). The Albuquerque factory also supplied Nokia, but they were not at all as badly hit as Ericsson. One reason for this was that they were not single sourced, another that they realised much earlier than Ericsson the extent of the negative consequences and could take actions that mitigated the consequences. Nokia had obviously both less risk exposure and better risk handling capacity than Ericsson in this situation. (Chopra & Sunil, 2004, p. 53).

Another example is Nilsson (fictitious name), a Swedish steel producing company selling special steel qualities. The production is complex, includes handling of dangerous material and has long lead times. JIT principles were not used except for a few input areas like hydrogen gas, where there was a constant inbound flow. Hydrogen gas was single sourced and bought from a supplier who had built a hydrogen plant just a few hundred meters away from the factory, delivering the gas in a special pipeline. A mistake by some hired craftsmen doing maintenance work at the hydrogen supplier's plant caused an explosion in the hydrogen factory and destroyed it completely. The production at Nilsson had to stop totally for a month, and it took several months before it was back to normal again. Their most important customer chose to end the business relation even though Nilsson, with the help of their inventory of finished goods, managed to maintain deliveries to that customer. Deliveries to other customers were severely delayed. Sale and market shares were lost (Artebrant et al., 2004).

The conclusion that many seem to draw today is that when dealing with supply chain issues, increased attention has to be devoted to risk aspects. One indication of this is the title of a recent journal article by Joseph Cavinato, "Supply Chain Logistics Risks. From the back room to the board room" (Cavinato, 2004) in a special issue in 2004 on "Logistics and supply chain risk and uncertainty" in International Journal of Physical Distribution and Logistics Management. Another indication is the Institute of Supply Management, whose new slogan is "Maximising Opportunities. Managing Risks" (www.napm.org. 2005-10-07).

> *"The point is simple, risk is broader then ever before. A risk and uncertainty lens is the newest and perhaps one of the most important capabilities and contributions that can be made to a firm's competitiveness and viability"*
> (Barry, J., 2004, "Supply chain risk in an uncertain global supply chain environment", p. 697)

1.1.3 <u>**Some trends affecting the supply chain**</u>

The *competition between different supply chains has increased* substantially, which has led to increased focus on efficiency and effectiveness by the individual firm in the chain (Christopher, 2005). Actions have therefore been taken within areas like production, product development, marketing, financing, distribution etc. to make companies more competitive. These actions have in their turn contributed to “new” trends affecting the supply chains.

One trend affecting the supply chain is the increased *globalisation* (Skjoett-Larsen, 2000; Bowersox, Closs & Cooper, 2002) both on the market side and on the supply side. On the supply side, raw material, components and services tend to be bought from the geographical part of the world where price and quality are most favourable at the moment. On the demand side, the same basic products are now often sold not only locally but also in many different geographical markets.

Traditionally, a company used to have several suppliers for every raw material, component or service that it was buying to spread the risks. Today it is becoming more and more common that the firm only has one (*single sourcing*) or two (*dual sourcing*) suppliers of each raw material, component or service because this is considered more cost-effective (Zsidisin, Panelli & Upton, 2000). Another way of increasing efficiency and effectiveness has been by *outsourcing*. The company concentrates on its core activities and buys from outside everything that is not part of the core activities. In that way the company hopes to be able to cut costs and increase service on the outsourced activities at the same time as they gain more time and attention to spend on improving their core activities (Lonsdale, 1999).

Another way has been time compression with the help of *shorter lead times* (Stalk & Haut, 1990; Beesley, 1997; Mason-Jones & Towill, 1998). We are today also seeing *shorter product life cycles* and *compressed time-to-market* for many new products. The *customization* of products and services is also increasing (Christopher & Towill, 2000; Akkermans, 2003).

Leanness is still another trend. To be able to do more with fewer resources can be said to be the goal for *lean production* and *lean distribution* (Fynes & Ainamo, 1998). Lowering or even eliminating stock levels is one common way to increase leanness. Another one is to reduce time slacks.

Flexibility, i.e. the ability to rapidly adapt to changes in volume and/or product mix, has been an important quality of the firm/chain for a number of years now. But today many markets demand more than that. They demand that the firm/chain is also *agile* i.e. has the ability to take care of the individual customers' wishes when it comes to e.g. packaging, documentation, delivery and payment, and to adapt rapidly and smoothly to changes in customer demands (Power & Sohal, 2001; van Hoek, Harrison & Christopher, 2001). This puts entirely new demands on the supply chain because now it has to be *both lean and agile* (Christopher & Towill, 2000; Mason-Jones, Naylor & Towill, 2000).

Together the different trends have created *a supply chain in rapid change*. Many of those changes tend to *add new disruption risks* to the supply chain.

But there are *also* some trends that are creating *increased possibilities to handle the vulnerability*. One trend here is the increased ease of crossing borders without delays, e.g. the borders between the member states of the EU. But above all it is the development of information technology in general. For example, the information systems of the companies along the supply chain "talk" to each other via the Internet and make possible automatic identification of goods by the help of bar codes and "track and trace" in almost real time. The latter has been facilitated through the rapid development of global positioning systems, international telecom and the Internet.

1.1.4 New disruption risks in the supply chain flow

Risks exist within a number of different activities in the chain. In this study *focus is on the flow in the supply chain* and the risks that are linked to this flow. The presumption is that the planned, normal supply chain flow creates a normal result and that disruption in that flow might decrease the result.

The *traditional physical distribution channel/chain* consisted of a number of separate links from the first production site to the final customer, each link just looking at its own role, keeping information to itself and acting only in its own best interests. (Kajüter, 2003, p. 326). Various disruption risks existed: Goods could be delayed; goods could be sent to the wrong place, goods could be damaged during transport, wrong articles could be delivered, and so on. So the traditional physical distribution channel was *vulnerable*. Common ways of *handling those risks* were to order early, keep big buffer stocks and have slack in lead times. In this way the different links in the chain were only loosely integrated. The risks in the chain were managed by each individual company/link, and the risk management scope was mainly limited to the direct consequences for and actions of that company.

Today the physical distribution channel is turned into a supply chain. The supply chain differs from the distribution channel in two ways: The chain is expanded upstream to the source of raw material, and the different links are deeply integrated with each other. From the latter follows that disruptions in one part of the chain can easily spread to other parts of the chain.

As was illustrated in the preceding section, a number of trends during the last decade have affected supply chain risks and together changed the "risk picture", which has turned supply chain vulnerability into an important business issue and research area (Christopher et al., 2002). To this can be added other trends like concentrating production in just one factory. Production costs per unit will probably decrease through scale effects in production, but a fire on the premises, for instance, could now mean a total elimination of production capacity.

Hidden quality problems, that is for instance that a component with inferior quality has already been used by the next link in the chain or has even reached the end market before the quality problem is detected, can further increase the negative consequences.

Some writers think that the spread of the effects of a disruption from one link in the chain to other links in the chain, the so-called "domino effect", have been exacerbated in the last decade (Jüttner et al., 2003, p. 198). The domino effect might also increase as you get further away from the point of the initial event in the chain. Such *escalating domino effects* could have huge negative consequences on the individual company in the chain. Today's deeply integrated supply chains *might* thus *be highly vulnerable* for the individual link.

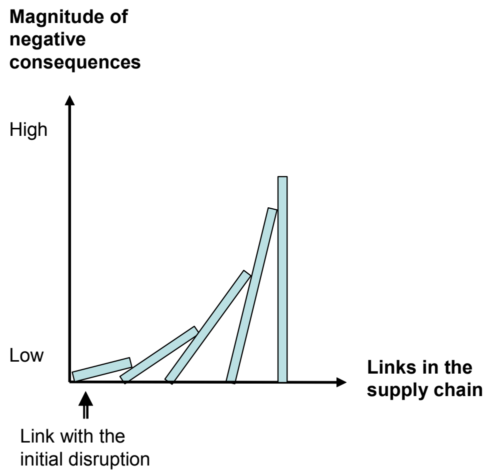

Figure 1.1: Illustration of escalating domino effects.

Market reaction to the disruption must also be regarded. This is especially important if the disruption reaches the end market. In most cases, consumers have other alternatives for fulfilling their needs and can react to even small disruptions by changing over to another brand or another product. Disruptions caused by quality problems in the product itself are especially serious, as such problems can severely damage the consumer's confidence in the product.

Although the negative consequences of some of the disruption risks in the supply chain have increased, the economic compensation for such disruptions is still very much the same as before. Compensation from the failing party, e.g. a logistics service provider who does not manage to deliver the right product with the right quality to the right place on time, is today in many cases negligible for the receiver compared to the negative effects of the disruption. Compensation from a third party – like an insurance company – is a traditional way of increasing compensation, but a 1993 report by HSE (Health and Safety Executive) claims *"that for every £1 of costs recoverable through insurance, another £5 to £50 are added to the final bill through a wide variety of other financial losses"* (Reference in: Reason, 1997, p. 239).

For the individual firm, *compensation* for the negative effects of a disruption thus *rarely covers fully the negative effects seen from a supply chain perspective*. This *limited liability* means that those companies in the supply chain that are especially vulnerable have to actively *engage themselves in a broader risk monitoring and risk analysis process*, a process that might in the individual case include the entire supply chain from natural resources to end customer.

As was illustrated by Ericsson vis-à-vis Nokia in the Albuquerque event mentioned earlier, supply chain risk management can become a considerable competitive advantage for the individual company that has a well developed and executed system for managing its supply chain flow risks.

Christopher & Lee (2004) have pointed out that *"Managing supply chains in today's competitive world is increasingly challenging"*. And Schwartz (2003) has underlined that *"/.../ in many cases, customers are demanding to see proof that a business is ready for trouble before they will award it a major contract or place a company within its supply chain of manufacturing"*.

An article summing up the results of a survey dealing with revenue threats to companies was presented in *Business Finance* in late 2005.

The title was "Number-One Revenue Threat: Supply Chain Disruptions".

> *"The survey polled some 600 finance executives in large organizations around the world. When asked to identify the top risk that affected their company's primary revenue driver, 25 percent of the respondents from North American companies and 19 percent of those based overseas – the largest proportion in both cases – choose supply-chain exposures."*
> (Brannen & Cummings, 2005, "Number-One Revenue Threat: Supply Chain Disruptions". Business Finance. Page 12, 5th of December 2005)

In a 2006 *McKinsey global survey*, two-thirds of the respondents say that the risks to their supply chain have increased over the past five years.[6]

And in the June 2007 issue of the journal *Strategic Risk*, the cover story is *Dangerous times* with the sub-title *Manage supply risks*.[7]

1.2 RESEARCH CHALLENGES AND OBJECTIVES

1.2.1 **Research challenges**

"Despite the increasing awareness among practitioners, the concepts of supply chain vulnerability and its managerial counterpart supply chain risk management are still in their infancy" (Jüttner et al., 2003, p. 197). More and more researchers and practitioners are now underlining the existence of a new risk situation in many supply chains, and the interest in supply chain risk management issues has increased considerably (Jüttner, Peck & Christopher, 2003; Kajüter, 2003).

An often heard opinion is that in the future organisations, as well as society as a whole, will need access to *more knowledge* about risks and

[6] *Understanding supply chain risk*. The McKinsey Quarterly, September 2006.
[7] *Dangerous times. Manage supply risks.* Strategic Risk, June 2007, pp. 10-12.

methods/strategies to handle them, and they will need to become more proactive, for which more more knowledge is also needed (Rasmussen & Svedung, 2000).

The new risk situation is being appreciated by an accelerating number of researchers and practitioners. One example of this is that the first international conference about "Risks in Supply Chains" was held in London in the autumn of 1999[8] and it has been followed by a number of other activities like seminars and workshops. Other examples are the increase in the number of produced research reports, articles[9], special issues of scientific journals and also books within the area of supply chain risk. Another case in point is the ISCRIM[10] network (ISCRIM stands for International Supply Chain Risk Management). The ISCRIM network was started in 2001 and is an international set of contacts for researchers who are actively doing research within the area. Also practitioners have paid increasing interest to supply chain risk issues. The number of articles in trade journals has for instance increased, as have conferences and seminars within the area of supply chain risk.

The *knowledge building* within the area is increasing rapidly. But this knowledge building has so far taken place within many different theoretical areas and been published in many different journals. This has made it more difficult to gain an overview of the state of the art. *There is therefore a need to map the state of the art concerning supply chain disruption risks.* This is the foundation for the first objective of this study.

A new area that is under expansion often lacks a "common language". A number of different concepts, theories and models exist side by side. This makes the creation of a common stock of knowledge and comparisons of results more difficult. Kloman, commenting on an Enterprise Risk Management Conference, pointed out that *"Most of the*

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[8] *Managing Risk in the International Supply Chain*. London 25th – 26th October 1999. A conference arranged by Triangle.
[9] See Paulsson, Ulf (2004) *"Supply Chain Risk Management"*. Chapter 6 in Brindley (ed): "Supply Chain Risk: A Reader". 2004.
[10] For more information about ISCRIM see www.iscrim.biz.

speakers agreed that a 'common language' for risk is necessary but few reported any progress in reaching this goal" (Kloman, 2003, p. 2). Today there is *obviously a lack of general theories and models about risks.*

In complex and rapidly changing situations, as today's supply chains tend to be, *models for analysis of disruption risks* are consequently *of special interest.*

> *"A very fast pace of change of technology is found at the operative level of society within all domains, such as transport, shipping, manufacturing and process industry. This pace of change is much faster than the pace of change presently in management structures".*
> (Rasmussen & Svedung, 2000, "Proactive Risk Management in a Dynamic Society", p. 10)

The current interest in supply chain risk management issues is the result of a number of trends that have affected the supply chain flow, and also, in many cases, changed the risk situation.

> *"Managing supply chains in today's competitive world is increasingly challenging. The greater the uncertainties in supply and demand, globalisation of the market, shorter and shorter product and technology life cycles, and the increased use of manufacturing, distribution and logistics partners resulting in complex international supply network relationships, have led to higher exposure to risks in the supply chain."*
> (Christopher & Lee, 2004,"Mitigating supply chain risk through improved confidence", p. 388)

Supply chains are different and the companies in the supply chain are different as well. The risks seen from the point of view of one company in one supply chain could be very different from the risks another company in another supply chain experiences. Suitable risk management actions differ also. Risks and risk management are *situation specific*.

The risk management methods in use today are basically the traditional ones. But in the dynamic and integrated society of today, with its new risks, those risk management actions have to be complemented and perhaps even replaced by more non-traditional methods. There are some developments that are creating new and *increased possibilities* to deal with risks in supply chains. One example is information technology.

> *"On one hand, the present dynamic and competitive society requires new approaches to risk management. On the other hand, the rapid development of information technology offers new opportunities for designing effective decision support tools"* (Rasmussen & Svedung, 2000, "Proactive Risk Management in a Dynamic Society", p. 9)

The development of information systems has e.g. led to an increase of the general visibility in the supply chain. Another trend creating new possibilities is shorter lead times. There is also today a more open-minded attitude among supply chain members to information sharing.

Many companies are, however, not fully aware of the present risks in their supply chains and of the new possibilities to handle those risks, and they who are aware often lack knowledge about how to manage those risks. *So there is a need for new generic models for managing supply chain disruption risks.* This is very much in line with the final conclusion by Jüttner et al. (2003, p. 209), which was *"we believe that it is an academic responsibility to establish supply chain risk management as an important, if so far neglected, area of applied research"*. This is the foundation for the second objective of this study.

1.2.2 **Purpose and objectives**

The purpose of this thesis is *to contribute to the knowledge on how to manage disruption risks in the supply chain.*

The *objectives* of the study are:

- *to identify, structure and summarize the state of the art on supply chain disruption risks; and*
- *to develop and test a generic, aggregate model for managing disruption risks in the supply chain.*

1.2.3 **Target groups**

One contribution to *academia* is the first objective – the identification, structuring and summarizing of the existing general knowledge about supply chain disruption risks. But also the second objective – the management model – is germane for academics, especially if it presents theoretically new ways to define, structure and handle disruption risks in the supply chain flow.

The main contribution to *industry* is the second objective – the management model. It gives risk managers and others dealing with disruption risk issues in companies a new tool for managing such risks in their supply chains. The model will hopefully help them to characterise their own supply chain, analyse the situation and choose the risk management actions that are in accordance with the company's supply chain flow risk characteristics. The model should be of interest not only to company management but also to shareholders, local communities, and other stakeholders like analysts at banks and other financial institutions.

Also the *public sector* can benefit from this study. Many public organisations are today largely dependent on different flows and their functioning to be able to produce their services. Disruption risks in these flows are a constant threat. Risk managers responsible for such flows can be found e.g. at hospitals and among infrastructure providers. The goals for these organisations differ from company goals, which means that negative effects tend to be measured in somewhat other dimensions than the ones used in companies. But when it comes to the sources of risks and how to handle them, the issues are very much the same as in industry. There are also several public organisations with responsibility for analysing and dealing with the vulnerabilities of vital functions in the society at large, and they, too, may find this study relevant.

1.3 THEORETICAL AREAS AND REFERENCES OF SPECIAL RELEVANCE

1.3.1 **Theoretical areas of special interest for the study**

Risk Management has been an established research area for decades, and research under this label has been conducted in many different disciplines like medicine, finance and road safety just to mention a few. According to the Royal Society, the general term used to describe the study of decisions subject to uncertain negative consequences is *risk assessment*, which can be divided into risk estimation and risk evaluation (Risk: Analysis, Perception and Management, 1992, p.3). When focusing on the decision process in a risk situation, the term *risk management* is usually used (Ibid. p. 5). Still another nomenclature frequently used is *risk analysis*.

Another research area for inspiration is *Business Continuity Management* (BCM). This is a relatively new area that deals with the issues of how an organisation, after a serious disruption of some kind, will be able to be "back in business" again as quickly and smoothly as possible (Hiles & Barnes, 2001). The tradition has here been to focus very much on IT-related risks (e.g. when entering the year 2000), but BCM can include any kind of organizational activity and any kind of disruption. Consequently, risks related to the supply chain flow are also treated.

Supply Chain Management is an integrating philosophy for managing the total flow of a supply chain, from first supplier to end customer or some part of that chain, which is becoming more and more popular among firms. It means focusing on the flows and especially the physical flow with regard to the whole supply chain. Using this holistic approach and increasing the integration of the different links in the chain can achieve benefits of different kinds achieved like lower costs, higher quality and increased service levels (Cooper et al., 1997; Christopher, 1998; Paulsson, Nilsson & Tryggestad, 2000)

Finally, a new research area called *Supply Chain Risk Management* (SCRM) will be mentioned. It could be described as the intersection of Supply Chain Management and Risk Management, and has emerged during recent years but cannot yet be regarded as a discipline in its own right.

1.3.2 **Some essential theoretical references**

Some of the most essential theoretical sources of inspiration for this research project will now be concisely presented in chronological order. For each reference, what is especially interesting is pointed out.

First up are Kaplan & Garrick (1981) and their article "On The Quantitative Definition of Risk", in which they present a general definition of risk based on "triplets" with three questions: What can happen?, How likely is it that it will happen?, and If it does happen, what are the consequences? The definition is principally *interesting* because it splits risk into different "elements/parts". From that follows that if you want to affect a risk you can do it by changing one or several of those elements. The basic concepts were further developed in Kaplan (1997).

The International Electrotechnical Commission (IEC) has developed a model of the risk management process and its different parts which it presents in the report "Dependability management - part 3: Application guide - section 9: Risk analysis of technological systems" (IEC, 1995). The risk management process is split in three different phases. Risk analysis is the initial phase. First the system border of the project/study is set. Then the hazards are identified and estimated. The second phase is risk evaluation i.e. to evaluate those risks compared to a defined acceptable risk level. Risks under this level are sorted out and not further considered. The third and final phase in the risk management process is risk reduction and risk control. This includes decision making, implementation and the following up of the action plan. These are important activities. Without an effective change exertion with continuous feedback, the time and resources spent on risk analysis and risk evaluation can be wasted. The model is *interesting* because it is a widely accepted and within many application areas used model for structuring the risk management process.

Peck et al. (2003), in their research report "Creating Resilient Supply Chains", discuss disruptions risks in the supply chain and present a model with five different risks. The model includes two risks that are internal to the focal firm, "Process risk" and "Control risk", two risks that are external to the focal unit but internal to the supply chain, "Supply risk" and "Demand risk", and a fifth risk, "Environmental risk", that is external to the supply chain. The report is *interesting* because it deals with disruption risks in the supply chain on a very high aggregation level. Only five risks are identified, of which four can be affected by the supply chain participants. One of these is "control risk". It is notable that "control risk" is identified as a risk in itself, stressing the fact that actions taken to handle risks in the supply chain, if you are unfortunate, actually can create new risks or increase existing risks.

1.4 OVERVIEW OF RESEARCH DESIGN AND CHAPTER STRUCTURE

1.4.1 **Research design**

Research design can be described as the art of finding the best way to fulfil the objectives. For each objective, different individual methods are chosen and put into a logical structure. In this way a basic research design is created. This thesis consists of *four* conceptually different *sections*.

In the *first section* the *purpose* and the *objectives* are presented after some pages of background to the study. Then the conceptual structure for the study is presented and linked to chapters and objectives. After that follows a short *methodological* chapter.

The *second section* deals with the fulfilment of the first objective – to identify, structure and summarize the state of the art on supply chain disruption risks. It starts with a *general search* in literature for theories within the areas of risk and risk management, supply chain management and supply chain risk. Included in the last is a *comprehensive search* for scientific articles; the articles found are stored in a database, which then is analysed from different angles. After supplementing the results from the literature review with some *empirical* material, the existing knowledge within the area is summed up and commented upon. Finally conclusions are drawn concerning the need for new knowledge.

The *third section* deals with the fulfilment of the second objective – to develop and test a generic, aggregate model for managing disruption risks in supply chains. To be able to easier distinguish the model developed from other theoretical models within the area, the model will hereafter be called the *DRISC model* (Disruption Risks In Supply Chains). First some starting points for the DRISC model are presented, including the definition of the construct *risk* in a supply chain setting. Then the basic structure for the DRISC model is presented and the initial part of the model – the framework for description and analysis – is developed. After that the different partial models for the risk management process are developed and finally integrated into the definitive DRISC model. The usability of the DRISC model is then tested in two different ways: through application on a *real case* and through a *survey* to risk managers. At the end of the section, conclusions are drawn and comments made concerning the developed DRISC model.

In the *fourth section* finally the results of the study are summed up and some final remarks about the area of the study and of the study itself are made.

1.4.2 The research design linked to objectives and chapters

In Chapter 1 the background to the project is presented, the research questions are explored and the purpose and objectives are set. In Chapter

2, methodological issues are discussed and the methods to be used are decided upon.

Chapters 3 to 7 all deal with the fulfilment of the first objective – the knowledge review. In Chapter 3, theories within risk and risk management are presented. In Chapter 4, theories within supply chain management are presented, and after that a number of different trends affecting the supply chain are discussed. Chapter 5 deals with supply chain risk theories. In Chapter 6, empirical data from some cases, based on real events and information from semi-structured interviews in the form of mini-cases, is presented. Then in Chapter 7 the results of the theory review and the empirical findings are summed up and commented upon, and the need for new research is identified.

Chapters 8 and 9 deal with the second objective – the DRISC model. The DRISC model is developed in Chapter 8. Then the DRISC model is tested in Chapter 9, through application on a real case and through a survey to a group of risk managers, and reflections on the use of the model are offered.

In Chapter 10, finally, the results of the study are summed up and commented upon, and some closing remarks are given.

The research design linked to objectives and chapters is illustrated below.

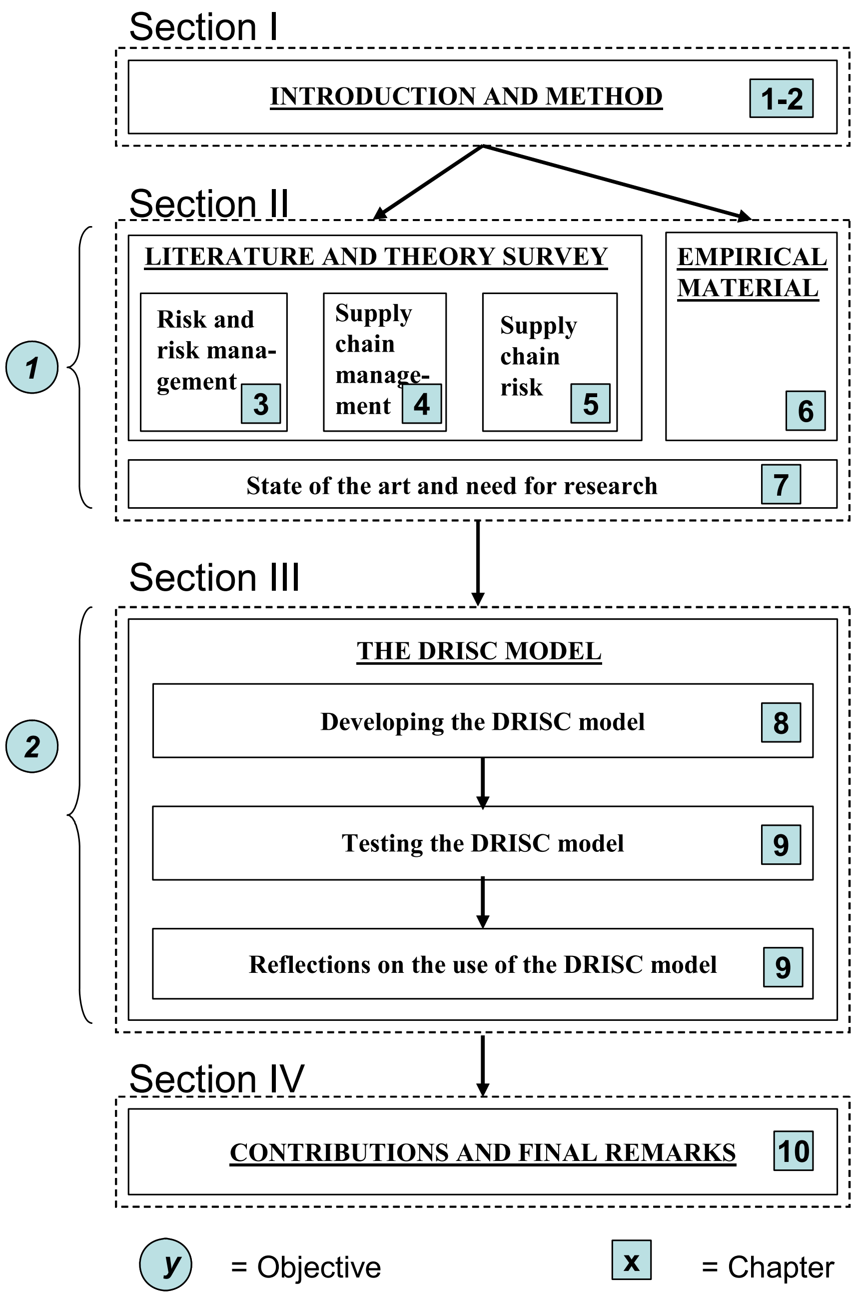

Figure 1.2: Objectives and chapters positioned in the research design.

2 METHOD

In this chapter some general theoretical methodological issues and a theoretical model for methodological design of a study are first presented. Then, for each of the two objectives established in Chapter 1, a specific research method is chosen, and links to the different separate theoretical issues in the design model are made. After that the chosen data collection methods are presented. Finally, references are made to methodological issues dealt with in later parts of the thesis.

2.1 GENERAL THEORETICAL METHODOLOGICAL ISSUES

2.1.1 The creation of new knowledge

The creation of new knowledge is the basic aim of scientific work. The concept *theory* is important in knowledge creation. According to The New Shorter Oxford English Dictionary (4 ed, 1993) can a theory be defined as *"a system of ideas or statements explaning something, especially one based on general principles independent of the things to be explained"*. What decides if a theory is a theory and not just a thought or a suggestion is thus that it can be used for explanation. But as Saunders et al. (2003, p. 26) point out: What can be explained can often be predicted and controlled.

Reflections on knowledge creation and its effectiveness can be dealt with on different levels of abstractions. Three levels often referred to are: philosophy of science, methodology and method, which are partly overlapping. Method has the lowest level of abstraction and philosophy of science the highest.

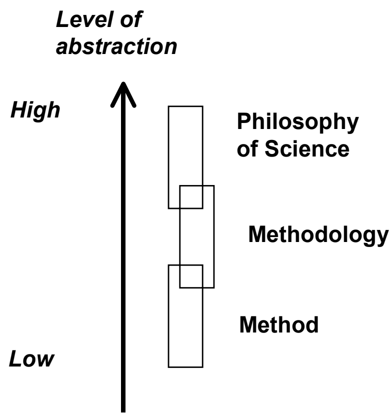

Figure 2.1: Level of abstraction

Philosophy of science deals with the ultimate or basic questions of existence, knowledge and knowledge creation. It includes ontology, epistemology and the character of human nature (Burrell & Morgan, 1979).

- *Ontology* deals with the basic philosophical questions about the nature of existence like "What do we mean when we say that something exists?"
- *Epistemology* deals with the basic philosophical questions about knowledge and tries to answer questions like "What is knowledge and what are the limits for knowledge?"
- *Human nature* deals with the question of what basic attributes of man (e.g. rational, profit-maximising, information-seeking) are taken for granted or explicitly assumed in research. These attributes are reflected in each individual study, in other words: What model of man is reflected in the theory used in the individual study?[11]

11 Burrell, G. & Morgan, G. (1979) *Sociological Paradigms and Organisational Analysis. Elements of the Sociology of Corporate Life,* pp 1-2.

Methodology deals with the basic principal questions of how to collect, analyse, and interpret data in a structured way. *Method* deals with the practical way in which you try to reach your objective.

In this study philosophy of science issues will not be dealt with at all.

2.1.2 **<u>A guiding methodological model</u>**

The issues of method and methodology can be described with the help of the following model (Figure 2.2) from Saunders et al. (2003) in which the choice of method for a study is illustrated as a level-by-level process where each level treats a separate methodological issue.

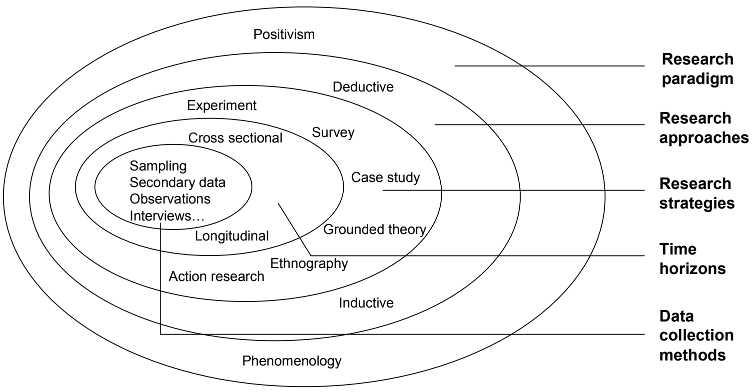

Figure 2.2: A guiding methodological model (Saunders, Lewis, & Thornhill, 2003, "Research Methods for Business Students", p. 83).

2.2 THE OVERALL METHODOLOGICAL DESIGN FOR THE STUDY

This thesis has two different objectives, and for each objective a special methodological design has been chosen.

The first objective
The first objective – to identify, structure and summarize the state of the art on supply chain disruption risks – is fulfilled through the identification and analyses of literature within supply chain risk and related areas complemented with empirical findings.

First a general search for literature about risk and risk management, supply chain management and supply chain risk is conducted, and the theories found are structured and presented. Then a thorough review of scientific journal articles within supply chain risk is conducted, and the information structured and stored in a database. Together these literature reviews describe the present theoretical knowledge base within supply chain risk and related areas. After that, empirical material is collected either from own case studies or by using information from case studies carried out by others. Then the results are summed up and conclusions are drawn regarding the state of the art within supply chain disruption risks. Finally the need for new research is discussed.

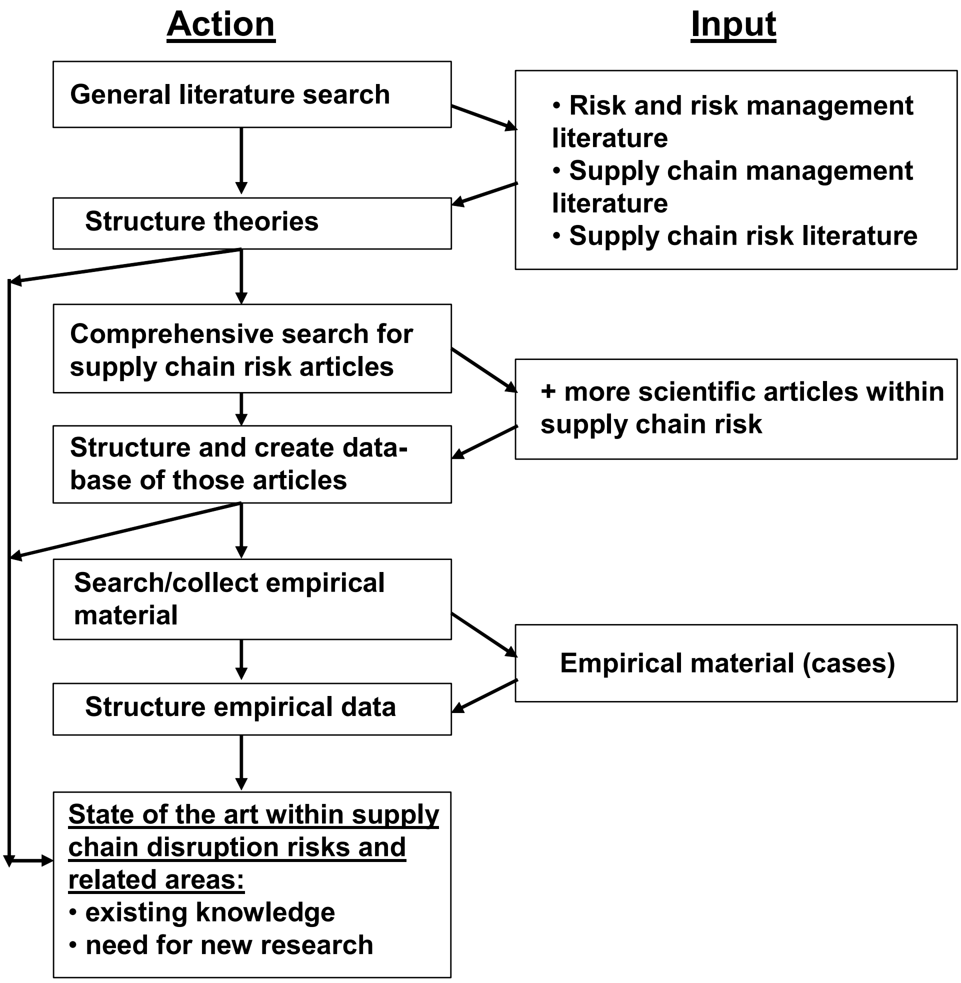

Figure 2.3: Method for objective one.

The second objective

For fulfilment of the second objective – to develop and test a generic, aggregate model for managing disruption risks in the supply chain – a model called the DRISC model is developed step-by-step.

The results from objective one are used as input: the identified need for new research, the theoretical overview, and the empirical findings. The identified need for new research is used as the point of departure for the development of the new DRISC model, individual theories in the theoretical overview are used as elements in the modelling, and the empirical base is used as general inspiration for that work.

After having settled the starting points for the DRISC model, a basic structure for the model is decided upon. Then some of the elements in that model are elaborated in one or more steps. For some of the partial models, descriptive cases are used as illustration and as a first check. After that the different partial models are summed up and integrated into a complete DRISC model. The usability of the model is then tested by application on a live case (Brämhults) and by a survey to risk managers. Finally, after having considered the feedback from the tests, the ultimate version of the DRISC model is presented.

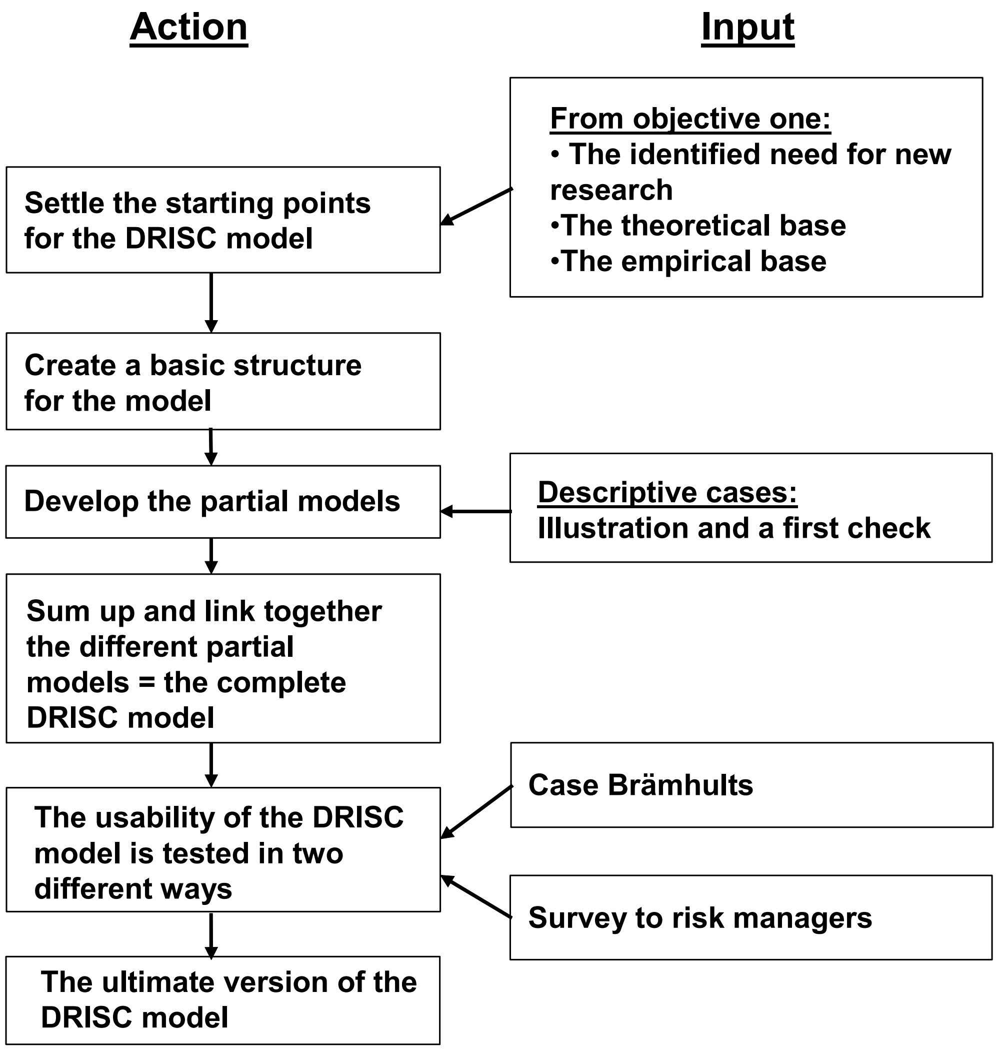

Figure 2.4: Method for objective two.

2.3 SEPARATE METHODOLOGICAL ISSUES AND THEIR LINKS TO THE STUDY

Using the structure from the methodological design model by Saunders et al. (2003), different separate methodological issues are presented and discussed and their links to the study shown.

2.3.1 **Research paradigm**

According to Saunders et al. (2003), there are basically only two research paradigms: *positivism* and *phenomenology*.

Paradigm shift

Thomas Kuhn (1970) introduced the concept *paradigm* to describe the basic theories and beliefs that link a number of researchers by being the common foundation for their research. Researchers from different paradigms have great difficulties to communicate and to understand what the others are doing. The paradigm sets the frame for the whole research process. It influences the methodological issues as well as the more practical matters of method. Kuhn also stressed that within a certain scientific area, like physics or chemistry, a stable period with a dominant paradigm is followed by an instable period with competing paradigms and ultimately a *paradigm shift*. Then there is a new stable period with a dominant paradigm until it is time for another paradigm shift.

Different paradigms and their application

Different authors have different opinions about paradigms. Some say that each scientific area has only one paradigm – others claim that there are a couple of different paradigms at any given time. Silverman (1993) claims that there are basically only two different paradigms: the *positivistic paradigm* and the *interpreting paradigm* (which Saunders et al. call phenomenology).

In the *positivistic* paradigm, the ideal is that the researcher is objective and non-interactive. He/she should try to act as a spectator at a football match who is not supporting either of the two teams – just observing them. According to the positivistic tradition, research must be conducted in such a way that the reader becomes convinced that the results are correct. If the reader doubts that, then he or she must have the possibility to repeat the study themselves to be able to check the results. In other words, it must be possible to verify or falsify the results.

During the last half century, this ideal has been questioned by research approaches like action research and participatory research. In Silverman's terminology they can be said to belong to the *interpreting paradigm*. According to this paradigm, the researcher should participate in and interact with the object under study. It is often not possible to prove the results or even to repeat the study. Therefore it is more a question of making the results likely. The researcher must first show that there is nothing in the material, e.g. logical contradictions, which makes the researcher's interpretation impossible. Then it is up to the researcher to convince the reader that the interpretation is reasonable. Talking in football terms, it would mean that the researcher could have been playing on one of the teams, wanting them to win the match, but is nevertheless able to give an interesting and reasonable description of what happened during the game. Those in favour of the more subjective methods argue that they give access to new types of knowledge, knowledge that could not be gained through the more traditional objective and non-interactive methods.

"Why does everybody claim that a pocket watch is round, which is unquestionably wrong because, if seen in profile, it consists of a small, elliptic triangle, and why the hell do you notice the shape only at the moment when the clock face is of interest?" (Asplund, 1970, p. 8 [my translation]). The quotation raises the question of our "blindness" regarding everyday activities and objects. From this follows the question of whether it is possible to overcome this "blindness", and if the answer is yes, how this could be done. Another question is whether this tendency to "blindness" is also present in research work. And if so, could certain methods make it more difficult to see new "patterns" while others make it easier? Some researchers would claim that positivistic approaches tend to make you see what you already have seen earlier, but

perhaps with higher reliability and precision, while interpreting methods will help you to see new things.

One problem with methods, such as action research, based on the interpreting paradigm is that it becomes very difficult to falsify the findings, and that this fact makes it possible for the researcher to tell a good story instead of telling the "truth". In any research however, including action research, there are some parts of the research process that can be conducted in an objective and non-interactive way.

The interpreting paradigm tends to be suitable when you want to produce new and interesting hypotheses, while the positivistic paradigm tends to be suitable for testing hypotheses. The hypotheses that have been proved can then in their turn constitute a new base for another round of hypothesis generation. The two paradigms thus tend to complement and support each other.

Formal and substantive theory

The aim of the individual research project could be to generate new theory or to verify/falsify already existing theory (sometimes it is a mixture of both). Both types of research projects are needed, but there is often a discussion about how much research of each type should be done. For example, Glaser & Strauss (1967) mention in their classic book "*The discovery of grounded theory*" that one reason they wrote their book was to "defend" and help researchers who are trying to create new theories from the strong pressure exerted by the many researchers who were dealing with the testing of already existing theories.

The authors are talking about two different types of theory: substantive theory and formal theory. *Substantive theory* is theory developed for an empirical or a substantive area, as *formal theory* is theory developed for a conceptual or a formal area. These theories are partly overlapping.

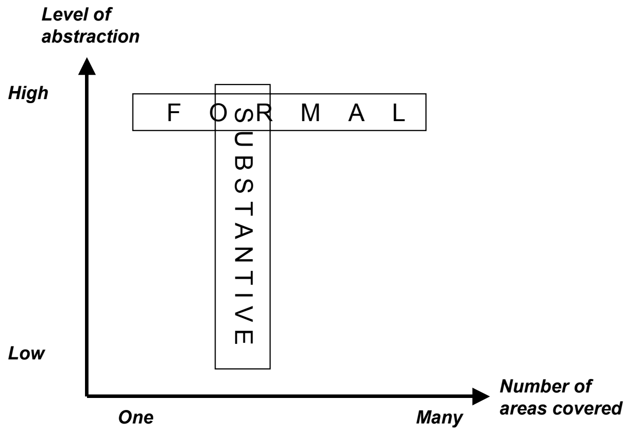

Figure 2.5: Illustration of the two Glaser and Strauss concepts "formal" and "substantive".

Links to the study
This study is conducted within existing paradigms. The positivistic paradigm dominates the study, but some examples of the interpreting paradigm can also be seen. Using Glaser-Strauss terminology, the first objective mainly aims at creating formal theory through the presentation of the state of the art concerning disruption risks in supply chains. The primary goal of the second objective is to create substantive theory – theory that is more practically oriented – through the development of the DRISC model.

2.3.2 Research approaches

According to Saunders et al. (2003), there are basically only two research approaches: *deductive* and *inductive*.

Deduction and induction categorisation
A new theory could have its origin in other theories, in data or in both. When a new theory has its origin in other theories it is arrived at through *deduction*. Deduction is when you draw conclusions about the individual phenomenon from general principles. It is called "the way of proving". The deductive method is also called the hypothetic-deductive method, because a common way of working in this method is to formulate a hypothesis, based on existing theories, and then to test it in practice. When a new theory has its origin in data (is generated from data), it is arrived at through *induction*. Induction is when a conclusion of a principle or general law is drawn on the basis of individual cases. It is called "the way of exploring". (Patel & Tebelius (eds), 1986, p. 17).

Some researchers also present a third alternative called abduction. *Abduction* is similar to induction in the sense that you start with the individual phenomenon and try to find or formulate a theory that explains its characteristics. However, this is rather complicated, and a trial and error process starts where you go between theory and empirical data until you have found a reasonable fit between the two. (Wallén, 1996, p. 48).

Another approach categorisation
Another way of categorising research approaches is presented by Arbnor & Bjerke (1997). They have clustered a number of different research approaches into three different types/groups: analytical approach, systems approach, and actors approach. In the *analytical* approach, the researcher is a distanced and objective investigator trying to find and determine cause-effect-relations. In the *systems* approach, the researcher seeks objectivity, tries not to be a part of the object under investigation, looks at it as a complex and interrelated system and tries to make classifications to better understand and explain how it works. Finally the *actors* approach finds the researcher inside the object under investigation, trying to understand how the people and groups of people in the investigated object think and feel, and why they behave the way they do.

Links to the study
Using the *deduction/induction categorisation* I can conclude for the first objective that the research approach is mainly deductive, since it is based on the identification of a number of individual theories (and some empirical findings) that in the end are linked together and summed up. For the second objective the research approach is inductive in the sense that the point of departure is the identified needs, yet deductive in the sense that the construction of the DRISC model is based on different existing theory-elements. But since the preliminary DRISC model is adjusted according to the findings in the test step, the whole process of creating the model can be described as abduction.

Using the categorisation *systems/analytical/actors* approach, it can be said that the systems approach is the basic approach in the whole study because here reality is regarded as objective and made up of objects that are related to each other. When studying supply chains this is appropriate, since supply chains/networks are complex and made up of many highly interrelated parts (e.g. firms, departments). In the work of creating the DRISC model, elements of the analytical approach can be seen. Finally, in the case studies there are elements of the actors approach, since the researcher is interacting with people in the organisation.

2.3.3 Research strategies

According to Saunders et al. (2003) there are a number of different research strategies; *experiment, survey, case study, grounded theory, ethnography* and *action research.*

Case studies
A research strategy that we will be taken a closer look at is the case study. The study of a case can be done in many different ways. A classic book on the concept of "case study" is "*Case Study Research – design and methods"* by Yin (1994). Yin describes a case study as an empirical inquiry that investigates a contemporary phenomenon within its real life context, where the research has to follow certain procedures. If those

procedures are followed and if the method is used for a suitable type of research and research question, Yin states that interesting and thrilling results can be derived from just one case. The results are, though, not in the form of established, generally accepted theories but in the form of *plausible rival hypotheses*. Those hypotheses are often quite new and creative.

Ellram (1996) argues in her article "The use of case study methodology in logistics research" that case studies have an important role to play in logistical research. In the field of logistics, a case is often defined as a process or phenomenon in a company or in a part of a company, and consequently a case study becomes a study of just one company. But as I see it, Yin gives you as researcher very free hands to define "case" as you like. Moreover there is nothing in Yin saying that you are only allowed to study one case. You might very well study two or more cases, but since you have to follow certain procedures that are time-consuming, you often simply do not have the time to study more than one case.

Links to the study
In this study the main research strategies are surveys, mainly in the form of literature surveys, and case studies. There are different kinds of case studies, but none of them follow all the procedures set up by Yin. Thus they are not case studies in the sense that Yin defines the concept "case study".

2.3.4 Time horizons

According to Saunders et al. (2003), there are basically only two time horizons: *cross sectional* and *longitudinal*.

A *cross-sectional* study is a study of several units or several phenomena at a certain moment of time while a *longitudinal* study is a study of one unit or phenomena over a period of time. It is also possible to combine the two.

Links to the study
For the first objective the *time horizon* is mainly cross-sectional. The case studies linked to objective one are conducted at a certain time and so is the search for literature. But when it comes to the scientific articles, their progress in some dimensions is followed during a couple of years, and here an element of longitudinal study can be found. For the second objective the time horizon is cross-sectional.

2.3.5 Data collection methods

According to Saunders et al. (2003), there are a number of data collection methods of which *sampling, secondary data, observations* and *interviews* are explicitly mentioned in the model.

Another categorisation is into *primary data* and *secondary data*, where primary data are data collected specifically for the study, while secondary data are data originally collected for some other purpose and already there to use. As examples of primary data can be mentioned interviews, observations and sampling made specifically for the study, and as examples of secondary data, books and articles of a general character. Another way to categorize research data is into *quantitative* and *qualitative data* according to the character of the data collected. Put in a very simplified way, quantitative research is research where the data can be expressed in figures or in some other quantitative form, and qualitative research is research where data are expressed in non-quantitative forms, e.g. in words. Traditionally, positivistic research has mostly been quantitative and interpreting research has been qualitative. The data collection methods applied in this study are presented and commented upon in section 2.4.

2.3.6 Triangulation – a mix of methods

The basic idea behind triangulation (Yin, 1994) is that if you look at your research object from two (or more) different angles instead of just one, you will get better knowledge of how it "looks" just as you get better knowledge of a mountain if you have the possibility to look at it from several different angles instead of just one. There are four types of triangulation: data, investor, theory and methodological triangulation (Yin, 1994, pp 92-93). One way of doing methodological triangulation is by mixing qualitative and quantitative research and thus gaining the best from both methods at the same time as you can offset the weaknesses of the individual methods.

Links to the study
For the fulfilment of objective one a focused article search, a general literature search and also some minor case studies are used, and thus triangulation can be said to be applied. For objective two, triangulation can be said to be used because one method is used to develop the model and two (case and survey) methods are used to test it.

2.4 METHODS USED FOR DATA COLLECTION AND ANALYSIS

For the *first objective* the data collection methods used are secondary data through literature surveys and written material about the cases, and primary data through case interviews. For the *second objective* different data collection methods are used. Most of the data that will be used were gathered when the first objective was fulfilled. The descriptive cases and the Brämhults case – the test case – are mainly based on interviews (primary source) complemented with secondary sources. Finally, the survey to risk managers is a primary source.

2.4.1 **Literature surveys**

The literature studies can be divided into *two parts* – a general part and a part focusing on scientific articles within supply chain risk.

The *general literature* has mainly been chosen from the areas of supply chain management, risk management, supply chain risk and related areas like logistics and business continuity management/planning. Literature has been searched for in several different ways on these and related concepts.

Scientific articles within supply chain risks were searched for mainly in *ELIN@Lund*[12] . In October 2003, the different searches had resulted in about 1200 hits and 400 unique articles, but most of them were not relevant and were therefore sorted out. 80 journal articles remained, and were all reviewed. The findings were structured with the help of a simple supply chain risk model. Some of the findings considering the articles have earlier been reported by the author as Chapter 6 "Supply chain risk management" in Brindley (ed) (2004). The methodology for finding, structuring and analysing the scientific articles will be further described in Chapter 5 and in Appendix 1.

2.4.2 **Cases**

The cases are chosen so that they include a wide variety of supply chain characteristics and risks. More precisely, the following *selection criteria* for the cases have been used:

- from different lines of business with different risk situations;
- from specific to general;
- from events that have happened to would-be analyses; and
- availability of data.

There are four types of cases in this study: Marsh cases, mini-cases, descriptive cases and a test case. The material for the Marsh cases was collected by three students working on their Master's degrees. The material for the other three types of cases was collected by myself.

The *Marsh cases* are picked from a Master's thesis by Artebrant, Jönsson & Nordhemmer (2004) of which I was the supervisor. Their thesis includes four different cases of companies that are or have been

[12] ELIN@Lund has access to about 10 million records via agreements with a very large number of publishers and other information providers (April 2003).

clients of Marsh – one of the leading risk consultancy firms in the world. Three of the cases are analyses of real events, like a fire, that have taken place. The fourth case is an analysis of what could go wrong.

The aim of the *mini-cases* is to collect general information about risks and risk management of disruptions in the supply chain flow from different industries and perspectives based on interviews. Four different mini-cases are presented.

There are three *descriptive cases*. These could be said to be enlarged mini-cases. One of the cases, presented as case Alfa, is of special relevance since it was conducted first and since it was chosen on the grounds of expected high exposure to supply chain risks. The other two cases, Beta and Gamma, were chosen later to complement Alfa.

The *test case* is used to test the usefulness of the DRISC model developed.

Table 2.1: Characterizing the four types of cases.

Cases	**Have happened**	**Could happen**	**x x**	**Other's data**	**Own data**
Marsh	3	1	**x**	4	
Mini		4	**x**		4
Descriptive		3	**x**		3
Test		1	**x**	1 (partly)	1 (partly)

See Chapter 6 for further descriptions of the Marsh and mini cases, Chapter 8 for the descriptive cases and Chapter 9 for the test case.

I spent two months in the autumn of 2004 studying the production at Alfa in X-town. Of the two months, 5 weeks were spent on the floor in two of the company's factories. That resulted in three internal reports to Alfa X-town in which different analyses, based on the estimation of supply chain flow disruption risks measured as lost time of deliverance to end customers, were presented and recommendations made. The analysis started with a mapping of the present flow. Then critical places/processes in the flow were identified and alternative solutions considered. The Alfa case has therefore also been a source of inspiration, and not merely an illustration.

2.4.3 **Other sources**

Participation during the period 1999-2006 in four NOFOMA (Nordic Research about Materials Administration) conferences, five ISCRIM (International Supply Risk Management Network) workshops and one CLM (Council of Logistics Management) conference. Papers were presented at three of the NOFOMA conferences and at all five ISCRIM seminars. Internal seminars and personal contacts with colleagues in the ISCRIM network and other colleagues have been an important source of information. References to other relevant literature have been found in books, reports and articles. Another source is the ISCRIM newsletter. Finally, the regular meetings within the tutorial committee have been a constant source of information and inspiration.

2.5 METHODS DISCUSSED ELSEWHERE IN THE STUDY

In Chapter 5 and Appendix 1, the methods for the literature search of scientific articles within supply chain risk are treated in detail. In Chapter 6 the choice of cases for the empirical base is discussed and justified. In Chapter 8 the selection of the descriptive cases and collection of their case material is explained. Finally, the choice of test case and the methodology of the survey to risk managers are discussed in Chapter 9.

SECTION II

3 RISK AND RISK MANAGEMENT[13]

The aim of this chapter is to give an overview of theories within risk and risk management with special focus on organizational risks and the management of such risks. The findings will be summed up and commented upon in Chapter 7.

3.1 RISK

3.1.1 Risk – a construct with many meanings

Risk is an ambiguous construct – the meaning varies depending on context and user. The origin of the word *risk* is uncertain, but it may have come to us from the Arabic word *risq* or from classical Greek via the Latin word *risicum.* A number of common meanings of the word can be distinguished:

- a threat or a danger (”There is a risk of flooding”);
- a probability (”Driving a car without safety belts means an increased risk of injury”);
- the total appraisal of probability and size of the consequence; and
- a measure of dispersion (“Taking out an insurance means a reduction of the risk”).[14]

The Royal Society in Britain describes risk in the following way:

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[13] The overview of risk theories is partly based on the presentations of different risk theories in Finnman (2002), Artebrant et al. (2003) and Nordström & Rettrup (2003) - three Master's theses that the author has tutored.

[14] Mattsson, B. (2000) *Riskhantering vid skydd mot olyckor*, p. 33.

> *"These definitions begin with risk as the probability that a particularly adverse event occurs during a stated period of time, or results from a particular challenge. As a probability in the sense of statistical theory risk obeys all the formal laws of combining probabilities. Explicitly or implicitly, it must always relate to the 'risk of (a specific event or set of events)' and where appropriate must refer to an exposure to hazard specified in terms of its amount or intensity, time of starting or duration."*
> (Risk: Analysis, Perception and Management, 1992, pp. 4-5)

Risks should not be confused with *risk sources*, i.e. phenomena that (can) cause an undesired event. An industrial plant is a typical risk source that can cause an event, e.g. an explosion, that leads to casualties or discharge of chemicals that are dangerous to both the environment and human beings.[15]

Uncertainty is occasionally used with *risk* in the phrase "risk and uncertainty". So the concept *risk* is often reserved for situations where you quite well know the negative consequences, their size and their probabilities. If this is not the case, then one talks about uncertainty. Here both situations will be included in the concept *risk*.

When discussing risk, it is important to distinguish between the risk to the *individual* human being, to the individual *company/organisation,* and to *society* as a whole. It is also worth noting that some risks are of a type that cannot be reduced through increased knowledge or information (*genuine risks*). Other risks can be reduced through better information and knowledge, and still others can be reduced through different actions. Although the risk source itself in some cases may not be affectable, the consequences of a risk event often can. Worth noting is also that similar consequences can often arise from very different causes.

When we focus on the decision process in a risk situation, the term *risk management* is usually used. Risk management includes three elements: hazard, assessment and action. Hazard includes the hazardous event and

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[15] Nilsson, J. (2003) *Introduktion till riskanalysmetoder.* Avdelningen för Brandteknik. LTH

the negative consequences of that event, as well as the causes and contributing factors behind that event. The negative consequences/outcomes can be structured in different ways: one is in immediate, short-term and long-term consequences, another one is in primary, secondary and tertiary consequences.[16]

Hazards are described as *"threats to people and the things they value"* (Risk: Analysis, Perception and Management, 1992, p. 89). Traditionally, in academic research, hazards have been divided into natural hazards (like earthquakes or hurricanes), technological hazards (like explosions or collisions) and social hazards (like theft or terrorism).

Risk assessment is the general term used to describe the study of decisions subject to uncertain negative consequences. It can be divided into *risk estimation* and *risk evaluation*.[17]

Actions are the ways in which individuals, firms/organisations and society try to handle the hazards. But before efficient action can be taken, assessment must first be done. One way to act is to be proactive, trying to eliminate or diminish the causes and contributing factors. Another approach is to react after an event has happened, but then try to minimise the negative consequences of that event. When you try to act proactively, then it is the *risk exposure* or rather the *experienced* risk exposure that you try to deal with.

Risk exposure is by Deloach described as *"Exposure arises when any assets or source of value of the enterprise is affected by changes in key underlaying variables resulting from the occurrence of a risk event"* (Deloach, 2000, p. 49).

[16] *Risk: Analysis, Perception and Management* (1992).
[17] *Risk: Analysis, Perception and Management* (1992), p. 3.

3.1.2 **Risk definitions**

3.1.2.1 Some general risk definitions

Risk was generally defined in Chapter 1 (section 1.1.2) as "*being exposed to the possibility of a bad outcome*" (Borge, 2001, p. 4).

Some other risk definitions are:

> *"the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge.*"
> (Risk: Analysis, Perception and Management, 1992, p. 2)

> *"Risk, in the general meaning: the possibility that something unwished shall happen. It can be individual risks, risks for the society of social or economic nature or environmental risks."*
> (Nationalencyklopedins Internettjänst. www.ne.se. 2005-09-30, concept "risk" [my translation])

> *"In everyday language, risk means a harmful event that might happen but it is not certain that it will happen. In research the concept is used in different ways. One way is to use it as the probability of a harmful event. If we can measure the harmfulness, then it can be measured as the product of probability and harmfulness, which in statistics is called the expected value. A third way is to use risk as a means of describing the spread of outcomes. The bigger the spread – the higher the risk. A fourth way is to use risk as the perceived risk by a person."*
> (Grimvall et al., 2003, "Risker i tekniska system", pp. 16-17 [my translation])

> *"By a risk is meant the danger of a random event to have a negative impact on the possibility of reaching the goals set up. Mathematically a risk can be expressed as a product of the probability and the damage the risk can cause."*
> (Hamilton, 1996, "Risk Management 2000", p. 12 [my translation])

> *"The distribution of possible outcomes in a firm's performance over a given time horizon due to changes in key underlying variables. The greater the dispersion of possible outcomes, the*

higher the firm's level of exposure to uncertain returns. These uncertain returns can have either positive or negative consequences. The organization's sensitivity to risk is a function of (1) the significance of its exposures to changes and events, (2) the likelihood of those different changes and events occurring and (3) its ability to manage the business implications of those different possible future changes and events, if they occur."
(Deloach, 2000, "Enterprise-wide Risk Management", pp. 271-2)

3.1.2.1 Risk definition by Kaplan & Garrick

Introduction
The risk definition that will be used as *a starting point in this study*, when looking specifically at supply chain disruption risks, is the one presented by Kaplan & Garrick (1981)[18] and which was further developed by Kaplan (1997)[19]. The motivations for choosing this specific definition are that it is a commonly used (but not by all disciplines accepted) operational definition of risk and that it explicitly splits up the concept of risk in different elements/parts, which facilitates adaptation of the general definition to more specific risk areas.

Presented below is a condensation of the discussions on the risk concept in the two articles mentioned above. The terms used are those presented in the articles.

> *"In analyzing risk we are attempting to envision how the future will turn out if we undertake a certain course of action (or inaction). Fundamentally, therefore, a risk analysis consists of an answer to the following three questions:*
> *(i) What can happen? (i.e., what can go wrong?)*
> *(ii) How likely is it that that will happen?*
> *(iii) If it does happen, what are the consequences?"*
> (Kaplan & Garrick, 1981, pp. 12-13)

[18] Kaplan, S. & Garrick, J. (1981) "On The Quantitative Definition of Risk". *Risk Analysis*.
[19] Kaplan, S. (1997) "The Words of Risk Analysis". *Risk Analysis*.

An answer to those three questions is called *"a triplet"*. There might be many triplets/answers to those questions, and each answer can be described by the help of the following formula:

$$<S_i, L_i, X_i> \quad [3.1]$$

where

- S_i is a scenario identification and description;
- L_i is the probability of that scenario; and
- X_i is the consequence or evaluation measure of that scenario, i.e. the measure of "damage."

A "set of triplets" could then be described as:

$$\{< S_i, L_i, X_i >\} \text{ where } i = 1, 2, \ldots, N. \quad [3.2]$$

Scenarios

Kaplan (1997) describes the normal state for a scenario (scenario S_0) as a trajectory in a state space and illustrates it in the following way.

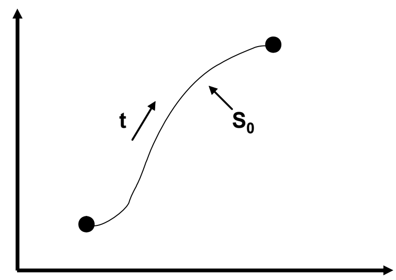

Figure 3.1: Scenario S_0 viewed as a trajectory in the state space of the system (Kaplan, 1997, p. 413).

Kaplan further describes a risk scenario S_1 as a departure from S_0 that starts with an initiating event (IE) and ends when an end state (ES) has been reached. An end state can generally be described as the state where the consequences of the scenario can be judged. That is in many situations possible first when you are back to "normal", or to stable conditions again after the incident.

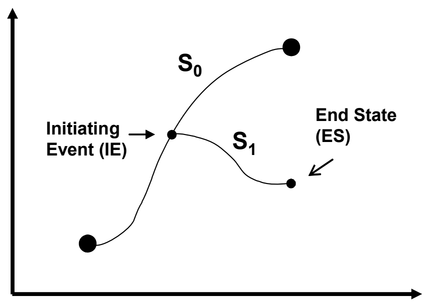

Figure 3.2: The risk scenario S_1 as a departure from S_0 (Kaplan, 1997, p. 414).

Kaplan then goes on arguing that the same initiating event could lead to several different end states – a so-called *out tree*.

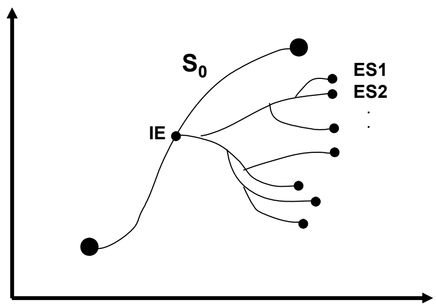

Figure 3.3: Scenario tree emerging from the initiating event (out tree) (Kaplan, 1997, p. 414).

Then he mentions that two branches from two different scenario trees can end at the same end state. If a number of branches end at the same end state then you can talk about an incoming scenario tree or just *in tree*.

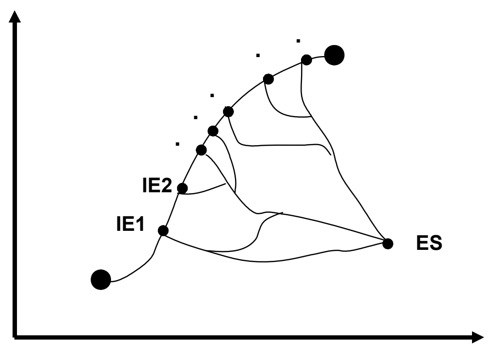

Figure 3.4: Incoming scenario tree (in tree) (Kaplan, 1997, p. 414).

You can also have combinations of in and out trees from a certain point that Kaplan calls a mid state (MS).

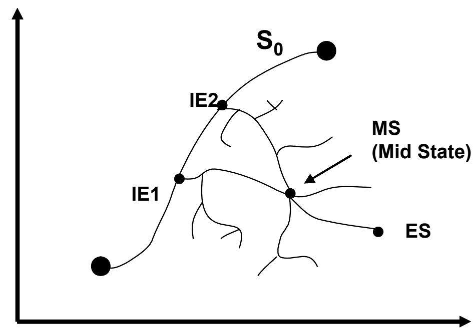

Figure 3.5: In/out tree (Kaplan, 1997, p. 414).

Complexity
A scenario can be more or less *complex*. A game of dice could illustrate a simple scenario: You throw the dice and a number comes up. A complex scenario example can be taken from "chaos theory" where it is mentioned that a butterfly flying in the Amazon could, by moving its wings, start a chain of events that ends with a storm in Europe.

An example that will be used as illustration is "Paper Clip Limited".

Example: Paper Clip Limited produces paper clips with the help of machine A, which needs electricity and one component – wire – to produce paper clips. If there is no electricity or if the wire is lacking, we cannot produce the paper clips. Since we can make a profit by producing and selling them, we consider such a disruption as negative. The company has no backup alternatives for electricity outages and only a 2 hour buffer stock of wires. One possible risk scenario is then an electricity disruption caused by a thunderstorm, and another one is a lorry loaded with wires being delayed due to a traffic accident causing unexpected congestion. When the electricity has come back on or the lorry has finally arrived we can judge the scope and size of the negative consequences, and thus we have reached the end of the scenario – the end state. The negative consequences may, however, continue for a period after the end state has been reached. It might e.g. take a week before we have caught up with the production loss.

Likelihood

If the dice are well balanced, the likelihood of throwing a "1" is 1/6 and the likelihood for each of the other five figures is the same. The likelihood in the "butterfly scenario" we do not know. It is a realistic scenario in the sense that it might happen, but the likelihood is probably extremely small. For Paper Clip Limited, based on past experiences of thunder storms leading to electricity breakdowns, we can calculate some figure of its likelihood, although not an exact one. And the same can be said about the congestion scenario.

Consequences

The *consequences* can be measured in dimensions like number of injured, lost production units, polluted litres of water, costs, or some other dimension that the person conducting the risk analysis finds useful. The consequence of throwing the dice might be that you win or lose money, e.g. the rule could be that you lose your money if number 1, 2 or 3 comes up and you double your money if the number 4, 5 or 6 comes up. For Paper Clip Limited we can measure the consequences in, for instance, lost production units. A storm in Europe will have a lot of consequences, both negative and positive. The consequences can thus be everything from limited and easy to understand to multiple and difficult to grasp.

A complete set of triplets
As long as the system hasn't been specified, the concept of risk *has no meaning* simply because you do not know what to include in the set of answers. But when the system being studied has been specified, you can start looking for possible scenarios and get an understanding of the character and size of the risk.

A "complete set of triplets (c)" is described by Kaplan (1997) as:

$$\{< S_i, L_i, X_i >\}_c \qquad [3.3]$$

Risk definition
The complete set of triplets according to Kaplan is the same as the risk (R):

$$R = \{< S_i, L_i, X_i >\}_c \qquad [3.4]$$

Kaplan also includes the S_0 scenario, i.e. the "as planned" or "success" scenario, in the risk definition.

The *general risk definition* by Kaplan 1997 is specified as:

$$R = \{< S_i, L_i, X_i >\}_c \text{ where } i = 0, 1, 2, \ldots, N. \qquad [3.5]$$

Where
- S_i is a scenario identification and description;
- L_i is the probability of that scenario;
- X_i is the consequence or evaluation measure of that scenario, i.e. the measure of damage;
- c stands for a complete set of triplets; and
- S_0 is the "As-planned scenario".[20]

Kaplan says that ideally we would like to know all the possible scenarios. He goes on to say that this is perhaps not possible, but at least we need to know the important ones.

[20] Kaplan, S. (1997) "The Words of Risk Analysis". *Risk Analysis*, p. 408-409.

3.1.3 Static and dynamic risks

Hamilton (1996) discusses the difference between dynamic and static risks. *Dynamic* risks are risks that can have either a positive or a negative outcome, e.g. market reactions. *Static* risks are risks that can only have a negative outcome, i.e. the outcome does not bring an economic advantage. An example of a static risk is a fire. Dynamic risks are often more interesting for companies, as they can bring in a profit as well as a loss. But the better a company is grasping its static risks, the bigger dynamic risks it can take. By taking bigger risks, bigger profits can in many cases become possible.[21]

Another aspect of risk is *risk relativity,* i.e. risk compared with your competitors, meaning that even though a certain event, e.g. a hurricane, leads to negative consequences it can give you a competitive edge if you can ensure *to be less affected* than your competitors by that same event.

3.1.4 Public risk and risk control

Policies addressed at reducing risk and compensating risk victims have become increasingly prominent components of the role of governments in modern society. And a lot of money is involved. In the US, the annual costs of risk and environmental regulation today exceed 150 billion dollars. Liability costs are also on the rise.[22]

Risk policy is not an easy task because individual risk perceptions are often in error. The public tends to overestimate dramatic risks, such as explosions, and risks that are outside of individual control. The amount of media exposure is also important. From a political standpoint, it might be tempting to say that we can accept no risk at all within a certain area, but the fact is that in most cases it is extremely costly or even impossible to eliminate all risks.[23]

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[21] Hamilton, G. (1996) *Risk Management 2000*, p. 13, and p. 130.
[22] Viscusi, W. (1998) *Rational risk policy*, Chapter 1.
[23] Viscusi, W. (1998) *Rational risk policy*, Chapter 2.

If people do not have access to full information about hazards, they cannot adapt their behaviour to the actual risk situation. But the widely held view among risk regulators has long been that information programs are ineffective in altering behaviour and that more direct intervention through regulatory actions is needed. The 1980s, though, marked the emergence of hazard warnings as a prominent policy alternative and also an increasing emphasis on right-to-know policies. Cigarettes can be taken as an example of this. Cigarette smoking is very dangerous indeed. The annual fatality risk is 1/150. Today every package of cigarettes has to have information telling about the dangers of smoking and such information is also spread through advertising campaigns and in other ways.[24]

A theory that has been much discussed is “the 90–10 principle” meaning that in the beginning you get a considerable risk reduction for a limited sum of money, but the effect is gradually diminishing and 90 % of the money has to be spent on reducing the last 10 % of the risk. This means that risk regulations have to be selective. Money should be spent where it can generate the biggest effect. But because of irrationality, lack of knowledge and conservatism, much money is spent on regulations that have limited effects.[25]

3.1.5 **The circle of risks**[26]

Traditionally the main focus within risk management has been insurable risks, but in a wider perspective commercial risks have been separated from non-commercial risks. Commercial risks include decisions that can lead to profit but also to a negative outcome, as opposed to non-commercial risks that can only lead to losses. Another classification of risks is into dynamic risks and static risks, where dynamic risks more or less correspond to commercial risks and static risks correspond to non-

[24] Viscusi, W. (1998) *Rational risk policy*, Chapter 3.
[25] Viscusi, W. (1998) *Rational risk policy*, Chapter 6.
[26] Hamilton, G. (1996) *Risk Management 2000*, Chapter 3 unless otherwise stated.

commercial risks. Hamilton presents the “circle of risks” as a comprehensive view of all risks that can threaten an organization.[27]

The circle of risks is divided into two natural halves. The right half includes operational, static risks within production where the risk with most impact is disruption in the production flow. Most of the work the risk manager is conducting is represented on this half. The left half includes dynamic risks found outside the production such as inflation, new laws and terrorism. This half is included in the circle of risks to offer a comprehensive view of the risk situation of the organization.

[27] *Säkra företagets flöden! (Secure the flows of the company!)* (1999), pp. 16-17.

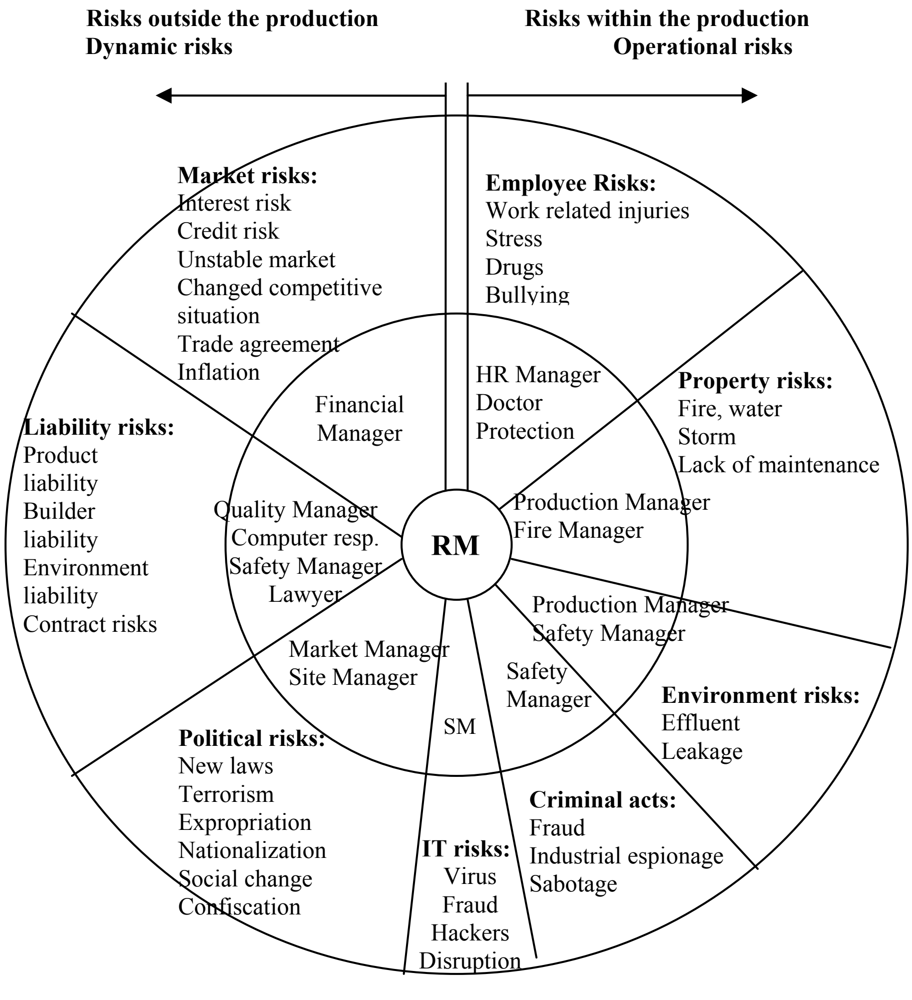

Figure 3.6: The circle of risks (Hamilton, 1996, p. 16, presented in a version translated from Swedish into English in Artebrant et al., 2003).

Risks within the production

Employee risks include such things as working injuries, problems related to stress and drugs and bullying among colleagues. A company with an inferior working environment produces discomfort and working injuries that result in increased absence and unwanted employee turnover. This creates disruptions in production, which can result in poor quality. In the long run this is a major threat to the organization. *Property risks* represent damages to property such as can be caused by fire, water, storms and inadequate maintenance. For a long time fire has been the most dreaded risk. Lately though, new technological advances have released new forces that may be difficult to control. Hence fire is no longer as feared as before. Still, however, the damage from fire is a big problem. *Environmental risks* include pollution and leakages. The environmental problems are gaining more and more attention. *Criminal acts* include sabotage, industrial espionage, theft and fraud. During the last decade there has been a significant shift from outside criminal acts to inside operations. Today the employees in a company are responsible for most of the economic crimes in the organization. Some ways to prevent this are clear routines and running of internal records.

Risks outside of production

Market risks cover inflation, trade agreements, changed terms of competition, currency risks and so forth. Financial transactions have become a considerable risk lately. Speculations in stocks, foreign currencies and other financial means have led to most big companies now having some form of finance policy to limit the associated risks. *Liability risks* include among other things responsibility for the environment and product and also risks involving contracts. Product liability means that a company is liable to pay for the damage when their product has caused injury to a person or a property. The risks of damage claims are by far most substantial in the USA, since the amounts demanded for compensation are generally very high. To avoid risks associated with product liability, it is important to have a quality assurance system in the company that results in products and services fulfilling the quality expected by the customer. *Political risks* involve new laws, terrorism, nationalization, social revolution etc. Countries with political instability are more affected by alterations that can change the conditions of economic life overnight. Hence there are great political risks in owning companies situated in such countries. The most obvious political risk is considered to be confiscation or nationalization of property.

Closing comments
It is important to put operational and dynamic risks in relation to each other to get a meaningful judgement of the company's risk environment and to be able to act rationally. But the risk manager often lacks the requisite knowledge about risks associated with the market. It is essential for every company to chart their own circle of risks to fully grasp the risk environment that is specific for each organization. There are some risks that are not represented in the circle of risks, such as the human factor and loss of trust.

3.1.6 Human error[28]

Many of the risks we face today have their roots in potential human errors. James Reason, in his book "Human error", describes e*rror* as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency.

He talks about three different types of errors:

- *slips,* which result from some failure in the execution of an action sequence;
- *lapses,* which result from some failure in the execution of a storage stage of an action sequence; and
- *mistakes,* which are deficiencies or failures in the judgemental and/or inferential processes involved in the selection of an objective or in the specification of the means to achieve it.

A knowledge-based classification of human performance is also presented:

- *skill-based level:* Human performance is governed by stored patterns of pre-programmed instructions;
- *ruled-based level:* Familiar problems governed by stored rules of the type *if* (state) *then* (diagnosis); and

[28] Reason, J. (1990) *Human Error*, Chapter 3.

- *knowledge-based level:* New and unknown problems tackled by using conscious analytical processes and stored knowledge.

The three types of errors are linked to the three levels of human performance, and the error-type mistakes are divided into two subtypes, rule-based mistakes and knowledge-based mistakes, giving us the following relations between "type of error" and "type of knowledge base":

- skill-based level – slips and lapses;
- rule-based level – rule-based mistakes; and
- knowledge-based level – knowledge-based mistakes.

In the book a division of human contribution to accidents in complex, high-risk technologies is also made, into:

- *active errors*, which are errors, usually associated with the performance of "frontline" operators like pilots and control room crew members, which have an immediate impact upon the system: and
- *latent errors*, which are errors generated by those not in immediate contact with the system like designers and high-level decision makers. Such errors may lie "hidden" for a long time, only making their presence felt when combined with other errors or local triggering events.

3.1.7 **Risk perception**

The way we perceive risk is an interesting and difficult issue for several reasons. First because risk perception is affected by so many cultural and social factors. Secondly because a lot of psychological factors also are present. Thirdly because there could be technical problems in identifying the hazards.[29]

The *technical approach* to risk perception assumes that hazards are objective facts that could best be perceived, analysed, assessed and

[29] *Risk: Analysis, perception, management* (1992), chapter 5.

managed by risk experts. The *social approach* assumes that from the perspective of social sciences, risk perception involves people's beliefs, attitudes, judgements and feelings, as well as the wider social or cultural values and dispositions that people adopt, towards hazards and their benefits. This is especially relevant when we talk about the public, but risk experts are also affected by e.g. cultural values. The social risk approach stresses issues like whether the risk is observable or not, whether the risk is old or new, whether the risk has an immediate effect or if the effect is delayed, and whether the risk is known to those exposed or not. The social risk approach also stresses that if there has not been any accident or incident for a period, risk perception goes down (although in fact the risk might be the same or even have increased). A basic assumption in the social approach is that although the public doesn't have expert knowledge, it always has the "right to know". Another assumption is that the public should not be viewed as an undifferentiated entity but rather as many groups within a society, and different groups may hold differing risk perceptions.[30]

If, for example, we look at figures showing the relationship between judged frequency and statistical estimates of the number of deaths per year for different causes of death, the public tends to overestimate some risks (like the risk of dying from botulism or in a tornado) and to underestimate other risks (like the risk of dying of stomach cancer or heart disease).[31]

Many authors stress the importance of research contributing to close the gap between the technical and the social approaches to risk perception, assessment and management.

A Swedish example can further illustrate the risk perception problem. Recently in Sweden, electromagnetic radiation has received a great deal of political attention, and demands from the public for actions like moving electric cables or burying them have been urged. A lot of money has also been invested in such actions, although scientific research proving electromagnetic radiation to be a serious hazard to public health

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[30] *Risk: Analysis, perception, management* (1992), chapter 5.

[31] Viscusi, W. (1998) *Rational risk policy*, p. 1.

is lacking. At the same time, we have solid scientific proof that radon radiation is dangerous, but public attention to this risk is minimal and so is public demand for action.

Some examples of psychological factors that can make the perceived risk differ from the calculated risk are:

- people tend to be more or less indifferent, i.e. more or less willing to accept risks;
- risks that the individual can affect (like driving a car) are often perceived as lower than those the individual cannot affect (like being a passenger in an airplane); and
- old risks are often perceived as less serious than new risks.

In certain situations, the perceived risk is more important than the actual risk because people tend to act on the perceived risk instead of the actual risk. If, for example, they get very scared of something that really is just a minor threat to them, then this fear is in certain situations a risk in itself (e.g. causing panic), and might therefore be of greater importance than the actual risk. For companies and organisations, as well as the individual itself, it is therefore important to get the right person into those positions where critical situations can arise.

The discussion above can be said to be an example of a more general problem discussed in an article by Ortwin Renn (1998). He puts the question: Are risks *social constructions* of different societal actors that can be checked at best against standards of consistency, cohesion and internal conventions of deduction, but cannot claim any validity outside of the actor's logical framework? Or are risks *technical estimates* of real hazards that can and will affect people as predicted by statistical values, regardless of the beliefs or convictions of those who conduct the assessment? Nick Pidgeon, another researcher, says both (Pidgeon, 1998). But it is not an easy task. He claims in his article that the balancing and integrating of the best available scientific judgements and evidence on one hand with aspects of public risk evaluations on the other, is one of the most difficult questions to be faced by democratic governments and their regulators today.

Perhaps the debate can be summarised in the following way: Is the objective of risk research and risk management to minimise the number of individuals killed and injured or is it to minimise the fears that people have? If we talk about economic risks we can perhaps formulate the dilemma like this: Is the objective of risk research and risk management to minimise the risk of economic losses or is it to minimise people's fear of losses?

Finally I would like to stress that if we can not perceive a risk, then we can neither analyse, nor assess or manage it. This means that the big hazards are probably not the ones that we have identified; the big hazards are those that we have not been able to perceive so far. This raises the very challenging questions of if and how we can become better at making the unknown hazards visible in the future.

3.1.8 **Risk assessment**

Risk assessment is the general term used to describe the study of decisions subject to uncertain consequences. It can be sub-divided into risk estimation and risk evaluation.[32]

If we consider the information on which the assessment has to be based, risks can fall into at least three different classes:

- risks for which statistics of identified casualties are available;
- risks for which there may be some evidence, but where the connection between suspected cause and injury to any one individual cannot be traced; and
- expert's best estimate of probabilities of events that have not yet happened.[33]

Risk assessment includes deciding values for different risks. However, it might not be possible to collect all the information necessary to do a solid risk calculation because the information is not there or it takes too

[32] *Risk: Analysis, perception, management* (1992), p. 3.
[33] *Risk: Analysis, perception, management* (1992), p. 13.

much time or is too costly to get. We are then faced with a choice. Either we choose to only assess those risks that we have enough information about to be able to do calculations based on “hard”, objective facts like statistics. Or we choose to say that it is better to consider all risks, although some of those risk assessments have to be based on “soft” data like subjective judgements by individual experts within the relevant area.

Risk assessment is what we as private persons do every day, e.g. when we decide to take the car instead of the train for a certain trip or when we choose to cross the street outside instead of inside the pedestrian crossing. Those decisions are partly based on objective information and partly based on our subjective judgements. Professionals would probably have taken other decisions in some of the situations because they have access to more knowledge, especially within their own special area, e.g. traffic safety. But although they are the experts, they cannot avoid subjectivity – but the degree of subjectivity ought to be lower than for a layman.

3.2 RISK MANAGEMENT

3.2.1 **The concept risk management**

In Chapter 1, section 1.1.2, risk management was defined as *“The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence”* (Risk: Analysis, Perception and Management, 1992, p. 5).

No human activity can be considered to be risk free. Therefore risk management is of relevance and interest to everyone. In today’s society, many of the traditional risks have been eliminated or substantially reduced. At the same time, new risks have emerged that are difficult to explore and interpret – risks that often have very severe consequences.

Risk assessment and risk management have therefore become increasingly important.[34]

> *"Risk management means taking deliberate action to shift the odds in your favour – increasing the odds of good outcomes and reducing the odds of bad outcomes."*
> (Borge, 2001, "The book of risk", p. 4)

That is why risk management is of interest to all of us. Since there normally is a *cost* linked to a risk handling action, and also the possibility that *other risks* might be spun off by that action, it is probably not optimal to try to cover all risks. Expected result impacts have to be balanced against risk handling costs.

The concept *Risk Management* and the title *Risk Manager* emerged in the US in the mid-1950s when the big industrial companies reacted to rising insurance costs and started to build their own competence and their own solutions within the insurance area.[35]

Risk management involves identifying threats and implementing measures aimed at reducing the likelihood that those threats will occur and minimizing future damage if they do[36]. This includes implementing cost effective processes that reduce risks to an acceptable level, and rejecting unacceptable risks[37].

> *"Risk management involves systematic and methodical work with the risks of the organization in order to protect its resources, results and continued existence. Risks have therefore to be identified and managed so that the goals of the organisation can be reached with a minimum of disruptions at lowest possible costs. The measures are given priority with regard to their cost-efficiency (benefit/cost)."*
> (Säkra företagens flöden!, 1999, p. 16 [my translation])

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[34] Hamilton, G. (1996) *Risk Management 2000*.
[35] Hamilton, G. (1996) *Risk Management 2000*, p. 9.
[36] Nosworthy J. (2000) "A Practical Risk Analysis Approach: Managing BCM Risk". *Computers Security*.
[37] Homepage of *The Business Continuity Institute* (www.thebci.org), 2003-10-24.

What are the elements of the risk management process? There are many different definitions depending on what academic field is addressed. The basic objective of all risk management processes is after all the same, i.e. to prevent undesirable and detrimental events from taking place and, if they do take place, to mitigate the consequences, thereby saving lives, property, environment, financial resources or something else considered "valuable". It includes all types of risks – from the risk of loss of competence when key employees leave the company to the risk of a harmful discharge into the external environment from production facilities or processes.

The following figure presents a detailed description of the process. This process is *proactive*, i.e. preventive, compared to what is usually called crisis management. *Crisis management*, although a crisis group might have been established and resources and routines decided upon in advance, is primarily *reactive*, that is events or incidents that develop into something critical to the organization are addressed ad hoc, i.e. separately and in each specific situation.

The risk management process identifies the existing risks and their possible consequences. By quantifying them in economic terms, you acquire an effective instrument by means of which you can communicate with management.[38]

The International Electrotechnical Commission (IEC) has developed the following model of the risk management process and its different parts.

[38] Zsidisin, G. (2001) "Measuring Supply Risk: An example from Europe". *PRACTIX.*

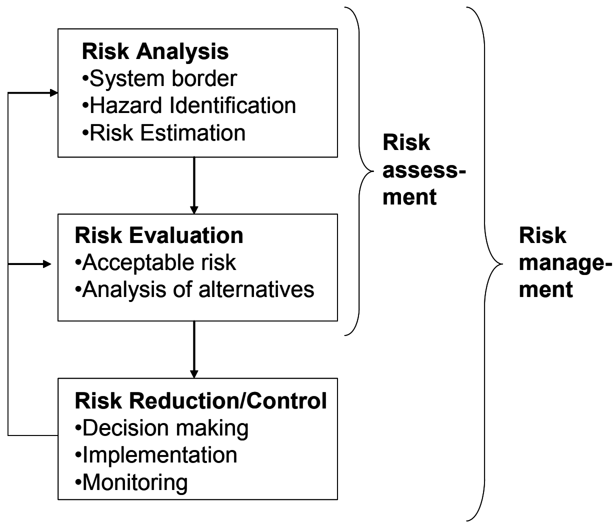

Figure 3.7: A risk management model by IEC (IEC, 1995, p. 41).

Risk analysis is the initial phase in the risk management process. First the system border of the project/study is set. Then the hazards are identified and estimated. The second phase is *risk evaluation* i.e. to evaluate those risks compared to a defined acceptable risk level. Risks under this level are sorted out and not further considered. The third and final phase in the risk management process is *risk reduction and risk control*. This includes decision making, implementation and the following up of the action plan. These are important activities. Without an effective change exertion with continuous feedback, the time and resources spent on risk analysis and risk evaluation can be wasted.

3.2.2 Description of risk analysis methods

Risk analysis means systematic identification of the risk sources and estimation of the risks. The estimation should include a judgement of the probability that an undesired event is going to take place and its probable consequences. A properly carried out risk analysis creates the basis for choosing the right actions for protection and safety.

There are a number of different analysis methods with varying degrees of complexity. Some of the methods are simple and quickly carried out, while others are complicated and time consuming. A couple of them will be introduced below.

Since the purpose of the risk assessment differs, since the risk situation differs and since different types of risks are investigated in risk assessments, different analysis methods have been developed with varying design and purpose. For every type of analysis method there are specific definitions, structures, calculation models and ways of expressing the final result. The analyses can be classified according to the degree to which they are quantifiable. The methods can roughly be categorized as quantitative, semi-quantitative or qualitative.

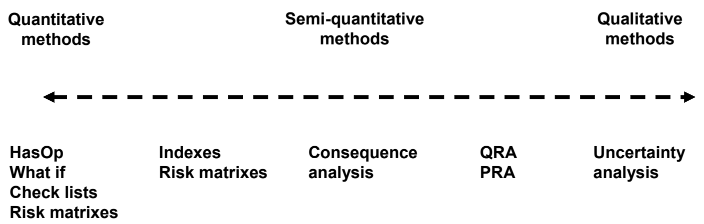

Figure 3.8: Different risk analysis methods positioned according to qualitative/quantitative degree (Nilsson, 2003, p. 20).

When choosing the type of risk analysis method suitable for the situation in question, the following circumstances must be considered:

- The chosen method must be applicable. The result of the risk analysis must be expressed in terms that can be understood and interpreted by the management.
- The chosen method must be useful. The value of a risk analysis must be bigger than the cost of carrying it out.
- The chosen method must be credible. The uncertainty of the result of the risk analysis must lie within acceptable limits. [39]

[39] Hamilton, G. (1996) *Risk Management 2000*, p. 74.

3.2.2.1 Qualitative methods

The qualitative methods are entirely based on *non-numerical values*. Qualitative methods are principally used for identifying risks. They are consequently most applicable in the initial phase of the risk analysis. They are adapted to different types of operations, and the objective is primarily to provide descriptions of processes in different types of conditions. In most cases ordinal measures are used, i.e. qualitative measures of the type very big, big etc. The purpose is often to compare different risks with one another. Even if probability and consistency are not explicitly expressed, they can sometimes be roughly estimated. Some frequently used qualitative methods are discussed below.

Checklists
Checklists ask questions concerning risks, vulnerabilities and damage exposure, and constitute a control tool that evaluates against an established security level. Checklists are constructed from past experiences, and are used to go through the traditional risk sources in a systematic way for a certain object and check that they are properly handled. All questions in the inquiry are included in the analysis, and the results from analogue analyses are comparable. However, this method yields no expected damage costs. Another disadvantage is that question forms may overlook important issues.

Preliminary Hazard Analysis
Preliminary Hazard Analysis (PHA) is often called rough analysis. PHA is used for identifying main risk sources in systems. The object is to get a rough estimation of what systems or which part of a system can lead to serious risks. It can often be appropriate to complete the analysis in areas where big risks are indicated with a more detailed working method. By letting people with experience of the system in question estimate the probability and consequence of different perils, evidence based estimation is obtained.

PHA is used primarily in two ways: to identify and estimate possible risk sources at an early stage of a project, and to identify and estimate risks as an introductory method in an existing system. The rough analysis is often a first step in risk analysis, and forms the basis for continued work.

HazOp[40]

HazOp stands for "Hazard and Operability studies", which are used to identify the reasons why the quality and production goals set for a process plant may not be reached. An analysis group is gathered to brainstorm about the functions to be analysed from a set of key words. In that way, possible deviations in the process can be detected. Then the deviations are analysed in order to locate the causes of the deviation and what consequences it may have. The method is especially practicable at the planning of a new process.

The What-if method[41]

The *What-if method* tries to identify critical risk sources by asking the question: What if this or that should happen? This method analyses the consequences that a deviation from the normal situation would give rise to. Exploratory questions are directed to employees with experiences from various risk areas. By scanning different parts of the object that is under consideration, a list of risks that need to be closer studied can be produced. The method is regarded as simple, but requires imagination. Since it is easy to overlook essential problems, the What-if technique should be applied for sub-analyses of the total risk environment.

Variance analysis

Another simple analysis tool is to make a *variance analysis*, where you start by studying how operations, processes or flows should normally work. The next step is then, for every operation, process and flow, to analyse where a variance from the normal can occur and what the consequences may be.

Scenario

A frequently used risk analysis method is a *scenario,* i.e. making a detailed description of the course of events in connection with a certain risk event. Instead of trying to cover all risks, a few are selected. The

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[40] Hamilton, G. (1996) *Risk Management 2000,* pp. 81-82.
[41] Hamilton, G. (1996) *Risk Management 2000,* p. 79.

selection can be based on different criteria, e.g. that the risk is typical or that it represents a worst-case situation. You can also combine the two, which was done in Mullai & Paulsson (2002, p.102-105), where the possible third-party claim costs for an oil spill in Öresund as the consequence of collisions between ships was studied. Four typical scenarios and two worst-case scenarios were chosen.

Risk matrix

In situations where the traditional technical assessment of risk as the product of probability and consequence can not be done, a *risk matrix* can be used. The risk matrix is a qualitative or semi-quantitative risk analysis tool[42]. The x-axis of the matrix shows the consequence level of the studied damage event. The scale is arbitrary but qualitative. The y-axis shows the probability of the occurrence of a damage event; this scale is also arbitrary. The joint size of those two factors decides the risk level.

[42] Nilsson, J. (2003) *Introduktion till riskanalysmetoder*, p. 21.

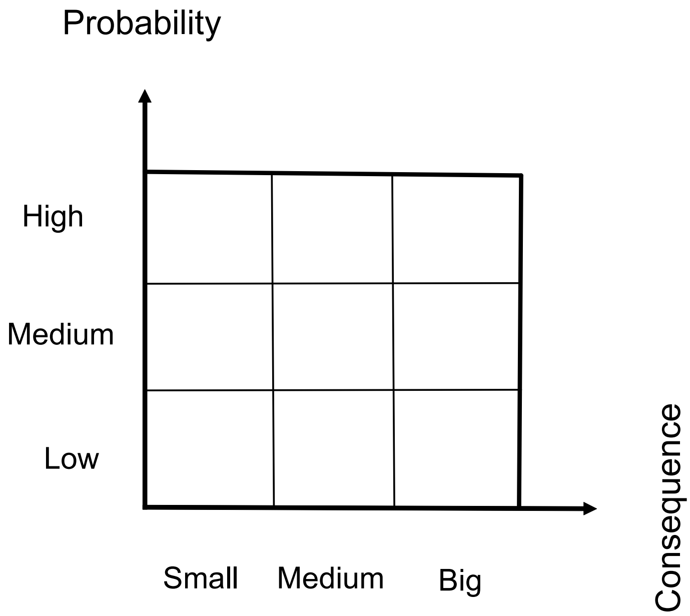

Figure 3.9: Qualitative risk matrix.

The qualitative risk matrix can be modified into a semi-quantitative one e.g. by using a scale divided into five degrees on the y-axis. The measures do not have to be exact; they can represent magnitudes for ranking and comparing different alternatives associated with different risks.[43]

Risk mapping[44]

Risk mapping is a tool for risk identification and prioritization. The idea behind risk mapping is that executives estimate their risks by using defined criteria. Their estimation is based on a number of risks identified as critical by people on the executive level. Alternatively, their estimation can be based on the system or the structure that the participants work in. When well-defined risks have been identified, they

[43] Nilsson, J. (2003) *Introduktion till riskanalysmetoder*, p. 21.
[44] Deloach, J. (2000) *Enterprise-wide Risk Management*, pp. 118-119.

are plotted into a chart in terms of how hard the risk hits the business and the probability that the risk occurs.

Leaders and executives classify the importance of a risk to business operations by using the criteria they understand and accept. For example: What is the potential financial effect of each defined risk? What is the potential cost for the business in terms of capital, cash flow, and profit? Can the occurrence of a potential future event damage reputation or brand, reduce investments in research and development or limit planned process improvements? In risk mapping it is recommended that the people with the most knowledge within a field are the ones who list the risks in order of priority.

The time perspective is a factor that must always be defined no matter what criteria are used to classify how big the negative consequences are. A short-term cost for e.g. capacity reduction can be a hard blow to manufacturing companies. But capacity is not a problem in the long term, as management then has more scope to make changes. Therefore it is appropriate to make separate risk maps for events in the short, medium and long term.

Risk mapping is a versatile tool. It can be developed for units, processes, and key performance indicators or according to big categories of risks. Many companies employ risk mapping in work groups with members from many different sections. The people in the work groups interact, discuss, and share information until they reach consensus.

Risk driver mapping[45]

The goal of *risk driver mapping* is to detect the universe of potential threats and opportunities, i.e. the risk drivers. After the risk driver map is completed, the risk drivers having the most impact on the risk are identified. They are designated in red and referred to as “the key drivers”. These are the risk drivers that receive attention. “Risk owner” is the person who is in the best position to oversee the risk.

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[45] Deloach, J. (2000) *Enterprise-wide Risk Management*, p. 68.

Delphi-technique

Delphi-technique means that an experienced and competent group from an organization is gathered to brainstorm about the risks within their company. The group first selects the risk area to be examined. Each member of the expert panel then anonymously answers a number of assessment questions. The results are compiled and distributed to the members of the panel, and then the assessment is repeated. The different experts can now adjust their assessments. The procedure is repeated either until consensus is reached or it is clear that there are different groups with different standpoints that will not change by further assessment rounds. The product of the Delphi-technique is subjective evaluations of important exposures, which implies that the result may be influenced by prejudice. Nevertheless, the method often produces credible results.

Event Tree Analysis (ETA)

The Event Tree Analysis (ETA) is an analysis used to decide what different damage events can occur in a system *after* the occurrence of a specific event. An event tree can e.g. describe the possible development after a collision between a car and a gas lorry or a machine breakdown in a factory. The analysis takes into account human action and the response of the safety system and equipment to the initiating event in order to determine its possible consequences. The analysis results in different courses of events presented in chronological tables. By assigning probabilities to the different events, a final probability for each scenario can be calculated.

Decision trees can be added to event trees. On one hand they enable decision-makers to make different decisions and accordingly influence the course of events, and on the other hand they permit evaluations of the different outcomes. Decision trees are also an excellent tool for risk assessment of different investment alternatives.[46]

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[46] Nilsson & Persson (1999) *Investeringsbedömning*, pp. 173-177.

Fault Tree Analysis (FTA)
Fault Tree Analysis looks at what causes and contributing factors there were or could have been for a certain hazardous event (top event). The method thus focuses on what was happening *before* the event. This is in contradiction to the event tree analysis, which looks at what happens after the top event has occurred, i.e. the consequences.

An illustration of ETA and FTA
I have used two methods (ETA and FTA) in an earlier research study of oil spills in Öresund[47] and were there illustrated in the following way:

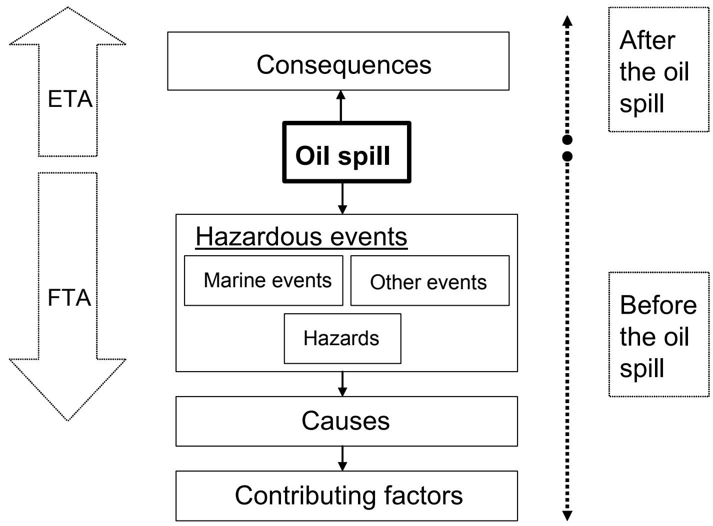

Figure 3.10: The ETA and FTA methods applied on a marine oil spill situation (Mullai & Paulsson, 2002, p. 14).

3.2.2.2 Quantitative methods

The quantitative methods are entirely based on *numerical values*. Quantitative risk calculations have in common that they often are affected by uncertainties in input data. These uncertainties are passed on

[47] Mullai & Paulsson (2002) *Oil Spills in Öresund*, p. 14.

in the calculations to the final results, which are correspondingly uncertain.

Expected damage cost analysis
Expected damage cost analysis is based on quantitative estimation of the frequency and consequences of different threats. Vulnerability factors and a calculated damage potential are also included. The analysis results in a direct choice of security measures and optimizes their costs.

Quantitative risk analysis
Quantitative risk analysis (QRA) means that for a certain object all risks are identified and their probabilities and consequences given numerical values. For example, you could build a model that describes the consequences of a leak in a tank from a petrochemical plant for those living in the neighbourhood. Running the model with different sets of variable values can give you good indications of where to build and not to build a new petrochemical plant. You could also use the model to see what happens if you make changes in plant design, for instance if instead of one big tank you have four smaller tanks.

Probabilistic Risk Analysis
Probabilistic Risk Analysis (PRA) is used for instance in the nuclear power industry and is similar to QRA, but more detailed. In PRA the initial factors are investigated more thoroughly and more attention is paid to event and fault tree analyses.

3.2.2.3 Semi-quantitative methods

Semi-quantitative methods mean that some part of the method is quantitative and some is qualitative. Semi-quantitative methods include to some extent numerical values for consequences and probabilities. The values, however, do not have to be exact; they can indicate magnitudes for ranking and comparing different alternatives.

The one-day analysis

The one-day analysis is limited to one day since both the managing director and his/her co-workers (the heads of production, staff, economy and the risk manager) must be able to participate. In addition, representatives from the insurance company and municipal rescue service are included. Together the group analyse the risk environment, and the risks are ranked by economic importance. The current protection against the prioritized risks is then examined. All this gives the risk manager a good foundation for the continuing work.

The Jonsson analysis[48]

In the *Jonsson analysis*, risks are not estimated in terms of money but in relative terms. The analysis gives a good general view of the distribution, probability and consequences of the risks. The probability and consequence are analysed and then graded after a specific scale.

The different probabilities are valued on a scale divided into three degrees, where a 3 on the probability scale stands for "often occurring", i.e. the probability of the risk occurring is high, a 2 stands for medium and a 1 stands for risks that seldom occur. On evaluating the consequences, a 3 indicates major consequences at the occurrence of a disruption, a 2 indicates medium consequences and a 1, small consequences. The level of risk is then calculated as the sum of probability and consequence.

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[48] Hamilton, G. (1996) *Risk Management 2000*, pp. 77-79.

	Probability	Consequences			Level of risk
1	Low Seldom occurring	Small Low cost, damage or loss		1-2	Acceptable Can be allowed Shold be dealt with
2	Medium Neither often nor seldom occurring	Medium More cost, more damage or loss		3-4	Unacceptable Not allowed and must be dealt with
3	High Often occurring	Big Cost which can not be carried		5-6	Catastrophic Inexcusable, must be dealt with immediately

Figure 3.11: Grading table used in the Jonsson analysis method (based on Hamilton, 1996, pp. 77-78).

The tolerable risk level is 2. For example, if there is a medium probability and small consequences (2+1=3) the risk level will be unacceptable.

The grading table is based on the same basic concepts as the qualitative risk matrix that was presented in Figure 3.9 but presents the information in a different way.

3.2.3 **Decision theory**

Decision theories can be divided into normative and descriptive methods depending on how they are used. *Normative* models describe how a decision-maker should make his/her decisions. The purpose of these methods is accordingly to help people find optimal solution alternatives and thereby make better decisions. The originators of these theories come from management, statistics and economics. *Descriptive* models try to describe how decision-makers make their decisions in real life. These models are essentially empirical and based on the fact that decision-makers do not always make rational cognitive decisions, and that they systematically violate axioms and principles set up in normative models.

3.2.4 **Risk management strategies**

> *"I do believe, however, that there are general principles of risk management and that if you are aware of them, you have a head start in making better decisions".*
> (Borge, 2001, "The book of risk", preface)

Different risk management strategies have evolved over time for different categories of risks. Rasmussen & Svedung (2000) present three different *accident categories* together with related risk management strategies:

- *Occupational safety control* is focused on frequent but small-scale accidents. The risk is related to a large number of work processes, and the level of safety is controlled empirically from studies of past accidents.
- *Evolutionary safety control* includes medium sized, infrequent accidents. The safety deals with controlling particular accident-creating processes. Protection against these risks has been established by an evolutionary increased effort towards improved safety. In this case, risk management is focused on removing causes of particular accidents.
- *Analytical safety control* is focused on rare, large-scale accidents. The frequency of these kinds of accidents is so low that a protection design can not be based on empirical material. The fast pace of technological innovation that contributes to new industrial installations is often the cause of these accidents, and the risks can only be predicted from models of the processes.[49]

A good risk management strategy has according to Kiser & Cantrell (2006) several key components, namely (in summery):

- It must identify risks for the entire life cycle

[49] Rasmussen, J. & Svedung, I. (2000) *Proactive Risk Management in a Dynamic Society*, pp. 27-28.

- It must be able to predict the financial impact that a supply chain disruption can cause
- It must offer strategies that can mitigate the effects
- It must delve deeper into the supply chain than the first tier.

Faced with a risk situation, as a risk manager you can choose among several different generic risks strategies to deal with it. Borge (2001, pp. 65-82) mentions the following ten risk strategies:

- *Identifying*: If you are not aware of the existence of a risk, you can not do anything about it. Identification of a risk does not solve the problem, but it gives you a chance to solve it.
- *Quantifying*: Most risks are intuitively estimated. When you try to quantify a risk, especially if it is done in a more formal way, you have to think harder, and even if the quantification is far from perfect it could be of great value.
- *Preventing*: Preventing a risk means finding a solution that eliminates the risk totally. By for instance dropping an alternative, you will of course also drop the risks linked to that alternative (and the opportunities as well).
- *Creating*: Risks should not be avoided in all situations. The risks linked to an alternative need to be compared with the opportunities of that same alternative. If for a certain alternative that is not being used there are opportunities that are greater than the risks linked to it, then this alternative should be put to use (thus creating new risks).
- *Buying and selling*: One way of getting rid of a risk is to "sell" it to someone else. That could be a good idea if your cost for "selling" it is lower than your expected result impact. The opposite may also be the case: You may "buy" a risk if your result impact for that risk is lower than the "revenue" you get for taking over the risk.
- *Diversifying*: Diversifying means spreading the risk, so that instead of having one big risk, for instance, you have a number of small risks. This is favourable in cases where the big risk is so big that it would be impossible or very tough to handle its consequences.

- *Concentrating*: Concentrating risks is the opposite of diversifying risks. Instead of a number of small risks you concentrate them into fewer risks, perhaps just one big risk. In this way you acquire better knowledge of where the risk is and can more easily take protective actions.
- *Hedging*: Hedging means creating an anti-risk to the actual risk so that the sum of the risk and its anti-risk is zero. If, for instance, you are exposed to a currency risk because you have a debt in a foreign currency that should be paid within three months and you know that the rate of exchange tends to vacillate, you can hedge that risk against a claim in the same currency, amount and day of payment.
- *Leveraging*: Leveraging a risk means magnifying it but also magnifying the good outcome that is linked to that risk. Leveraging means in other words magnifying both the good and bad outcomes at the same time. One example is borrowing money on your invested shares to buy more shares. If the stock market goes up you will magnify your profit, and if it goes down you will magnify your loss.
- *Insuring*: Insuring means that you will receive economic compensation for the loss of something, like a car or a house, which has been specified in the insurance policy. To be able to insure a risk, it has to be identifiable, quantifiable, and manageable. Insurance policies are often quite standardized, which means that they could rarely cover all of your risks. Furthermore, insurance policies seldom cover 100 % of the loss. There is normally an excess and a maximum payout limit.

In practise a *combination* of strategies is often used.

3.3 MANAGING ORGANIZATIONAL RISKS

3.3.1 Organizational risks

Risks in organisations[50]

Organizational risks have been more and more in focus during the last decade, both in media (Simons, 1999) and as a research topic. An often heard opinion is that organisations, as well as society as a whole, need to be more proactive in the future if we are to be able to handle risks (Rasmussen & Svedung, 2000). In some countries new legislation has been put forward making it compulsory to include risk assessment information in the annual report.

Every company or organisation is exposed to many different hazards that may cause losses. But companies also have defences that might defuse the hazards so there will be no losses or only limited losses. Since the company cannot and shall not defend itself against all risks, it is important for the company to decide which risks to accept and which to defend itself against.

A special kind of risk is *"the danger of the un-rocked boat"*. This refers to the fact that a lengthy period without a serious accident can lead to the steady erosion of protection. It is easy to forget to fear things that happen rarely.

The idea of *"defences-in-depth"* means successive layers of protection, one behind the other, each guarding against the possible breakdown of the one in front. This multiplicity of defence systems is effective against single failures, both human and technical. But it is not equally effective when we have combinations of several failures at the same time.

The *"Swiss cheese"* model illustrates the fact that in the ideal world all defence layers are intact, allowing no penetration by possible accident scenarios – but in the real world each layer tends to have weaknesses

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[50] Reason, J. (1997) *Managing the Risks of Organizational Accidents*, Chapter 1, unless otherwise stated.

and gaps, illustrated by the “holes” in a sliced Swiss cheese. Over time new slices come and old ones disappear. And on each individual slice the holes tend to move, change size, or disappear, while new ones are created etc. Since the Swiss cheese with its slices is changing all the time, there is a risk that at some point an accident trajectory may pass through all the corresponding holes in the layers of defences, barriers and safeguards, since the holes at that moment happen to be aligned, and an accident or even catastrophe will happen.

To be able to handle the risks, risk actions are needed. Reason claims that the actions of a company can be divided into two categories, actions linked to *production* and actions linked to *protection*, and that there must be a *balance* between the two. If a company protects itself too much and in the wrong way, production will go down and costs will go up, and the company might wind up in bankruptcy. On the other hand, if a company doesn't protect itself enough it might be hit by a catastrophe and go out of business for that reason.

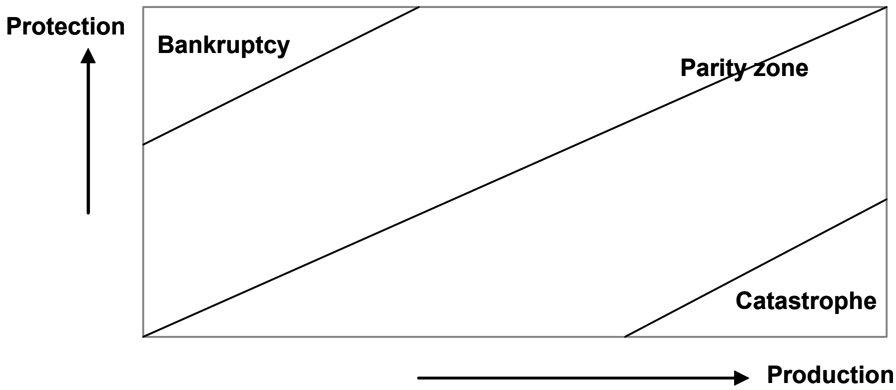

Figure 3.12: Outline of the relationship between production and protection (Reason, 1997, p. 4, simplified version).

The distribution channel could be taken as an example. By making the chain more lean through the eliminating of buffer stocks, you will surely increase productivity but you will also, if nothing else is done, have fewer possibilities for protection against disruptions.

Another interesting issue is the *safety culture*. More and more companies realise the importance of having the right kind of safety culture, but what is the content of such a culture and how do you maintain it? A safety culture of an organisation can be defined as the product of individual and group values, attitudes, competencies, and patterns of behaviour that determine the commitment to, and style and proficiency of, an organization's health and safety programmes. A safety culture has a tendency over time to decline unless actions are taken to maintain or increase the level. One basic issue here is whether you should use rewards or punishment. Another issue is whether actions should be immediate or delayed.[51]

Risk economy[52]

Risk economy means adapting risk protection to the expected costs of damage and the cost of protection measures in a way that maximises the likelihood of the continued existence of the company. Hence all the risks that a company is exposed to are to be calculated.

According to Hamilton, risk economy is based on the following conditions:

- An economic balance between the damages and the protection against them. The costs of protection must never be higher than the expected damage costs.
- An optimal balance between different kinds of protection. How much is to be invested in preventing and restricting damages and how much in insuring them? With good preventive protection, a higher insurance excess can be chosen and consequently the insurance premium will be lower.

In the concept of total result impacts the following costs are included:

Insurance premium costs
+ Uninsured expected damage costs
+ Damage preventive measures costs
<u>+ Risk management administration costs</u>

[51] Reason, J. (1997) *Managing the Risks of Organizational Accidents*, Chapter 9.

[52] Hamilton, G. (1996) *Risk Management 2000*, pp. 118-120 and p. 130.

= *Total result impacts*

It can be noticed that in the total result impacts, both cost before the eventual event (e.g. insurance premiums) and after it (uninsured damage costs) are included.

Company risks

Decisions about company risks are often taken on the basis of incomplete information and under time pressure. In some situations that are well-defined and deal with specific risks, the expected value of the risk can be calculated quite accurately. Playing games like roulette is one such example where the rules of the game will generate the needed information. In other situations you will have access to reliable statistics. The calculated expected value of the risk can therefore be said to be objective or reasonably objective. This is the situation for most of the insurable risks. But there are also many situations where information is insufficient or lacking, and we have to rely on subjective judgements.

When dealing with risks within one part of a company, we will often have to take into account also what might happen in *other parts* of the company and outside the company. Another aspect is that risk in a company setting is always linked to *opportunity* in one way or another, because if it were not there would be no reason for the company to expose itself to the risk.

3.3.2 Risk management in companies

Risk Management in companies became a topical subject in the 1950s. At that time high insurance costs, originating from commercial insurances with low deductible, was a burning issue, and the big companies in American industry searched for new solutions. The first risk manager in Sweden was established in 1975, and was soon followed by others with the assignment to handle questions of risk and insurance within their company. The tasks included in the job of a risk manager have changed drastically over the years as new areas of risk have arisen, for example issues concerning the environment and IT. The objective of risk management is to minimize the total cost of risk, which includes reducing future loss and damage.[53]

Very basic in risk management is also the balancing of actions that can reduce risks or the consequences of risks against the resources needed for such actions, since the amount of money, time and effort that can be "spent" on risk issues is usually limited. Someone has to guide that process, and that is the risk manager. Who then is the risk manager?

> *"The point is not to become a risk manager but to become a better risk manager, since we are all risk managers already. We make risk decisions every day, often without thinking about it. If you got out of bed this morning, you made a risk decision. If you lit up a cigarette, you made another."*
> (Borge, 2001, "The book of risk", p. 4)

Everyone in a company thus takes actions that have risk implications, but normally when we talk about a *risk manager* we think of a person specifically responsible for risk management issues in a company or organisation.

Since risks exist within all activities in all areas of a company, risk management is relevant within many different areas of the company. One important area is company *flows*. In all companies and organisations, flows of information and physical flows exist that need to be more or less continuously running. Disturbances and disruptions in those flows may have serious consequences for the company's economy, and if they remain for a longer period they may lead to bankruptcy.

> *"Disruptions in the production in tough optimised production systems can rapidly have disastrous economic and marketing consequences, and subsequently no company top management will live with big unknown disruption risks."*
> (Säkra företagets flöden!, 1999, p. 3 [my translation])

[53] Hamilton, G. (1996) *Risk Management 2000*, pp. 10-11.

Traditionally, the focus has been on disruptions in company activities caused by natural catastrophes like hurricanes and earthquakes, and accidents like fires and explosions. But little by little the area of application has been widened to also include such things as disruptions in the logistical system of the company, and disruptions in its administrative system.

There is also a widening of the consequences. More and more companies realize that a disruption could not only lead to higher costs and lost revenues in the short run, but could eventually have a substantial negative impact on customers' confidence in a company's products and brand.

A subject that has received special attention is the IT area. The Gartner Group conducted already in 1991 a study of 400 American companies; it showed that even two days of disruptions would have noticeable consequences on the annual result for 45 % of the companies, and if the disruption was longer than a week many of the companies would go bankrupt.[54]

Risk research has traditionally focused on how to handle physical threats, like fire and hurricanes, to human beings and property. Another area has been financial risks, e.g. in connection with trading in stocks or foreign currencies. Still another is investments in new products, markets and production processes.

Some of those risks can be covered by insurances. To be able to insure a risk, it must be well defined and easy to identify, its likelihood easy to predict and of relevance for many actors, and the negative consequences must be easy to measure or judge. This means that many of the risks that a company is exposed to cannot be insured.

The usefulness of insurance is thus limited. You can only take out insurance against some of your risks, not all. Besides, normally it is the immediate, primary consequences that you can insure yourself against. Unfortunately those consequences are in many cases only a small

[54] Hamilton, G. (1996) *Risk Management 2000*, p. 27.

fraction of the total consequences. In his book “Managing the risks of organisational accidents” James Reason (1997, p. 238) refers to an investigation from HSE (Health and Safety Executive) from 1993 saying *“that for every £1 of costs recoverable through insurance, another £5 to £50 are added to the final bill through a wide variety of other financial losses”*. Among those non-recoverable costs are mentioned “production losses” and “lost sales”. For the supply chain, this can mean that the most important negative consequences from an accident resulting in lost goods is not the loss of the goods in itself but the effect that the loss has on production, sales and so on in the total supply chain. This stresses the importance for firms to broaden their scope of interest and not simply look at immediate, primary effects. This in turn will mean that working proactively becomes something much more than just taking out traditional insurance.

Within risk management, an area called *Business Continuity Management* (BCM), focusing on risks linked to disturbances and disruptions and dealing with the issue of finding ways to get back to normal as quickly and smoothly as possible, has recently emerged. That area will be presented in section 3.3.4. Another, quite new, area is *Supply Chain Risk Management*, which focuses on the risks in the supply chain. The area is presented and discussed in Chapter 5 “Supply chain risk”.

3.3.3 **The process of managing risks in companies**

The process of risk management is built on systematics and common sense. It includes identifying the risks, protecting the company against them as far as possible, and making sure that there is money available to cover the losses if the company is struck by an accident. The risk management process often starts with a risk analysis. The risk analysis charts the risk environment of an organisation and gives a “picture” of the existing vulnerabilities. To collect background knowledge it is often rewarding to examine previous damages and losses and their economic impact on the company. Future expected losses are calculated in monetary, quantitative or qualitative terms, and then evaluated as acceptable or non-acceptable. The risk analysis is supposed to stipulate a foundation when planning cost effective preventive actions.[55]

The risks can be structured and illustrated in a business risk profile which maps risks in terms of impact and likelihood.

Unfortunately, only few risks can be eliminated, but most of them can be reduced. This is accomplished by gathering information about the risks and how to protect the organization against them. Since the preventive actions are never a hundred per cent safe, companies must supplement them with plans to limit the damage in case of an accident.[56]

One way to handle a risk is to transfer it to someone else. The most common way to transfer a risk is to use insurance, which transforms an uncontrollable risk exposure into a cost that can be accounted for in a budget. Even though a company may be fully insured, many hidden costs will not be covered. Hidden costs include costs attached to damage and losses that can not be insured or have been overlooked, such as loss of market shares and goodwill. Many people claim that the hidden costs are at least as big as the visible costs.[57] (See also Reason, 1997 p. 238.)

Managing risks is not a one time effort, but a continuous process. It is of great importance to revise and update risk management systems and routines on a regular basis to reflect changes in personnel, technology and essential business operations.[58]

Risk management is, according to the ARM method, a process that can be divided into five steps:

Step one; risk analysis

In the risk analysis step the sources of risks are identified and assessed. When assessing a risk the normal procedure is to estimate the probability

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[55] Hamilton, G. (1996) *Risk Management 2000*, pp. 72-73.
[56] Hamilton, G. (1996) *Risk Management 2000*, p. 97.
[57] Hamilton, G. (1996) *Risk Management 2000*, pp. 98-99.
[58] Harrington, L. (1996) "If disaster strikes, are you prepared?" *Transportation & Distribution Journal.*

of an unwanted event and consider the consequences that follow from that event.

Step two; preventive actions

In the preventive actions step, the focus is on what can be done to eliminate or mitigate the most serous risks. It is often very effective to make a list of measures that can easily and at low cost be taken to eliminate risks. Examples of such means are keeping a neat and tidy working environment, informing and educating employees regarding risks, developing fire protection and clarifying liabilities in agreements.

Step three; actions to limit the consequences

It is essential for organizations to be prepared with clear lines of action in order to overcome unexpected situations and limit their consequences. Both society and other interested parties expect companies to be well prepared, especially in the case of accidents where human lives might be threatened. Every company should have a designated plan with a line of action limiting the damage if a disaster strikes. The actions used to restrict the damage can be divided into the following areas:

- *administrative actions*, which includes having routines to follow in case of an accident and also the mental preparedness of the employees;
- *production focused, technical actions*, which covers the ability to use alternative processes, backup systems and technical installations such as sprinklers and fire alarms; and
- *legal actions*, which restrict damage claims and transfer responsibilities through contracts.

Step four; damage finance

In this step it is analysed from where the money is to be taken in case there is damage.

Step five; follow-up and control

The actions that have been decided upon have to be implemented and followed up – otherwise they are of no value to the company. The measures taken often also require a changed approach.[59]

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[59] *Säkra företagets flöden! (Secure the flows of the company!)* (1999), pp. 18-25.

3.3.4 **Business continuity management**

Business Continuity Management (BCM) can broadly be defined as *"a business process that seeks to ensure that organizations are able to withstand any disruption to normal functioning"*. More precisely, BCM can be defined as *"a holistic management process that identifies potential impacts that threaten an organization, and provides a framework for building resilience with the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities"*. [60]

The importance of the area can be judged in different ways – one is through the number of members in organisations within the profession. One such organisation is SURVIVE[61] with almost 3 000 members.

A BCM strategy describes how the continuity of business processes is to be maintained in the event of a disaster or other serious disruptions in an organization. The strategy should cover both risk reduction and recovery options. Results from risk analyses are used to determine risk reduction options in order to diminish vulnerabilities. The business recovery strategies determine how the business is to proceed on a day-to-day basis. These strategies ought to provide the acceptable minimum requirements to enable the critical business processes to continue to operate in order to keep trading according to "business as usual". To obtain an effective BCM strategy, there should be a cost-effective balance between risk reduction and business recovery activities.[62]

Insurance is a key component of an overall BCM solution, but it does not win back lost market shares. While it may provide for the financial

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[60] Homepage of *The Business Continuity Institute* (www.thebci.org), 2003-10-24.

[61] SURVIVE is an international, industry-wide group for business continuity practitioners. The organisation was founded in 1989. About 85% of its members are users of services and the other 15% are suppliers (www.survive.com).

[62] Nosworthy, J. (2000) "A Practical Risk Analysis Approach: Managing BCM Risk". *Computers security.*

aspects of a loss or incident, it does not provide a method to recover and rebuild the organization or win back customer confidence.[63]

Today most companies are aware of IT-related risks. But there are many other serious risks of which they are less aware. Continuity in all processes and flows, not only the IT-related flows, is crucially important. When there is a disruption, it is often too late to do anything very radical about it, unless you have taken actions in advance. That is why you need to work *proactively*. BCM means working systematically in advance to prevent disruptions in processes from happening, and, if they happen anyway, quickly and safely getting the processes going again.

One example of the latter is a big fire that hit the central booking system at British Airways (BA) a couple of years ago and destroyed it totally. If BA had not foreseen this possibility and taken precautionary actions, it would probably have taken several weeks until activities were back to normal again. Now it only took 4 hours. [64]

One important part of BCM is to do a *business impact analysis and risk analysis* of critical functions of the business, crucial dependencies, the potential loss, and the time window in which recovery has to take place before losses become unsustainable. Another important part of BCM is to develop a *business strategy plan*. Such a plan can be a mix of different options, such as strengthening the facilities to make them less vulnerable, Business Process Re-engineering to reduce risks, stand-by facilities, quick re-supply of equipment, working from home, maintaining buffer stocks, outsourcing, and insurance. It is also important to develop a *business continuity plan* – a plan that tells what to do *when* there is a disruption. Such a plan can include: Immediate reaction procedures, provision of emergency facility, resumption of

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[63] Homepage of *The Business Continuity Institute* (www.thebci.org), 2003-10-24.
[64] Risk Management Bulletin Newsletter.

business production under emergency arrangements, and restoration of the permanent facility.[65]

An example of a business continuity planning process is the Roadmap to Recovery™ [66].

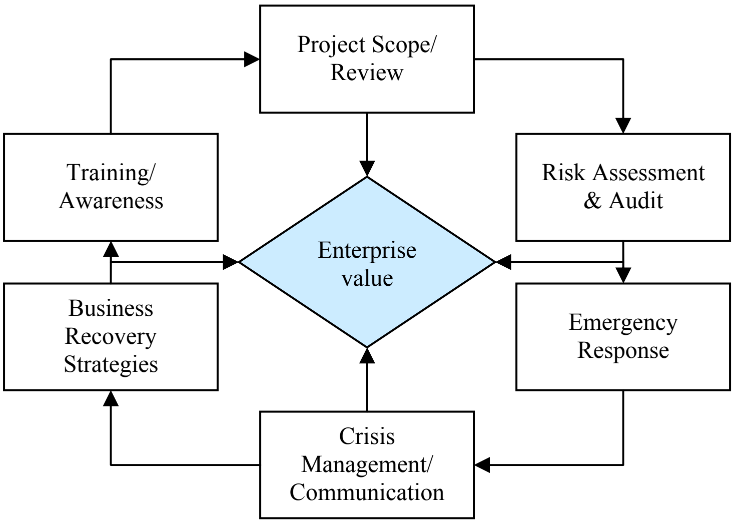

Figure 3.13: Roadmap to recovery™ (de Waij, Marsh).

This business continuity planning process is based on six sub areas:

- *Project scope/review* formulates the scope of work, objectives and project management conditions.
- *Risk assessment and audit* identifies the internal and external critical key processes, dependencies and risks.
- *Emergency response* includes notification procedures and overall authority and layout of an emergency response structure. The delegation of tasks within a response timeframe is specified, and legislation requirements are examined.
- *Crisis management and communication* specifies overall authority and layout of a crisis management structure and, as

[65] Hiles & Barnes (2001) *The Definitive Handbook of Business Continuity Management*. Chapter 12.
[66] de Waij, D. BCM Practice Leader, Continental Europe, Marsh, 2003-09-18.

above, notification procedures. Communication actions in relation to stakeholders and legislation concerning management of administration are also included.

- *Business recovery plan* puts the recovery strategy in relation to identified value chain dependencies. The recovery of critical processes, focused on cash-flow protection, is prioritized.
- *Training and awareness* includes maintenance of the existing plans and training of crisis management teams. [67]

And finally we can conclude that:

> *"No organization is immune from disaster – not even the best run ones. But experience has shown that those with effective recovery plans are likely to survive, while those without do not."*
> (Hiles & Barnes, 2001, "The Definitive Handbook of Business Continuity Management", p. xvi)

3.3.5 **Enterprise-wide risk management**

In the book "Enterprise-wide Risk Management – Strategies for linking risk and opportunity", written by James W. Deloach, who was a partner of Arthur Andersen, the ideas behind the concept "Enterprise-wide risk management (EWRM)" are presented. "Enterprise-wide" means an elimination of functional, departmental or cultural barriers. It is a holistic, integrated, forward-looking and process-oriented approach to managing all key business risks and opportunities with the intent of maximising shareholder value.[68]

To describe the evolution and give an understanding of the background of the EWRM, three stages of risk management have been identified: risk management, business risk management, and enterprise-wide risk management. The evolution of the stages is described below and visualised in Figure 3.14.

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[67] de Waij, D. BCM Practice Leader, Continental Europe, Marsh, 2003-09-18.
[68] Deloach, J. (2000) *Enterprise-wide Risk Management,* p. 5.

Risk management
Most organizations view risk management primarily from the view of the traditional model for managing selected financial and hazard exposures. Measures in connection with risks are often largely financial in nature. The classic risk management model uses derivates, indexed price adjustments or currency risk sharing, insurance policies and the like to mitigate the potentially negative effects of different events. These tools transfer the financial exposures to an independent counterpart. Internal controls are used to manage operating exposures. They are primarily aimed at preventing risk incidents from occurring.[69]

Business risk management
Business risk management takes a broader approach than traditional risk management. It does not view risks as something delegated to separate functions such as insurance, treasury, finance or internal audit. Rather, understanding and managing risks become “part of everyone’s job”. Firms evolve by implementing a more systematic risk evaluation process, assigning accountability for managing risk areas to appropriate managers and applying proven risk management processes and techniques to all critical risks.[70]

Enterprise-wide risk management
EWRM finally integrates business risk management activities with the strategic management and business planning process, because it can be difficult for leaders to evaluate the total effects of risks on the whole business. EWRM therefore moves on from business risk management to a more disciplined or rational process directly linked to the business model of the firm. At the same time, EWRM keeps the traditional risk management with its focus on reducing loss exposure to an acceptable level.[71]

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[69] Deloach, J. (2000) *Enterprise-wide Risk Management*, p. 23.
[70] Deloach, J. (2000) *Enterprise-wide Risk Management*, p. 26.
[71] Deloach, J. (2000) *Enterprise-wide Risk Management*, pp. 28-31.

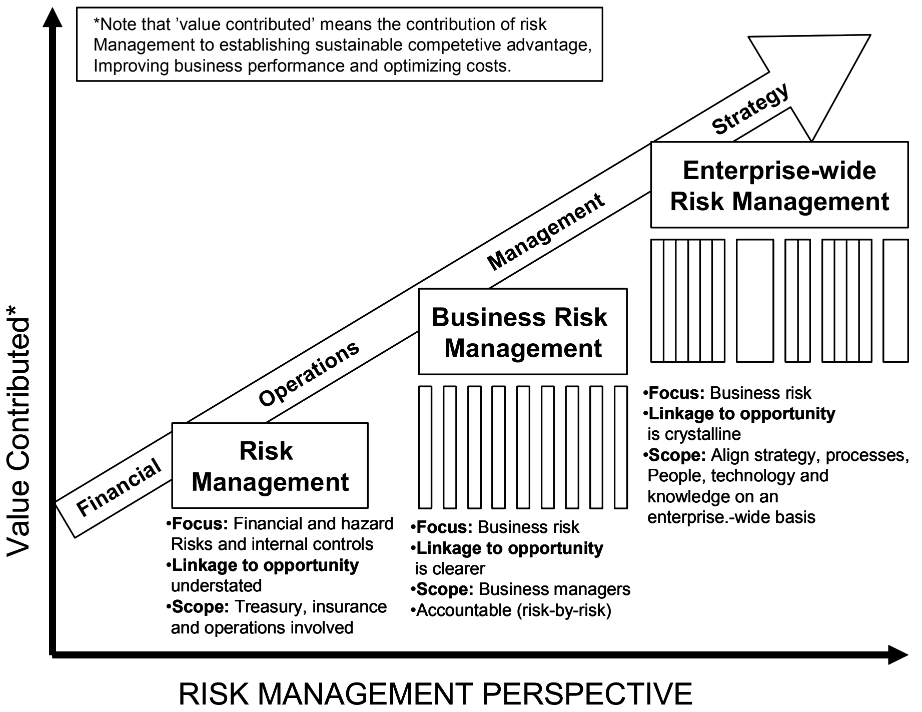

Figure 3.14: The evolution of risk management into a strategic process (Deloach, 2000, p. 24).

Steps in the development towards enterprise-wide risk management
The development from risk management towards enterprise-wide risk management can be described in eight individual steps, where the first step is to "adopt a common language" and the last to "formulate an enterprise-wide risk strategy".

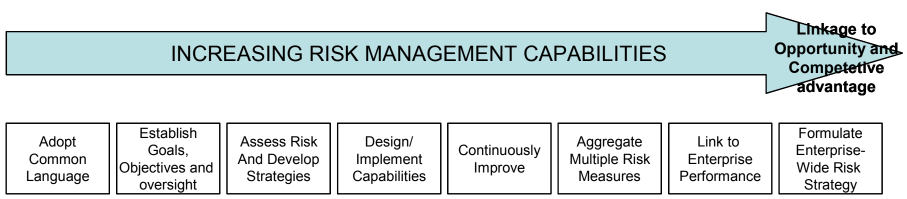

Figure 3.15: Steps along the journey to enterprise-wide risk management (Deloach, 2000, p. 34).

Risk management process
Risk management cuts through divisions/departments and functions in a company – it is an element in *all* company activities. Therefore there is a need of a common process for identification, quantification and management of risks. The risk management process according to "The Arthur Andersen business risk management process" is illustrated in the figure below. The model describes the cornerstones in an effective risk management programme, but the actual process varies from company to company.

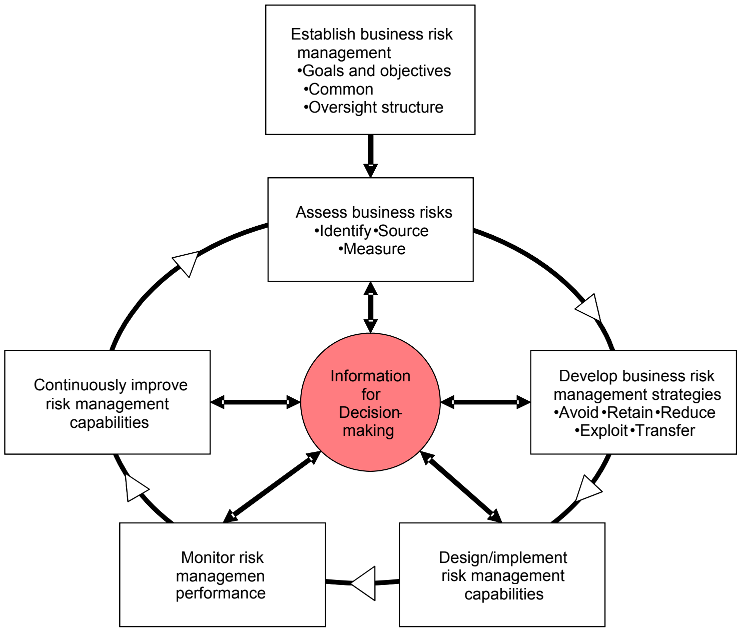

Figure 3.16: Arthur Andersen business risk management process (Deloach, 2000, p. 116).

3.3.6 Strategies for managing company risks

The choice of strategies is often of great importance to the company.

> *"Strategic risk management may become a new source of competitive advantage to companies. Effective risk management may allow a company to pursue business ideas that otherwise would be too risky".* (Huovinen, 1999, "Strategic Risk Management", abstract)

As Hiles & Barnes (2001, Chapter 12) have pointed out, there are two types of recovery strategies; pre-incident and post-incident.

When confronting a risk a company has different choices concerning how to proceed when handling it. First there is a question of whether or not to avoid the risk. If the risk is too big to be handled or not in line with company strategy, it should be avoided. If the company chooses not to avoid the risk, several options are available.

According to Deloach (2000), aside from avoiding there are four other main strategies – retain, reduce, transfer and exploit – and a number of sub-strategies for each of them. The risk can be retained at its present level, or it can be reduced in terms of severity and/or likelihood of occurrence. The risk can also be exploited by increasing the company's exposure to it, and finally, the risk can be transferred. Figure 3.17 below shows the different ways of handling a risk.

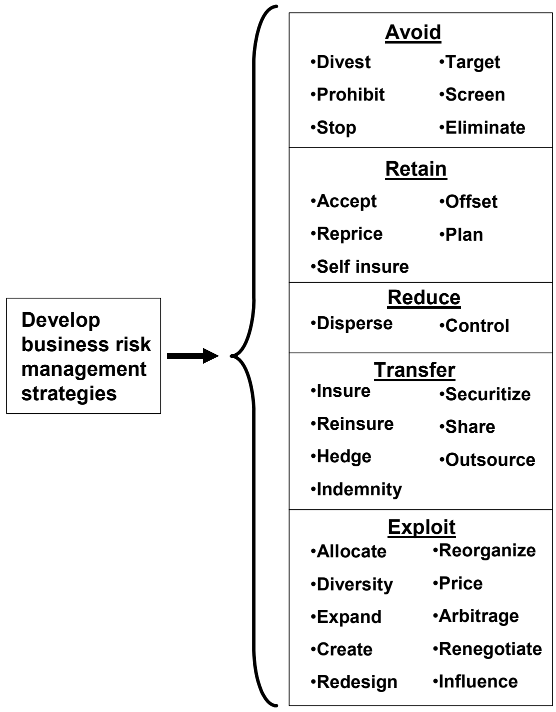

Figure 3.17: Basic risk management strategies according to Deloach (Simplified version of Deloach, 2000, Enterprise-wide Risk Management – An executive summary, Figure 4.3 on page 20).

4 ***SUPPLY CHAIN MANAGEMENT***

One aim of this chapter is to give a short presentation of theories within supply chain management. Another is to identify different trends in supply chain development, and for each of those trends discuss how they affect the disruption risks in the supply chain. The findings will be summed up and commented upon in a later chapter, Chapter 7.

4.1 SUPPLY CHAIN MANAGEMENT

4.1.1 **Physical distribution channel development**

The chain of transport and storage activities from first supplier to end customer will here be called the *physical distribution channel*. This chain has over time changed character and gradually developed from a step-wise chain via a logistical chain into a supply chain. In the *step-wise chain* material and products are moved one step at time and management, in the form of transportation management and warehousing management, is focused on just one link. In the *logistical chain,* management, in the form of logistics management, not only considers their own link but also one link upstream or one link downstream. Finally, in the *supply chain,* management, in the form of supply chain management, considers three links or more; theoretically the whole chain could be included[72].

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[72] Cooper, Lambert & Pagh (1997) ”Supply Chain Management: More Than a New Name for Logistics”. *The International Journal of Logistics Management.*

Table 4.1: Characteristics of three variants of the physical distribution channel.

Characteristics of three variants of the physical distribution channel			
Type of chain:	Step-wise chain	Logistical chain	Supply chain
Number of links:	One link	Two links	Three links or more
Management:	Transportation and warehouse management	Logistics management	Supply chain management

4.1.2 Utilities created by the physical distribution channel

To be able to consume, four utilities have to exist: *form utility*, *possession utility*, *place utility* and *time utility.* Time utility is created through storing activities and place utility through transportation activities. Logistics is traditionally seen as the "art" of finding the best way to produce the needed time and place utility.[73]

To the four utilities a note is often added that they have to be produced at a competitive cost. By definition every link in the chain, with the exception of the first one and the last one, is both consuming and producing.

4.1.3 Supply chain management characteristics

In their article "Supply Chain Management: More Than a New Name for Logistics" Cooper et al. (1997), the authors deal with the issue of what the difference is between Supply Chain Management on one hand and Logistics and Logistics Management on the other. Their conclusion is that supply chain management is something different from and more than logistics. The basic mission, as in logistics, is to create place utility and time utility, but in supply chain management it is also to assist in the

[73] Lambert, Stock & Ellram (1998) *Fundamentals of logistics management*, p. 11.

creation of form utility and possession utility and thus make consumption possible in the next link of the chain

> *"This makes it more than just logistics. To achieve the objectives of integrated SCM, most, if not all functions and business processes are developed"*
> (Cooper, Lambert & Pagh, 1997, "Supply Chain Management: More Than a New Name for Logistics" pp. 10-11)

In the article, a model for supply chain management with four basic elements (Figure 4.1) is also presented.

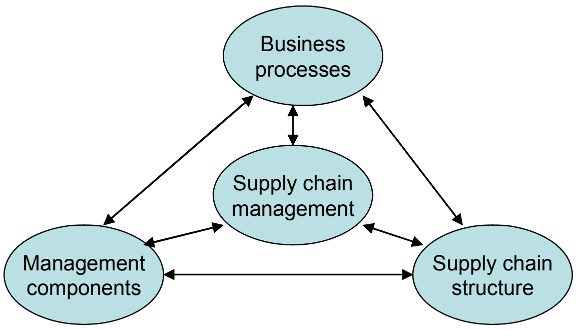

Figure 4.1: Elements in the framework of supply chain management (Cooper et al., 1997, pp. 10-11).

Chains of suppliers/companies have always existed, and so has the effort to achieve integration of the chains, but the concept of supply chain management has not been in common use before the 90's. In the article by Cooper et al. (1997), it is claimed that the concept of Supply Chain Management was used in the literature for the first time in 1982, and that from about 1990 it has been of interest for the academy. But let us first take a look at the concept of supply chain.

A supply chain is defined by Aitken et al. (2005, p.74) as *"the network of connected and interdependent organizations that work together to enable the flow of products into markets"*. And a supply chain is defined by Beamon (1998, p. 292) as *"a set of relationships among suppliers, manufacturers, distributors, and retailers that facilitates the* *transformation of raw materials into final products"*. The latter **definition** will be chosen here because it explicitly mentions that the supply chain goes from raw material to final product, and also because it stresses improving the transformation.

In a way, no such thing as a supply chain exists because everything tends to be related to everything else, and in a long-term perspective no starting and ending points can be found. But if a single company, a single product and a limited period of time are chosen, the supply chain concept makes sense. In the literature there are sometimes references to the supply chain as if it were a natural unit with a specific size and structure and a life of its own. This is, as I see it, not the case. The supply chain is created/specified through the choice of a company, a product and a time period. The supply chain is *perspective dependent*. If the supply chain is looked at from the perspective of one company (one link) in a supply chain there is one supply chain, and if the perspective of one of its suppliers or customers is chosen there will be a different supply chain. The only situation where the supply chain is the same regardless of which link in the supply chain you choose to focus on is when there is only one company in each link of the supply chain. Such supply chains with only one company in each link might exist, but are probably very marginal.

A supply chain cannot take actions as it does not exist from a legal point of view – what exist from a legal point of view are the different individual *companies* and organisations within the supply chain, and they can take action. In those cases where one company dominates the supply chain, that company could on its own initiative more or less manage and run the whole supply chain (or parts of it) from a supply chain perspective. In other cases where no single company dominates the chain, the participants in the chain can nevertheless find it favourable to co-operate and apply a supply chain perspective. So although the supply chain does not exist legally, the actions in the chain might very well be taken *from a supply chain perspective*.

> *"The objective of every supply chain is to maximize the overall value generated. The value a supply chain generates is the difference between what the final product is worth to the customer*

and the effort the supply chain expends in filling the customer's request. For most commercial supply chains, value will be strongly correlated with supply chain profitability,…"
(Chopra & Meindl, "Managing Risk To Avoid Supply Chain Breakdown", 2001, p. 5)

That value is split between the supply chain participants. If for a certain company in the chain the revenues linked to its added value are higher than the costs for creating it, then it has made a profit. The individual link/company in the chain is probably not interested in remaining a part of the supply chain, at least not in the long run, unless it makes a profit.

The flow in a chain can be initiated in two different ways. One is prognosis-based: A company decides to place an order based on sale prognosis with its supplier, which in its turn places an order with its supplier based on its own prognosis, and so on. The other is demand-initialised: The end customer buys a product leading the seller to place an order with its supplier, which in turn orders from its supplier, and so on. In many cases it is thus not supply but demand that initialises the physical flow in the chain, and consequently in these situations the concept ought to be demand chain rather than supply chain.

Another aspect is that the concept of "supply chain" is used although in reality the chain is not really a chain but a network with many "branches". According to Martin Christopher, the correct concept would therefore be "Demand network" rather than "Supply chain" but he believes that the concept "supply chain" is so well established that it is probably not possible to replace it.[74]

By supply chain could be meant the total supply chain starting with the natural resources taken from nature and ending with the final product delivered to the end customer or just some part of it (but it ought to be at least three links). A final product can be defined as a product that the end customer, who might either be a private customer or a company, experiences as "an entity ready to use". The mission of the supply chain

[74] Christopher, M. (1998) *Logistics and Supply Chain Management*, p. 18.

is to efficiently and effectively transform and distribute resources taken from nature into final products that serve end customer needs.

The concept of supply chain management has, like most other new management concepts, no clear and generally accepted definition (they also tend to change/develop over time). The **definition** that will be used in this study is one by M. Christopher from 1998. *Supply chain management* will thus be defined as *"the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole"* (Christopher, 1998, p. 18).

Examples of other definitions are:

> *"an integrative philosophy to manage the total flow of a channel from earliest supplier of raw material to the end user and beyond, including the disposal process".*
> (Cooper & Ellram, 1993, "Characteristics of Supply Chain Management and the Implications for Purchasing and Logistics strategy", p. 13)
>
> *"DuPont's director of logistics (Clifford Sayre) defines supply chain management as a loop: 'It starts with the customer and it ends with the customer.' Through the loop flow all materials and finished goods, all information, even all transactions. 'It requires looking at your business as one continuous process'...."*
> (Gattorna & Walters, 1996, Managing the Supply Chain – a Strategic Perspective p. 12)

A more precise description of the concept is presented by Paulsson et al. (2000) where the characteristics of supply chain management are summed up as:

- *focusing the flow/flows*
- *starting with the needs and demands of the end customer*
- *trying to maximise the customer value of the end customer*
- *trying to lower the ready-to-use additional costs*
- *trying to lower the total cost of production*
- *looking at the total chain as one unit*
- *integrating the different links in the chain*

- *giving higher priority to the needs of the chain than to the needs of the individual link*

(Paulsson, Nilsson & Tryggestad, 2000, "Flödesekonomi - Supply Chain Management", p. 32 [my translation])

Traditionally, competition has existed between different individual firms. Since each firm in the chain now tends to add less and less value, competition however acquires a new meaning. Today's competition tends to be between different supply chains, each of which aims to deliver a product or a service with a high customer value in a cost-effective way to the end consumer. Raising the degree of integration in the supply chain through the use of *Supply Chain Management* is one important way to reach higher efficiency[75].

It is no coincidence that supply chain management became popular in the 90s. It was the result of a number of new factors which made the ideas/theories behind the concept more relevant than before. Two such factors are presented below.

The advantage of looking at the supply chain from a holistic perspective increases when each company in the chain adds less value. One of the strongest trends during the late 90s has been to focus on core competencies and core activities. If a company is going to survive in the international arena, it is not enough simply to perform well. The company has to be really good at what it is doing/producing. Since it is difficult to be excellent at many different things simultaneously, non-core activities are sold out and replaced by components/services bought from the outside – so-called "outsourcing". Today, we find that up to 80–90 % of a company's turnover derives from outside the company, and that the added value of the company itself might amount to only 10–20 %. The more companies focus on core competencies and the more they outsource, the greater the advantages are of analysing the whole chain from a holistic perspective.

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[75] Neuman & Samuels (1996) "Supply chain integration: vision or reality?". *Supply chain management: An International Journal.*

Today competition is global. The same applies to co-operation with the other firms in the supply chain. Through globalisation, the supply chains tend to become more geographically dispersed, which increases the need for a holistic and integrative approach. Within marketing there is a concept called "channel captain", meaning that one of the companies engaged in the marketing and distribution of a product or group of products dominates for one reason or another (Smith, 2003). That company is the one that makes most of the strategic decisions for the marketing channel as a "unit", although the channel might consist of several independent companies. Correspondingly, there are cases where a single company in a supply chain dominates the supply chain. You could here talk about a *"supply chain captain"*.

Another aspect of globalisation is that the traditional supply chain design often becomes obsolete when supply markets and demand markets get global. New strategies for choosing suitable design for global supply chains have to be developed. That issue is treated in a recent article by Christopher, Peck & Towill (2006) with the title "A taxonomy for selecting global supply chain strategies". In the article the authors present a four-boxed model based on the two dimensions "Supply characteristics" and "Demand characteristics". The former is split into long lead-times and short lead-times and the latter into predictable and unpredictable. It gives four possible combinations and for each combination a "pipeline strategy" is proposed.

4.1.4 **Time-based approaches**

Today it is common to focus on time in the supply chain when trying to create a more efficient and effective chain. *Time-based management* implies a focus on the time aspects of the different processes that are necessary to run a business. The purpose is to become more time effective. By eliminating activities/operations that are not value adding, by performing different activities in parallel rather than in a time sequence and by reducing the waiting time in different activities/operations, the organisation will become more time-efficient.

Among the first to discuss the importance of time for the overall efficiency in the organisation were Stalk and Haut back in 1990 in their book "Competing against time"[76]. When they compared different companies they found that those companies focusing upon time had a better record. A central concept in time-based management is *lead time*.

When you look closer at the total lead time you often find that a large part, up to 95 %, of the total time consists of waiting time.[77] Waiting time is in many situations non-value adding, and subsequently the customer is not prepared to pay for it. The customer is only prepared to pay for what is value adding. Therefore an important part of the Supply Chain Management concept is the effort to achieve reductions in the lead times. Professor Peter Hines has shown that by identifying and reducing different kinds of wastes it is possible to reduce the lead times substantially. Shorter lead times often give substantial reductions in tied up capital, higher flexibility, and other positive effects.

Among the Swedish researchers who have studied the importance of lead times can be mentioned: Abrahamsson (1992) in "Tidsstyrd direktdistribution" (Time controlled direct distribution), Wedel (1996) in "Lead time Reduction in Manufacturing – from initiation to realisation", and Norrman (1997) in "Organizing time-based distribution in trans-national corporations".

Lead time is both a very simple and difficult concept. Lead time could be defined in many different ways depending on the situation. If a customer wants to place an order, the lead time can be defined according to Coyle et al. (1996, p. 615) as "*the total time that elapses between an order's placement and its receipt*". If you look at it from a total supply chain perspective, it is the time from the raw material being processed by the initial supplier all the way through the different links in the supply chain to when the final product is bought by the ultimate customer (end customer).

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[76] Stalk & Haut (1990) *Competing against time.*
[77] Storhagen, N. G. (1995) *Materialadministration och logistik (Materials administration and logistics)*, Chapter 5.

4.2 TRENDS AFFECTING THE SUPPLY CHAIN FLOW RISKS

The *mission* of the supply chain is to efficiently and effectively transform and distribute natural resources taken from nature into final products that serve end customer needs. *Disruptions* can make that mission impossible or at least decrease the efficiency and effectiveness in the chain. The supply chain is *vulnerable*.

A disruption is an unexpected sudden interruption in the supply chain flow that constitutes a risk, but all interruptions are not disruptions since not all interruptions constitute a risk i.e. have negative consequences. An interruption might further lead to a number of consequences of which some are negative and some are positive. A risk is only at hand when the negative consequences of an sudden unexpected interruption outweigh the positive consequences. There are numerous things that could cause disruptions. Below a look at some of the trends that might affect supply chain flow risks will be taken.

4.2.1 **Individual supply chain trends and their risk influences**

For the individual company, *competition* is a constantly present *driver for increased efficiency and effectiveness*. To become more competitive, changes have to be done and actions have to be taken within areas like product development, marketing, financing, distribution etc. But today competition tends to be between different supply chains rather than between different individual companies, and that has led to increased focus on the competitiveness of the whole supply chain (Christopher, 1998). The actions taken to increase the efficiency and effectiveness in the chain can be clustered into different trends. But some of those trends not only increase supply chain competitiveness, they also affect supply chain vulnerability.

The trends discussed in the first chapter will here be gone into in somewhat greater detail, and their effects on the vulnerability in the supply chain discussed. Each trend is affecting the supply chain flow and changing its structure. This structural change will in its turn change the supply chain vulnerability.

Below, different identified trends are presented *in basically alphabetical order* and their affects on supply chain flow structure and vulnerability discussed.

Many markets today demand that the firm/chain is *agile* i.e. has the ability to take care of the individual customer's wishes when it comes to e.g. packaging, documentation, delivery and payment, and to adapt rapidly and smoothly to changes in customer demands (Power & Sohal, 2001; van Hoek, Harrison & Christopher 2001). This leads to a more dynamic physical flow, which results in increased risks of making mistakes. Traditional buffer stocks will also give less protection than before, as they are more likely to contain obsolete material and products.

Customer demands have been increasing and new demands are being formulated all the time. Higher demands e.g. on service levels are more difficult to fulfil and can be risky because there are very small margins. New demands are more risky to fulfil because you cannot lean back on past experiences. It is therefore more difficult to identify and evaluate the risks in a new supply chain than in an old one.

There is also an increasing demand for *customized products* i.e. products produced according to the specification/wish of the individual customer (Christopher & Towill, 2000; Akkermans, 2003). Risk handling becomes more difficult since you will probably not have any buffer stock of a customized product. On the other hand, the customer might be more willing to accept a delay.

Globalisation (Skjoett-Larsen, 2000; Bowersox, Closs & Cooper, 2002, pp. 24f) means that on the purchasing side raw material, components and services are bought from that geographical part of the world where price and quality for the moment is most favourable. But there is also a trend towards globalisation on the market side – products are no longer sold only locally but in many different geographical markets. The increased globalisation on both the market side and the purchasing side has had the consequence that the suppliers and customers of a company grow geographically farther away from the company than before, and are perhaps also situated in parts of the world with which the company is not so familiar. It often also means new suppliers and new groups of customers. All this leads to new and increased risks.

Lead times are shortened through reductions in the time that different activities need for execution or through reductions in lead time buffers. Reductions in lead time buffers increase the risks (Beesley, 1997; Mason-Jones & Towill, 1998). On the other hand, shortening lead times through more efficient execution of activities means that you could get replenishment quicker when needed.

Lean production and *lean distribution* means doing more with fewer resources and often leads to lower stock levels or even eliminated stocks (Fynes & Ainamo, 1998). This might lead to greater risks.

Outsourcing means that the company concentrates on its core activities and buys from outside everything that is not part of the core activities. Owing to the increased rate of change, it might be difficult for a single company to be able to afford the development costs of all the components in its products. Therefore, companies tend to focus their development efforts on their own core competence area, letting other firms develop the other components. Another motivation could be difficulties of reaching the same economies of scale as the supplier. Outsourcing has the effect that the company loses its direct control over the quality, and that quality problems could be more difficult to deal with. Product development becomes narrower than before. The company loses its competence within the outsourced area after a while, and becomes a less qualified purchaser. All this increases the risks. Outsourcing also implies that the chains are growing longer than before, and there are more companies that should coordinate their activities with each other. This makes it more difficult to "grasp" the whole value adding process since everyone is doing a smaller part of it (Lonsdale, 1999). The risks are consequently heightened.

The *product life cycles* for many products tend to get shorter. This leads to a more dynamic situation and new risks. Today *time-to-market* is also being compressed for many products. This leads to a more dynamic situation and new risks.

Traditionally, companies used to have several suppliers for every raw material, component or service that it was buying to spread the risks. Today it is becoming increasingly common that the firm only has one (*single sourcing*) or two (*dual sourcing*) suppliers of each raw material, component or service because this is more cost-effective (Zsidisin, Panelli, & Upton, 2000). If a company goes from multiple sourcing to single sourcing and there is a disruption, e.g. a fire affecting the sole supplier, that disruption totally cuts off deliveries from the supply side. Then there are no deliveries of the actual component at all – the risk increases. At the same time, there is no other regular supplier from whom the company might obtain extra deliveries – risk handling is becoming more difficult than before. Increasing risks in combination with decreasing risk management actions leads to an increase in uncovered risks. The change from multiple to single or dual sourcing has created a new risk situation (Zsidisin, Panelli & Upton, 2000).

4.2.2 Examples of risk influences from the trends

Table 4.2: Examples of risk influences from the trends.

Trend	Influences on supply chain flow	Influences on disruption risks
Agility	A more dynamic flow	More mistakes
-"-		More obsolete inventory
Customer demands	Higher demands on delivery service might lead to more frequent deliveries	Higher service levels are more difficult to reach
-"-	New demands	Higher risks of marketing and distribution failures
Customized products	A more complex flow with many more products to keep track of	More complexity leads to increased risk of disruptions
Globalisation	More geographically spread suppliers and customers	Longer distances with more transport links imply the exposure to more potential disruptions
-"-	-"-	Greater cultural differences increase the risk of misunderstandings
-"-	-"-	More time zone differences makes communication more difficult
-"-	-"-	Longer distances make personal face-to-face contacts more costly
Lead times	Shorter lead times	Less time to react if anything goes wrong. On the other hand, quicker to get a new delivery
Leanness	Fewer buffer stocks	Fewer possibilities to handle disruptions with the help of buffers
-"-	Less slack in lead times	Fewer possibilities to handle disruptions with the help of lead time slack
Outsourcing	More links in the chain	Greater complexity and probably also longer distance from beginning to end of supply chain leads to increased risks of disruptions.
Product life cycle	Shorter product life cycles	Less stability in the supply chain increases the disruption risks.
Single and dual sourcing	Fewer branches in the supply chain tree	Fewer backup alternatives means greater negative consequences if anything goes wrong.
Time-to-market	Shorter time-to-market	Less time to build up and test the new supply chain means increased disruption risks

4.2.3 **Commenting on the trends**

A number of trends during the past decade and their influence on the supply chain flow and on the risk situation in the chain have been discussed above. Many of those trends tend to lead to new and increased risks for disruptions in the flow, and also to more serious negative consequences of such disruptions for the chain as a whole as well as for the individual company in the chain – conclusions that have also been reached by other researchers within the field (Zsidisin & Ellram, 1999; Ritchie & Brindley, 2000).

At the same time, the importance of many of the traditional risk handling methods like buffer stocks and lead time slack has been substantially reduced by these trends. The conclusion is therefore that the trends have created *a changed risk situation* for many companies. If the companies are not aware of this and do not take proper actions, the consequences in the event of a disruption might become *very serious.* This makes issues of *supply chain risk* of critical importance in many firms and organizations – an area that is presented in the next chapter.

5 ***<u>SUPPLY CHAIN RISK</u>***

The aim of this chapter is to identify, structure and present the general knowledge within supply chain risk management and related areas as it is reflected in the scientific literature. The findings will be summed up and commented upon in Chapter 7.

5.1 CHARACTERIZING THE AREA

There is a long tradition of studying individual disruption risks in the supply chain within a rather narrow perspective. One example of this is not to look only at the price and the quality of the product but also consider the ability to deliver (purchasing risk) when choosing among different suppliers. But today risks tend to be at hand everywhere in the supply chain.

> *"The rapid development of transport systems, information technology, and just-in-time schemes and the effects of a single decision can have dramatic effects that propagate rapidly and widely through the global society".*
> (Rasmussen & Svedung, 2000, "Proactive Risk Management in a Dynamic Society", p. 10)

A new risk awareness and probably also new risk handling actions are thus needed. But those actions could themselves create other new risks <u>(Peck et al., 2003, pp. 43-44).</u> That means that the company or organisation, when introducing changes in its risk management, needs to be observant so that the risk situation does not become worse instead of better.

During the last decade or two there has been a clear tendency to look at the risks in the supply chain from a more holistic and integrated perspective than before, and stressing how they can be managed. This is the background to the new and emerging area of supply chain risk management.

One of the first international conferences on managing risks in supply chains took place in 1999 and had the title "Managing Risk in the International Supply Chain – exploring critical aspects of logistics effectiveness".[78] In 2001 the International Supply Chain Risk Management (ISCRiM) network was constituted in Crewe, UK, and has since then arranged an annual meeting, distributed a quarterly newsletter, and published a book (with a second one in the pipeline). Other indications of the expansion of this academic area are that a couple of books, special issues by leading journals and a number of individual journal articles have been published.

Supply chain risk management was described by myself in Brindley (ed) (2004) as the *intersection* between "Supply chain management" and "Risk management".

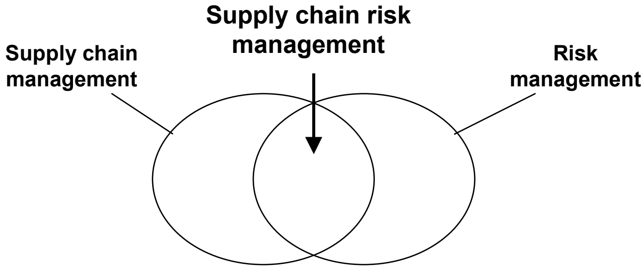

Figure 5.1: Supply chain risk management described as the intersection of supply chain management and risk management (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 80).

Supply chain risk management may be regarded as a collaborative and structured approach to risk management, included in the planning and control processes of the supply chain, to handle risks which might affect the achievement of the supply chain goals.[79]

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[78] *"Managing risk in the international supply chain – exploring critical aspects of logistics effectiveness".* London, 25-26 October, 1999. Arranged by Triangle.

[79] Kajüter (2003) *"Risk Management in Supply Chains"*. Chapter in Seuring et al., 2003, p. 327.

There exists no generally agreed definition of *supply chain risk management.* The definition below is one that I, in an earlier work, have developed based on Norrman & Lindroth (2002, p. 7). This description is used to **define** the concept of *supply chain risk management* in this study.

> *Supply chain risk management is to, collaboratively with partners in a supply chain or on your own, apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources in the supply chain.* (Paulsson, 2004, "Supply Chain Risk Management". Chapter 6 in Brindley (ed), 2004, p. 80)

5.2 SEARCH METHOD FOR THEORIES

Normally it takes some time before the amount of knowledge within a new academic area is broad enough and sufficiently established to be presented in books. Supply chain risk, and especially supply chain risk management, can be considered to be a rather new area. The overview therefore consists of two parts. The first one is a presentation of a scientific journal article review. This source has been chosen since journal articles are the main source of quality controlled new academic knowledge and because the review conducted has already been presented as a book chapter and as such passed certain quality checking. The second part is a presentation of theories from dissertations, research reports, books and other scientific journal articles than the ones included in the review in part one.

5.3 JOURNAL ARTICLE SURVEY

This section is based on a study by myself which was presented as a chapter[80] in Brindley (ed) (2004). The individual chapters in the book were sent by the publisher (Ashgate) to one American and one European professor for quality checking. My chapter had the title "Supply Chain Risk Management " and was based on intensive searches in library databases for articles within supply chain risk management and related areas. A total of 80 relevant journal articles were found and they are listed in the end of the chapter. A database of the articles was created and information from this database was then analysed and presented. Subsections 5.3.1–5.3.5 are directly taken from the book chapter but presented in a condensed form.

5.3.1 **Introduction**

To be able to describe existing theories within supply chain risk management and related areas, as presented in scientific journals, relevant articles need to be identified and structured both by their external characteristics and by their contents. The actual method for finding and selecting the articles is presented in Appendix 1. In section 5.3.3 the articles are structured according to external characteristics, and in section 5.3.4 by contents.

5.3.2 **Dimensions for structuring**

The *external characteristics* that will be used are: printing year, journal, author and author nationality.

[80] Paulsson (2004) *Supply Chain Risk Management.* Chapter 6 in Brindley, 2004.

To be able to characterise the *contents* of the articles, certain dimensions for description need to be specified. Lindroth & Norrman (2004)[81] have proposed the following three basic dimensions: "unit of analysis", "type of risk and uncertainty" and "risk and business continuity management process". For each basic dimension in the model a number of *dimension elements* are given. For instance, the dimension "type of risk and uncertainty" has the following three elements: operational accidents, operational catastrophes, and strategic uncertainties.

To those three basic dimensions a fourth one will be added here, and that is the *interest direction* in the chain. Is our focus primarily upstream or downstream? Or if you look at the supply chain from the perspective of a single firm in the chain: Are you looking at the supply side, or internally, or at the demand side? The extended model is presented below (Figure 5.2).

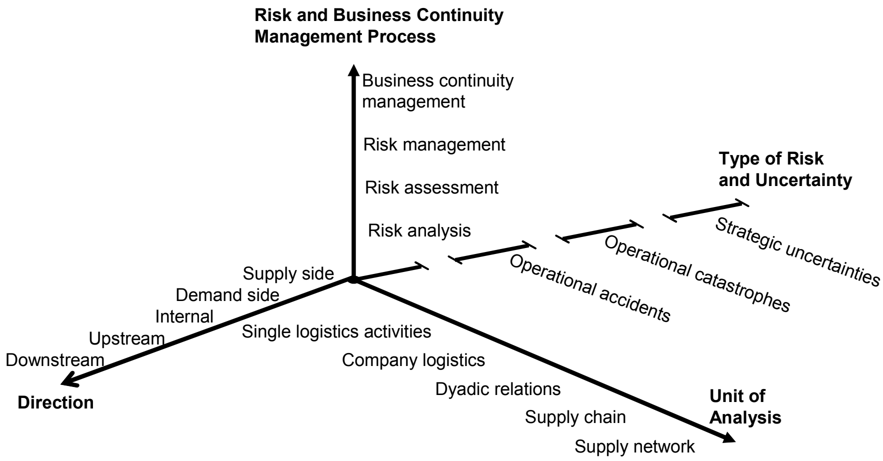

Figure 5.2: A framework for positioning supply chain risk issues (expanded from Lindroth & Norrman in Brindley (ed), 2004, p. 15)

[81] Lindroth & Norrman (2004) *Categorization of Supply Chain Risk and Risk Management.* Chapter 2 in Brindley, 2004.

5.3.3 External article characteristics

Printing year
The oldest article is from 1983 – that means that it is more than 20 years old – and the second oldest from 1987. Then there is a jump to 1995. The period 1995–2003 is illustrated in Figure 5.3 below.

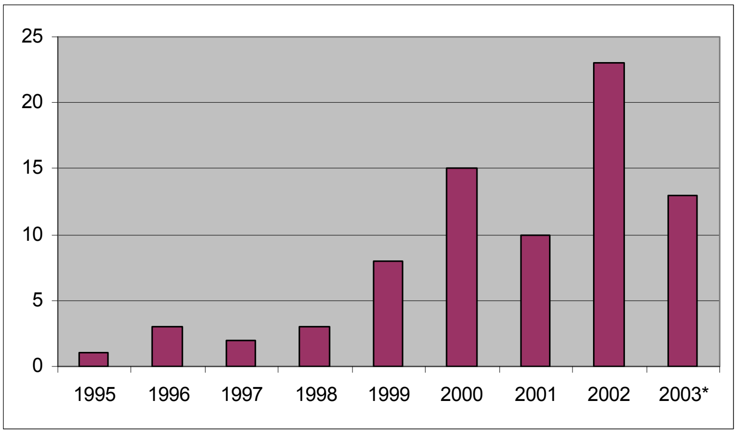

*Figure 5.3: The number of scientific articles within supply chain risk management published during the years 1995–2003 (*Part of 2003 only) (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 85).*

The number of articles is clearly increasing during the period, so the area is under expansion. But we must remember, too, that the total number of published journal articles in the world tends to rise for each year.

Scientific journal
The 80 articles were published in 53 different journals. 42 of them had just one article, while eleven had two or more. The *International Journal of Physical Distribution & Logistics Management* was the leader, with eight articles. Four of them were written by the same author (Göran Svensson).

Table 5.1: Scientific journals and the number of published articles within supply chain risk management (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 86).

Scientific journal:	**Number of articles:**
International Journal of Physical Distribution & Logistics Management	8
Supply Chain Management: An International Journal	5
International Journal of Production Economics, Journal of Business Logistics, and Journal of Supply Chain Management	4
Supply Chain Management Review	3
Computers & Operations Research, International Journal of Logistics Management, Management Science, Manufacturing & Service Operations Management, and PRACTIX	2
42 other different journals	1
Total: 53 different journals	**80**

Author

The 80 articles reviewed were written by 133 different authors. One person was engaged in the writing of seven articles, one in five articles, seven in two articles, and finally 124 persons in one article.

Table 5.2: The number of article contributions for different authors (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 86).

Author:	**Number of article contributions:**
Göran Svensson	7
George Zsidisin	5
Vipul Agrawal, Clare Brindley, Lisa Ellram, Eric Johnson, Hau Lee, Bob Ritchie and Andy Tsay	2
124 other authors	1
Total: 133 authors	**150 article contributions**

On average, an article had 150/80 = 1,88 authors. 28 articles had just one author, 38 had two, ten had three and finally four had four authors. No article had more than four authors.

Author country
Author country has here been defined as the author's working place, i.e. a certain university or a certain company in a certain country. By that definition it can be concluded that the articles were written mainly by persons working in the United States or in the United Kingdom, but contributions came from a total of 19 different countries.

Table 5.3: The number of article contributions for different author countries (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 87).

Author country:	**Number of article contributions:**
United States	72
United Kingdom	23
Sweden	9
China and Finland	7
Canada	6
Germany and Taiwan	4
Belgium, Netherlands and South Korea	3
Australia	2
7 other countries	1
Total: 19 countries	**150 article contributions**

5.3.4 Basic article contents characteristics

The contents of the 80 journals are here structured with the help of the model presented in Figure 5.2. Each article has been categorized in the four dimensions by using these dimension elements. For most articles only one element for each dimension has been chosen for the classification, but for some articles two or more elements were used.

Unit of analysis
Unit of analysis is described by the help of the five elements: *single logistics activities*, *company logistics, dyadic relations*, *supply chain*, and *supply network*. Supply chain means that at least three links in the chain are studied with an integrating approach. Supply network is regarded as a supply chain of high complexity.

Table 5.4: Number and percentage of unit of analysis elements for the 80 articles (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 88).

Unit of analysis element	Number of articles	Percentage of the articles
Single logistics activities	0	0
Company logistics	1	1,3%
Dyadic relations	33	41,3%
Supply chain	49	61,3%
Supply network	8	10,0%
Total classification number:	***91***	

On an average, each article is classified with the use of 1.14 (91/80) elements. No articles deal with *single logistics activities* and only one with *company logistics*. This is not surprising, as the area of the study is supply chain risk management. The most frequent element is *supply chain*, which fits well with the earlier stated definition of supply chain risk management. So does the element *supply network*. More surprising is that more than 40 % of the articles are classed as *dyadic relations*.

Type of risk

Type of risk is described by using the three elements: *operational accidents*, *operational catastrophes*, and *strategic uncertainties*.

Table 5.5: Number and percentage of type of risk elements for the 80 articles (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 88).

Type of risk element	Number of articles	Percentage of the articles
Operational acidents	30	37,5%
Operational catastrophes	32	40,0%
Strategic uncertainties	54	67,5%
Total classification number:	***116***	

Strategic uncertainties are the most frequent element, followed by operational catastrophes and operational accidents. On average, 1.45 elements are chosen for each article.

Management process
Risk and business continuity management process is described with the help of the four elements: *risk identification/risk analysis*, *risk assessment*, *risk management*, and *business continuity management*.

Table 5.6: Number and percentage of management process elements for the 80 articles (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 89).

Management process element	Number of articles	Percentage of the articles
Risk identification/risk analysis	10	12,5%
Risk assessment	14	17,5%
Risk management	77	96,3%
Business continuity management	6	7,5%
Total classification number:	***107***	

The element *risk management* is here by far the most frequent element – only 3 out of 80 articles are not classified as risk management articles. One explanation is that risk management covers very many different kinds of risk activities, another is that the purpose of many of the articles is to develop new models/new theories that will make the management process more efficient and effective.

Direction
The chain interest direction in each article is described by using five elements: *upstream*, *downstream*, *supply side*, *internal*, and *demand side*. The last three elements are used when the supply chain issues are studied from the point of view of an individual company in the chain; the two first elements are used when the focus is on the supply chain as an entity and not on any specific link.

Table 5.7: Number and percentage of direction elements for the 80 articles (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 89).

Direction element	Number of articles	Percentage of the articles
Uppstream	9	11,3%
Downstream	16	20,0%
Supply side	50	62,5%
Internal	8	10,0%
Demand side	39	48,8%
Total classification number:	***122***	

Supply side and *demand side* are the two most frequently used elements here. That means that most articles look at the supply chain from the perspective of an individual company. Since supply side dominates it might mean that the problems are experienced to be greater at the supply side than at the demand side, and/or that there are greater possibilities to deal with those problems.

5.3.5 Risk sources

Based on the articles reviewed, five different *risk sources* have been identified. They are presented in Figure 5.4 on the right side. On the left side of the figure three different types of risks and uncertainty that were earlier presented (Figure 5.2) are shown so that the correspondence between *type of risk* and *risk source* can be seen. Each risk source will now be discussed and exemplified by suitable articles from the review.

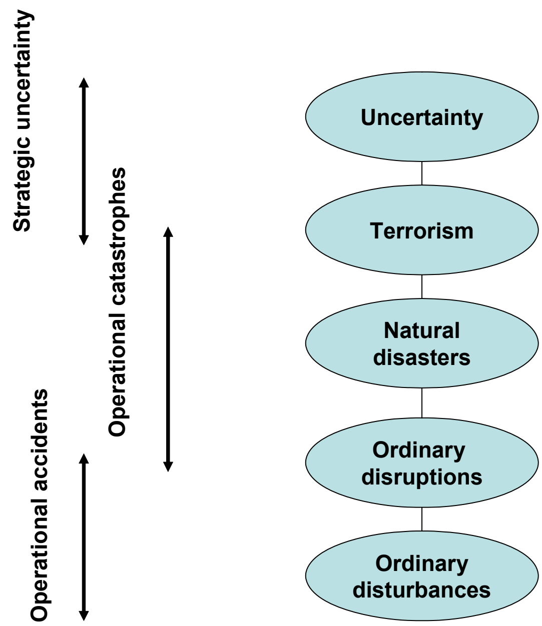

Figure 5.4: A model of different risk sources and their links to the three types of risk elements (Paulsson, 2004. Chapter 6 in Brindley (ed), 2004, p. 90).

Uncertainty exists within a number of areas. Many of the articles deal with the issue of how to handle *supply* side uncertainty. A classic here is the article by Kraljic (1983), where the author presents a four-box model that can be used to manage supply risks. Articles about supply uncertainty often focus on dyadic relations (Svensson, 2000; Zsidisin, 2001) and employ methods like risk-pooling (Tagaras, 1999) and contracting (Eppen & Anath, 1997; Agrell, Lindroth & Norrman, 2004). Mathematical models are also applied in many cases (Agrawal & Seshadri, 2000; Arcelus, Pakkala & Srinivasan, 2002).

Uncertainty in *demand* is also dealt with in a number of articles (Christopher, 2000; Cohen, 2000). These articles are often, like the supply articles, focusing on dyadic relations and applying mathematical models (Weng 1999; Applequist, Pekny & Reklaitis, 2000). There are also articles dealing with uncertainties on *both* the supply and demand side (Ritchie & Brindley, 2000; Johnson, 2001; Harland, Brenchley & Walker, 2003).

In some articles, *weather* is mentioned as a source of uncertainty (Luc & Carruth, 1997) and there are also articles stressing the importance of *political uncertainty* (Umali-Deininger & Deininger, 2001; Tsai & Su, 2002).

Terrorism is a "new" source of risk, at least when it comes to articles within supply chain risk management. None of the articles reviewed published before September 11, 2001 dealt explicitly with terrorism. After that date there have appeared several articles about terrorism and its threat to the supply chain flows (Sheffi, 2001; Lee & Wolfe, 2003).

Flooding, *earthquakes* and *hurricanes* are examples of traditional natural disasters. A new kind of natural disaster, at least in the articles reviewed, is the spread of *international sicknesses* among humans and animals like SARS and BSE (Martha & Sunil, 2002). Hence quality control and the ability to track and trace are of great importance, especially in the food chain (Ropkins & Beck, 2000; Fearne, Hornibrook & Dedman 2001; Schroeder & McEachern, 2002).

Ordinary disruptions and how to handle them are treated in a number of articles. Serious disruptions can lead to bankruptcies (Warren & Hutchinson, 2000; Rice & Caniato, 2003) and even catastrophes (Burrage, 1995).

Ordinary disturbances are also treated in a number of articles, touching on everything from minor, everyday disturbances (Boronico & Bland, 1997; Owens & Levary, 2002) to the year 2000 problem (Jones, 1999).

5.4 OTHER LITERATURE

5.4.1 **Individual research contributions**

Different research contributions that are of general interest in one way or another will here be presented in chronological order starting with the oldest ones.

Fahlén (1997) has studied the consequences of disruptions on manufacturing companies' effectiveness and written a doctoral thesis on the subject with the title; "Störningars konsekvenser för tillverkande företags effektivitet (Consequences of disturbances on manufacturing companies' effectiveness)". In his thesis he studies different disruption risks in the flow from first tier supplier to first tier customer, and discusses different ways to manage those risks. According to Fahlén, a disruption can be defined as *"An unwished, random event, which leads to deviations from plan and whose consequences are negative for someone or some of the stakeholders on the arena"*.

Svensson (2000) develops in his article "A conceptual framework for the analysis of vulnerability in supply chains" a model for the analysis of vulnerability in supply chains that consists of two dimensions; categories of disturbance, and sources of disturbance. Categories of disturbance are quantitative and qualitative disturbances. Sources of disturbance are atomistic, i.e. direct disturbances, and holistic, i.e. indirect disturbances. The atomistic approach is suitable for low-value, non-complex standard components, and only a limited part of the supply chain has to be analysed. The holistic approach is suitable for high-value, complex and unique components, and an overall analysis of the supply has to be conducted.

In his doctoral thesis "Sårbarhet i logistikkanaler (Vulnerability in supply chains)" (Svensson, 2001), Göran Svensson discusses the vulnerability in the supply chain, which he divides into an inbound and an outbound logistical channel. The production part (internal part) of the focal unit is not included in the study. The general model developed (Svensson, 2001, page 163) for the analysis of vulnerability in logistical channels consists of two main parts: source of disturbance and category of disturbance. Two sources are identified: direct and indirect. Two categories are also identified: quantity and quality. This yields four possible combinations; direct quantity disturbance, indirect quantity disturbance, direct quality disturbance, and indirect quality disturbance.

In their article "Supply Chain Risks and Risk Sharing Instruments – An Illustration from the Telecommunication Industry" Lindroth & Norrman (2001), the authors first discuss supply chain risks in general and then turn to ways of handling those risks through different kinds of risk sharing instruments. The first part generates a model (Figure 5.5) with the help of which supply chain risk issues can be assessed and positioned. (The model was later further developed by Lindroth & Norrman in Brindley (ed) (2004).

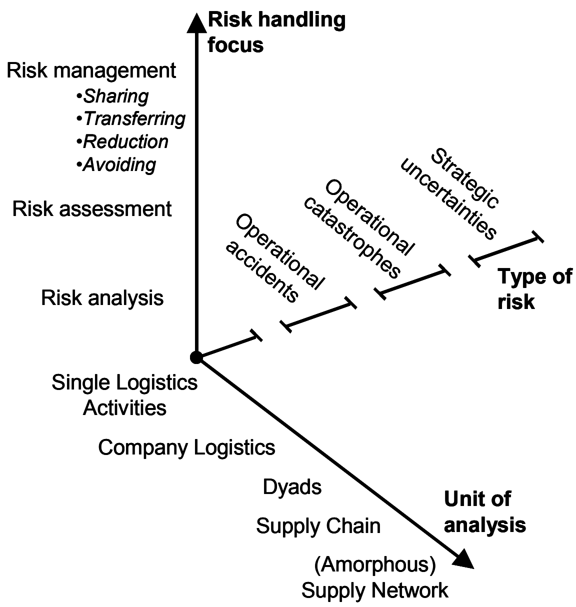

Figure 5.5: A framework for assessing and positioning supply chain risk issues (Lindroth & Norrman, 2001).

The second part of the results is a model for categorization of different methods for handling risks in supply chains, which will be presented in section 5.5.

In his article "Learning from Toys: Lessons in Managing Supply Chain Risk from the Toy Industry", Johnson (2001) stresses the importance of focusing on how to manage both supply risks and demand risks simultaneously and presents the following model.

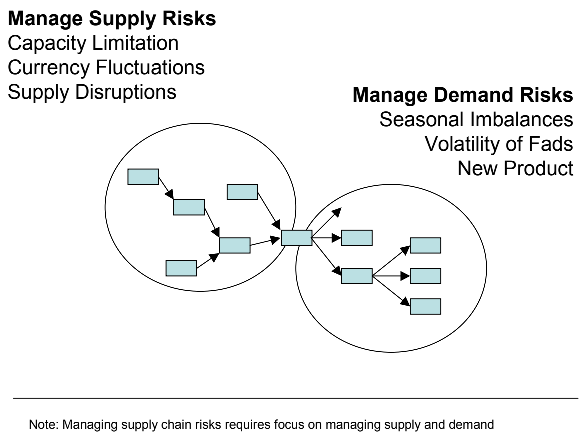

Figure 5.6: Managing supply chain risks (Johnson, 2001, Exhibit 3).

The author also identifies different specific risks on the two sides and discusses how to handle each of them. The risks include market risks, financial risks, and political risks as well as disruption risks in the flow. The focal unit is a trading company with no traditional production activities. No risks within the focal unit are discussed. The supply chain goes from the toy manufacturer to the distribution centre of the retailer.

Svensson (2002) says in his article "A conceptual framework of vulnerability in firms' inbound and outbound logistics flows" on page 3 that the construct of vulnerability consists of two components: *disturbance* and *the negative consequence of disturbance*. He continues by defining a disturbance "*as a random quantitative or qualitative deviation from what is normal or expected*".

Peck et al. (2003) discuss (in their research report "Creating Resilient Supply Chains") disruption risks in the supply chain and present a model with five different risks. The model includes two risks that are internal to the focal firm – "process risks" and "control risks", two risks that are external to the focal unit but internal to the supply chain – "supply risks" and "demand risks" and a fifth risk, "environmental risk", that is external to the supply chain.

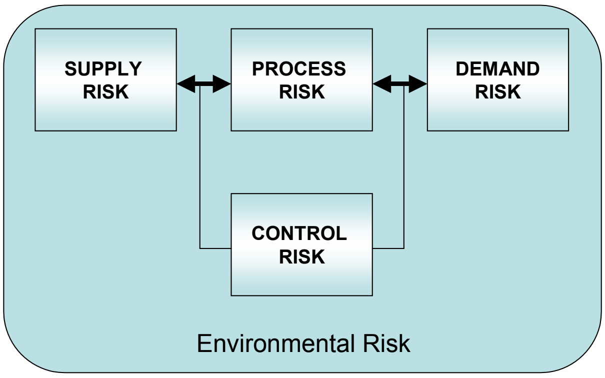

Figure 5.7: Sources of risk in the supply chain (Peck et al., 2003, p. 44).

Kleindorfer & Van Wassenhove (2004) claim in their chapter *Managing Risk in Global Supply Chains* that there is an increased recognition of the relationship between supply chain management and return on assets (ROA) – a relationship that is illustrated in the figure below.

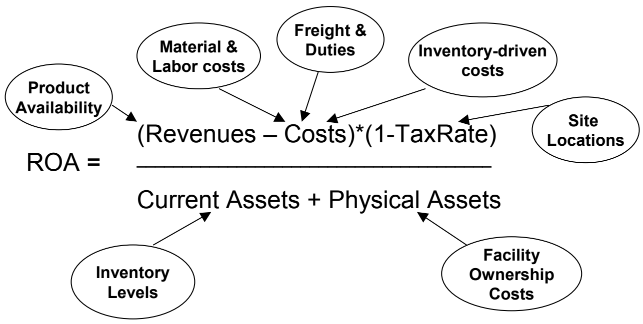

Figure 5.8: The supply chain's impact on return on assets (Kleindorfer & Van Wassenhove, 2004, Figur 12.2).

The authors identify two basic types of risk management issues in global supply chains: matching supply to demand, and addressing disruptions to supply chain activity. Three different strategies have typically been used by global companies: supply chain design, contracting, and risk management systems. Then a couple of strategies suitable for managing supply-demand coordination risk are presented. After that, the focus is directed to how to manage disruption risks. The strategies are here split into two groups: one for strategies addressing purposeful triggers like the consequences of a terrorist attack, and one for strategies addressing accidental triggers including natural hazards. In the first group, "red-blue teaming" is mentioned, i.e. role playing where one team tries to attack and the other one tries to defend. For the second group, "benchmarking" is mentioned.

The journal article "Ericsson's proactive supply chain risk management approach after the Albuquerque accident" by Norrman & Jansson (2004) consists of four parts. In the first part, a general background to the increased interest in the area of supply chain risk management is discussed and some basic concepts and theories within the area are presented. In the second part, the Albuquerque accident and its consequences for Ericsson are described. In the next part, the lesson learned by Ericsson and their new risk management organisation and routines are discussed. Finally, in the fourth part, a general discussion is carried out about the need to extend the traditional logistical models with their three dimensions – time, quality and cost – with a fourth dimension – risk. The focus is on supply chains with at least three links.

Svanberg (2004), in her doctoral thesis, analyses the interaction between risk and logistics with special focus on total offers in the aerospace industry. She concludes among other things that logistics activities tend to be the most important source of risk in such a setting.

Kleindorfer & Saad (2005), "Managing Disruption Risks in Supply Chains". The authors start by mentioning that there are two broad categories of risks affecting supply chain design and management. The first category consists of risks arising from co-ordinating supply and demand, and the second category of risks arising from disruptions of normal activities. The article then focuses entirely on the second category. Disruption risks may come from natural disasters, from strikes and economic disruptions, and from acts of purposeful agents. The article provides a conceptual framework for disruption risk management in supply chains that includes the joint activities of risk assessment and risk mitigation. The foundation for disruption risk management is three tasks: Specifying sources of risk and vulnerability, Assessment, and Mitigation (SAM). The first task – specification of risk sources – may be of three kinds: operational contingencies; natural hazards such as earthquakes, hurricanes and storms; and terrorism and political instability. The authors then discuss ten different principles that must be understood and practised to be able to implement SAM efficiently and effectively.

Asbjörnslett & Rasmussen (2005), in their conference presentation "Maritime Logistics" at the NOFOMA 2005 conference present a model that they call "The SeaChains model". They define a maritime logistics chain as a logistical chain containing at least one seaborne transport. Robustness is one out of four dimensions with the help of which the supply chain is described and evaluated. The other three are Time, Cost and Quality. The maritime logistics chain has a Door-to Door focus instead of the traditional Port-to-Port focus. This means that the whole supply chain from point of origin to point of consumption can be covered (or less, but it must be more than just the traditional Port-to-Port). The model is based on five different generic building blocks, some of them in their turn containing generic categories. The generic model can be used in a whole spectrum of applications from situations with simple calculations with the help of a paper and a pen to complex calculations with the help of advanced software programs.

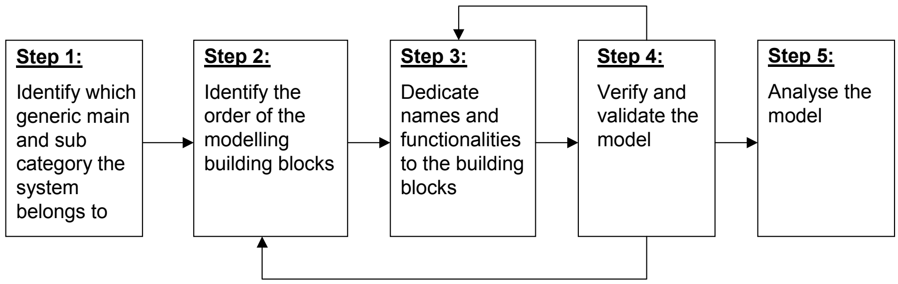

Figure 5.9: The five steps in the SeaChains model (Asbjörnslett & Rasmussen, 2005, PowerPoint-presentation, slide 18).

Gaudenzi (2005) shows, in her PowerPoint presentation "Managing risks in the supply chain", the results of a project that took its starting point in three thematics that are partly overlapping: supply chain management, risk management, and measurement philosophy. It is stressed that supply chain risk management is a mission-driven process where the major objective of the supply chain is the creation of customer value. The theory is based on the existence of a focal unit. The supply chain can contribute to this major objective by fulfilling the perfect order objectives: on time delivery, order completeness, order correctness, and damage/defect free. The performance measurement tool that is used in the project is the AHP (Analytical Hierarchy Process). Step one in the AHP process is assessment of the criticalities affecting these objectives. Step two is a quantitative evaluation of the importance of each objective. In step three there is an assessment of the weights for the objectives. Five supply chain areas were presented: transport/distribution, manufacturing, order cycle, warehousing, and procurement. Each of those five areas is then linked to the four perfect order objectives.[82]

Sheffi (2005) stresses that the vulnerability in the supply chain has increased generally, using the Albuquerque accident as an illustrative example. Sheffi suggests a division of the supply into three different parts: the *inbound* or supply side, the internal processes or *conversion*

[82] The research project has later also been presented in a journal article: Gaudenzi, B. & Borghesi, A. (2006) "Managing risks in the supply chain using the AHP method". *International Journal of Logistics Management.*

part, and the *outbound* or customer-facing side. He also points to the increased attention that has to be paid to *intentional disruptions*, especially after the September 11 tragedy and the growth of international terrorism.

Peck (2005) presents in her article "Drivers of supply chain vulnerability: an integrated framework" the findings of a cross-sector empirical study of the sources and drivers of supply chain vulnerability in today's networked world. Of special interest here is an integrated multi-level model, of the supply chain as an adaptive system, with four different levels (p. 218):

- Level 1 – value stream/product or process
- Level 2 – assets and infrastructure dependencies
- Level 3 – organisations and inter-organisational networks
- Level 4 – the environment.

The model with its four levels offers an interesting possibility to analyse the vulnerability in a supply chain in a systematic way.

It is also interesting that the author in the end of the article argues that slack is a necessity for a resilient supply chain: *".. no supply chain strategy is ever likely to be risk-free, and no system, however well managed, is invulnerable. Therefore, it seems that slack in the system, whether in the form of inventory, capacity, capability and even time, plus constant awareness and vigilance are needed if supply chains are to become and remain truly resistant"* (Peck, 2005, p. 255).

In her article "Reconciling supply chain vulnerability, risk and supply chain management" (Peck, 2006) Helen Peck starts with an examination of the concept supply chain and then gives an up-to-date overview of supply chain vulnerability, risk and supply chain management and an analysis of the relationships between those three.

5.4.2 ARM – a risk management method for physical flows[83]

The book Säkra företagets flöden! (Secure the flows of the company!) (1999) treats the ARM-method. The ARM-method is a risk analysis method that has developed mainly from the everyday handling of flow-related risks in the process industry, and not from theory.

Background
The method was originally developed by Ingemar Grahn and his risk management team at AvestaSheffield, a big producer of speciality steel. The steel industry is a process industry where even minor disruptions in the flow can have severe consequences in a supply chain perspective. In the model, the negative consequences are measured by the help of lost production weeks, and probability by a scale with only a few alternatives. Special interest is paid to the upstream and downstream consequences of a disruption. Based on the ARM-method, a software package called SW.IRMA has been developed.

The main objective of this method is to "protect the operations of the company and secure the result by showing and describing the most serious risks of disruptions – in time and money – in the business". The analysis is normally carried out at the request of management. The method offers a suggestion for work procedures for the risk management effort. The work procedure can be divided into the following five risk analysis steps:

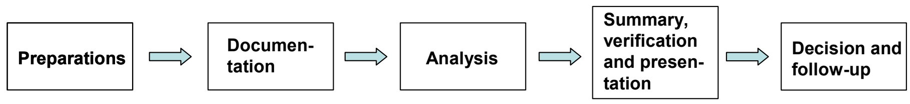

Figure 5.10: Risk analysis steps according to the ARM method (Based on "Säkra företagets flöden!", pp. 32-34).

[83] *Säkra företagets flöden! (Secure the flows of the company!)* (1999). Chapter 3.

Preparations
In order to increase the understanding and create acceptance among all parties for the work that is to be carried out, the management or the person with the main responsibility must communicate that a study is being initiated, and the scope of the study. In this initial phase a general schedule is also created.

Documentation for the analysis
The phenomena to be analysed are complex, and therefore different kinds of documentation are needed. The documentation illustrates the real difficulties and identifies the concealed problems in the company. Everything from spontaneous and temporary observations to systematic registration and accurate statistics of e.g. incidents, disruptions and delays are documented. A great amount of the information can be gathered from regular company sources, but in many cases they must be complemented by interviews.

The analysis
To a large extent, the analysis is focused on understanding how the different flows in the company can be disturbed. The understanding of technical and logistical connections is fundamental also when it comes to finding effectively preventive and damage-limiting measures. The analysis according to the ARM method is carried out within three fields:

- risks of disruptions in the company's own production machinery, including the risk of fire damage;
- risks of disturbances and disruptions in regular supply systems; and
- risks of disruptions in the supply of other external resources.

5.5 DISTRIBUTION CHANNEL RISK MANAGEMENT DEVELOPMENT

Over time, different risk management strategies and methods have been used to handle the development of distribution channels. Here this development will be described with the help of two dimensions: one is *time strategy* and the other is *resource base strategy*. The time strategy could either be *reactive*, *proactive* or some mixture of both. The resource base could either be *physical surplus*, *information systems* or some mixture of both.

Three variants of the development over time of the physical distribution channel can be identified: *step-wise chain*, *logistical chain* and *supply chain*. Risk management in each of those three variants will now be discussed. In the step-wise chain the risk management "area" is local, the time strategy is reactive and the resource base is physical surplus like buffer stocks. This type of risk management will be called *transportation/ warehouse risk management*. In the logistical chain, the area treated is the area from first tier supplier to first tier customer. Risk management is here called *logistics risks management* and is mainly using a reactive time strategy and a physical surplus base. Finally, the supply chain risk management is described. Here the area of the supply chain is at least three links in the chain but it could be more – even the whole supply chain. The time strategy here tends to be more proactive than reactive, and the resource base strategy based more on information systems than on physical surplus. This type of risk management will be called *supply chain risk management*.

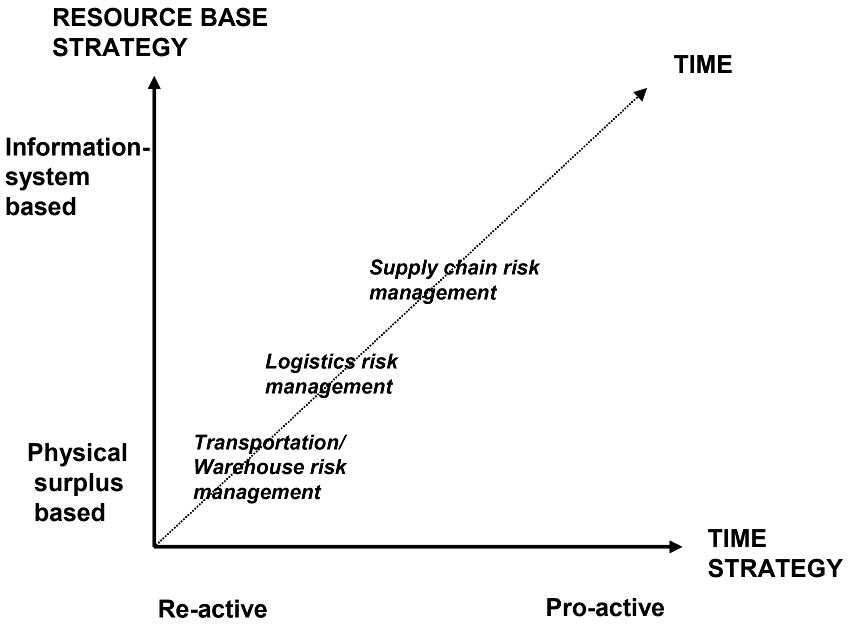

Figure 5.11: Distribution channel risk management development

5.6 SUPPLY CHAIN RISK MANAGEMENT CHARACTERISTICS

Supply chain risk management aims at identifying the potential areas of risk and implementing appropriate actions to contain that risk. One definition of risk management was presented at the beginning of this chapter in section 5.1 (Paulsson, 2004). Another definition is *"the identification and management of risks within the supply chain and risks external to it through a co-ordinated approach amongst supply chain members in order to reduce supply chain vulnerability as a whole"* (Christopher et al., 2002, p. 38).

The main objectives of supply chain risk management are:

- to maintain the supply and continuous availability of a product;
- to increase the supply chain's ability to cope with disruptions in the supply chain of products if necessary;
- to avoid possible domino effects throughout the chain; and

- to make the supply chain more resilient to disruptions.[84]

Implementing supply chainwide risk management is not a simple task. Often it is difficult already to assess risks at a supplier's supplier, and it becomes less practical and more extensive to analyse the exposure further on in the chain, both up- and downstream. Therefore all parties involved must make information about their own situation available to the others. When assessing risk exposure, the company must highlight not only direct risks affecting the operation, such as the loss of raw material or process capacity, but also the potential causes of those risks throughout the supply chain.

To ensure that supply chain risk management is practiced in a structured way throughout the supply chain, it is necessary to define and communicate a risk strategy that establishes the general rules and procedures for the risk handling. This strategy enables a common understanding of risk and risk management for the parties involved. Such a common understanding is particularly important in global supply chains whose members may be subject to different national risk management regulations and might hold different views concerning the relevance of communicating risks to supply chain partners.[85]

Another purpose of the strategy is to provide a guideline for the risk management process by defining a number of basic principles. These principles are:

- supply chain risk management requires close co-operation among all partners;
- risk identification is a continuous procedure in all firms;
- an open communication of the identified risks is vital for supply chain performance;
- if possible, risk should be insured in a cost-efficient way; and
- the remaining risks must be actively monitored.[86]

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[84] Christopher et al. (2002) *Supply Chain Vulnerability*, pp. 38-39.

[85] Kajüter (2003) *"Risk Management in Supply Chains"*. Chapter in Seuring et al., 2003, p. 327.

[86] Kajüter (2003) *"Risk Management in Supply Chains"*. Chapter in Seuring et al., 2003, p. 328.

5.7 STRATEGIES AND METHODS FOR MANAGING SUPPLY CHAIN RISKS

In the article "Supply Chain Risk Management: Outlining an Agenda for Future Research", Jüttner et al. (2003) present different strategies for mitigating risks. The discussion takes its starting point in Miller (1992) who, from a single organization view, distinguishes five generic risk strategies that companies could undertake in order to mitigate risks. Of those, according to Jüttner et al. (2003), four are adaptable to a supply chain context, namely: avoidance, control, co-operation, and flexibility.

From a supply chain perspective, *avoidance* can be related to products/geographical markets and/or supplier and customer organisations. A company could drop specific products, suppliers or geographical markets if they are regarded as too risky. Another strategy is to seek to *control* contingencies from the various risk sources, rather than passively treat the uncertainties as constraints within which the company must operate. Examples include vertical integration, increased stockpiling and the use of buffer inventory. Maintaining excess capacity in production, storage, handling and/or transport are others. Still another one is imposing contractual requirements on suppliers. Another strategy is *co-operative* responses that involve joint agreements as a means of achieving uncertainty reduction. The aim of the joint efforts could e.g. be to increase visibility in the supply chain and the sharing of risk-related information. Finally, *flexibility* is also mentioned as a risk mitigating strategy. Flexibility leaves the predictability of factors unchanged but increases responsiveness. One example of this is postponement.[87]

In the paper "Supply Chain Risks and Risk Sharing Instruments – An Illustration from the Telecommunication Industry" by Lindroth & Norrman (2001), presented at the LRN annual conference 2001, the authors present twelve different examples of categories for risk handling

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[87] Jüttner et al. (2003) "Supply Chain Risk Management: Outlining an Agenda for Future Research", *International Journal of Logistics: Research and Applications*, pp. 206-208.

methods, especially those with a focus on contract relations (Figure 5.12).

← Contracts →

Trust	Information	Insurance products	Futures & Options Instruments	Sourcing Strategies	Allocation Rules	Inventory	Joint Investments	Buy back Agreements	Flexibility	Minimum Purchase Commitment	Pricing
	•Advanced demand information •RTE •Collaborative forecasting •Collaborative planning			•Single sourcing •Dual sourcing •Multiple sourcing •Factory locations	•Allocation of limited capacity to buyers •Even allocation •"Turn and earn"	•Safety stock •RMI •JMI •VMI •Inventory pooling •Product standardisation	•Joint product development •Investment in equipment •Limited Life Consortium Company •Acquisition of shares in equity	•Buy back •Back up agreements •Return policies	•RHFI •Quantity flex •Time flex •Capacity flex •"Pay to delay" •"Take or pay" •Relational contracts	•Min total Q over horizon •Min total Q per period •Min value •Min of product family, not specific product	•Quantity discount •Two tariffs •Two tier pricing •Franchise fee •Price windows

Figure 5.12: Examples of categories for supply chain risk handling methods (Lindroth & Norrman, 2001, in Proceedings of the LRN 6th Annual Conference, Edinburgh, pp. 297-303).

6 ***EMPIRICAL MATERIAL***

The aim of this chapter is to create an empirical base, complementing the theoretical base created in the three previous chapters. All the findings, will be summed up in the next chapter, Chapter 7.

6.1 INTRODUCTION

The empirical base is created through the presentation of two different groups of cases and commenting on them. The first group – the Marsh cases – represents cases (except one) where there has been a disruption with severe negative consequences. In the second group – the mini-cases – the focus is not on any actual disruption but on how the company experiences and handles its disruption risks generally.

6.2 MARSH CASES

The method used here is a condensation of case descriptions from a Master's thesis by Artebrant, Jönsson & Nordhemmer (2004). There are four Marsh cases. The first three cases are based on real disturbances/accidents (the authors are using the concept *disturbance* and not *disruption*) and the fourth one is based on a real professional risk analysis conducted by external risk consultants. The names of the companies are changed, and the description of each company is generally managed so that it will not be possible to identify the company.

6.2.1 The Andersson Case

Company – Products – Production – Supply – Demand
Andersson is a Danish company designing, producing and selling capital goods for homes. The products are carefully designed and sold in sets of products where the different individual products have their design adapted to the other products in the set. The company has no production of its own; all production is sub-contracted to different suppliers, each supplier only producing a part of a set. The three main suppliers are Sun A/S, Water A/S, and Wind A/S. Andersson is selling their products on several foreign markets as well as their home market, Denmark. The company had recently entered the UK market.

Risk exposure
The fact that each supplier only produces a part of the set reduces the risk of design theft but increases the risks concerning disturbances in the flow. Each supplier could become a bottleneck, and there is little flexibility within the supply chain. The products have a relatively low degree of complexity, but production is dependent upon a skilled working staff at the supplier. The company does not apply the JIT idea; it allows itself to have buffer stocks.

Risk management – Risk handling
Andersson takes little interest in risk management and supply chain management issues, and has no business continuity plan. If there is a disturbance, actions have to be improvised. The company has a good relation to its suppliers, and business partners are involved in their long-range planning process. The company has a cost-efficient insurance solution but few other strategies for handling its risks.

Table 6.1: Case Andersson; Summary of strengths and weaknesses (Artebrant et al. 2004, p. 120).

ANDERSSON	
Strengths	**Weaknesses**
Risk exposure	
- Low degree of complexity in the supply chain - Low time-dependence	- Dependence towards the suppliers - Little flexibility within the supply chain
Risk management	
- Good relationship with the suppliers - Business partners involvement in the long term planning	- Low prioritisation of risk management and SCRM - No existence of Business Continuity Management (BCM)
Risk handling	
- Good efficient insurance solution - The extent of the property insurance	- Few other strategies for handling risks - Short indemnity period

The disturbance and its consequences

A fire at Sun A/S destroyed their lacquering department completely and stopped deliveries. Since Andersson only sold and delivered full sets, this meant considerable delays in deliveries. It took quite a while for Andersson to find replacement production, and when they finally did they chose to focus on producing as much as possible instead of producing to complete sets of products. This caused more delays. All markets received the same priority, which probably also increased the negative consequences. The company could further not tell their customers when deliveries were possible. The end effects were increased costs and lost sales, but more seriously, lost market shares and lost credibility.

6.2.2 **The Nilsson case**

Company – Products – Production – Supply - Demand

Nilsson is a Swedish steel producing company selling special steel qualities to their customers. Production is complex, includes the handling of dangerous material, and has long lead times. Most of the production is in-house but some parts have been outsourced. JIT principles are not used except for a few input areas like hydrogen gas where there is a constant inbound flow. Hydrogen gas is bought from a supplier who has built a hydrogen factory just a few hundred meters away from the Nilsson factory, delivering the gas in a special pipeline. The hydrogen is single sourced. Nilsson has managed to maintain and even strengthen their position in the market in recent years. Nilsson has close relations to many of their customers, especially to those who have JIT deliveries, because they are producing special steel qualities upon which their customers are dependent. Nilsson is especially dependant upon one large customer who uses JIT deliveries. Nilsson keeps an inventory of finished goods to be able to fulfil its JIT deliveries.

Risk exposure
Nilsson's production uses potentially dangerous material, which makes production risky. On the supply side Nilsson is dependent upon a constant flow of hydrogen gas as well as some other inputs. Those inputs are very vulnerable since they are single sourced, there is no alternative way to be supplied, and no buffer stocks exist. The risks on the market side are mainly that JIT customers are very dependent on reliable deliveries, and failures in this aspect can easily cause the customer to change supplier.

Risk management – Risk handling
Nilsson has a substantial insurance coverage including both property insurance and a business disturbance insurance. The indemnity period of the latter is short, however. The company has few other risk management strategies than insurance.

Table 6.2: Case Nilsson; Summary of strengths and weaknesses (Artebrant et al. 2004, p. 126).

NILSSON	
Strengths	**Weaknesses**
Risk exposure	
- Existence of inventories - Special features of the products	- Time dependence towards critical suppliers - Vulnerabilities within the production
Risk management	
- Efforts to somewhat improve the risk management - Alternatives to some suppliers	- No existence of BCM - Little awareness of SCRM
Risk handling	
- Wide extent of insurance solutions - Including suppliers in the business interruption policy	- Few other strategies for handling risks - Short indemnity period

The disturbance and its consequences
A mistake by some workers doing maintenance work at the hydrogen supplier's plant caused an explosion in the hydrogen factory and destroyed it totally. Production at Nilsson had to stop for a month and it took several months before it was back to normal again. Although Nilsson, with the help of their inventory of finished goods, managed to maintain deliveries to their most important customer, this customer chose to end the business relation. Other deliveries were severely delayed. Sale and market shares were lost. But Nilsson was rather well financially compensated for the disturbance through the insurances, although the compensation might have been somewhat larger if the indemnity period had been longer.

6.2.3 <u>The Olsson case</u>

Company – Products – Production – Supply – Demand
Olsson is producing office furniture. All manufacturing is outsourced, and the production therefore has the character of assembly of parts into a complete piece of furniture, and that is not very complex. Production is streamlined with low level of inventories and short lead time. A high degree of production made-to-order exists. Frequent applying of the idea

of JIT leads to a high degree of interdependence with the suppliers and their skilled personnel. Single sourcing with several of its suppliers. For manufacturing a mould is often needed. This mould is often produced in only one copy by Olsson and then lent to the supplier. Only one production unit exists and production and storage are situated in the same building. The company has many customers. The customers are often loyal to the Olsson brand.

Risk exposure
The fact that there is only one factory and that production and storage are in the same building is of course a severe risk especially as furniture material easily catches fire. The virtual non-existence of buffer stocks creates great dependencies with other links in the chain. A disturbance can easily spread from one link to another. The existence of just one copy of each mould, and the fact that it takes some time to produce a new one, underline those risks further. Loyalty to the Olsson brand is quite high, but there are several competitors with a similar product assortment on the market and delays in deliveries could mean that the customer switches to another supplier.

Risk management – Risk handling
Risk management focus is very much on preventing fire, and within this area the company has very good risk handling routines including a business continuity plan about how to react in case of fire. Other possible risks are mainly neglected. Olsson relies heavily on insurance solutions. They have a substantial insurance coverage with a focus on fire. They also have a business disturbance policy. Important business partners are involved in the long-range planning of the company. Besides this, they have few other risk handling strategies.

Table 6.3: Case Olsson; Summary of strengths and weaknesses (Artebrant et al. 2004, p. 132).

OLSSON	
Strengths	**Weaknesses**
Risk exposure	
- Customers loyal to the trade mark - Large and reliable suppliers	- Almost no inventories - High level of time-, relationship- and functional dependence
Risk management	
- Some procedures concerning BCM - Business partners involvement in the long term planning	- Too much confidence in current risk management - Low evaluation of critical suppliers
Risk handling	
- Substantial insurance coverage - The including of both suppliers and customers in the business interruption policy	- Few other strategies besides handling the risk of fire

The disturbance and its consequences
One of the most important suppliers to Olsson is Pebbles. The components delivered from this supplier are single sourced. On one occasion Pebbles had a fire which destroyed a mould owned by Olsson. Fortunately this mould was not in use at that moment. If some of the other moulds at Pebbles had been destroyed, the consequences could have been severe. Now they were limited. Olsson also had very good help from their business continuity plan, which enabled them to rapidly inform their customers and the media about the expected consequences of the fire.

6.2.4 The Persson case

In this case no disturbance has taken place, but the company has felt a need to get a better understanding of the risk situation. They therefore engaged Marsh to do a risk analysis of the company, and the case description below is mainly based on that risk analysis.

Company – Products – Production – Supply – Demand
Persson is a company producing and selling industrial doors. It has production units in several countries. Production is flow oriented with no buffer stocks and based on JIT principles. Most production is kept in-house. Production of panel B which will be dominating the total production in a few years time is only taking place in one of the factories – the factory in Holland. Production is based on made-to-order. Dangerous chemicals are used in the production process. Most suppliers deliver material of a low degree of refinement, and dual sourcing is practised but one supplier is very critical since that supplier delivers an important component and that component is single-sourced. Persson has long-term relations with most of its suppliers. Customers are mainly within the building industry. Persson has many customers who normally order rather small quantities. Persson offers their customers service operations, like repairs, maintenance and upgrading, which are very extensive compared to their competitors. Competition on the market is high.

Risk exposure
The efficient production, with its lack of buffers, means high risk exposure to disturbances. The high degree of in-house production also means that there are more internal risks. The factories are also exposed to external risks like flooding. Dangerous chemicals are used in the production process. Since much of the total value adding takes place in-house, the total dependency on the suppliers is moderate, but there is one critical component that is single sourced. Total market demand is closely linked to factors affecting the total volume in the building industry. Market competition is high, and a customer could easily change to another supplier of industrial doors. The extensive service offerings, however, are a competitive advantage for the company.

Risk management – Risk handling
Persson is aware of the high risks caused by a high degree of JIT and the lack of buffer stocks, but the company has chosen to accept those risks. The company is also aware of the risks arising from the use of dangerous chemicals in production. Persson is practising BCM, and has identified the risks within production and developed a disaster recovery plan that

includes evacuation procedures for the personnel. Sprinklers are also installed in most facilities. Persson is aware of the existence of a critical, single-sourced component, but the contingency plan does not cover alternatives in case of a disturbance at the critical supplier. The company has substantial insurance coverage but potential flooding in Holland is not included. There is also a business interruption insurance with a reasonable business disturbance value (raised as a consequence of the risk analysis) and a long indemnity period.

Table 6.4: Case Persson; Summary of strengths and weaknesses (Artebrant et al. 2004, p. 138).

<table>
<tr><th colspan="2">PERSSON</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><th colspan="2">Risk exposure</th></tr>
<tr><td>- Low dependence on outsourced functions
- Good service operations to attract customers</td><td>- Process optimisation in order to reduce costs
- High risks regarding both business disturbance and property</td></tr>
<tr><th colspan="2">Risk management</th></tr>
<tr><td>- High awareness of risk management
- Implemented risk management through for example BCM</td><td>- No alternative production for panel B
- Too large internal focus</td></tr>
<tr><th colspan="2">Risk handling</th></tr>
<tr><td>- Good correlation between the need and the insurances
- Awareness of other strategies for risk handling besides insurances</td><td>- Deliberate choices not to reduce risks
- Expensive insurance solution</td></tr>
</table>

6.2.5 Commenting on the Marsh cases

- Good awareness of internal risks, especially risks to properties like buildings and machinery, especially fire risks.
- The property risks are handled through traditional property insurance solutions.
- Less awareness of risks linked to disturbances elsewhere in the supply chain than internally.
- Two of the companies are using buffer stocks as a risk-reducing alternative.

- The risks linked to outsourcing are not made clear.
- Especially risks caused by single sourcing tend to be underestimated.
- Several of the companies have long and close relationships with their key suppliers and include them in the planning process, but the companies do not seem to realize that a close relationship cannot compensate for e.g. a fire totally destroying the production capabilities at the supplier. If the supplier does not have any production capacity then he cannot produce – close relations cannot change that fact.
- The case companies have business disturbance insurances, but the disturbance value tends to be too low and the indemnity period too short.
- In half of the cases, responsibility issues are unclear and there is no planning. Actions are based on improvisation when there is a disturbance.
- In half of the cases a written business continuity plan existed but did not include all the risks.
- In one case the risk of design theft has been considered more important than the risk of disturbances in the supply chain, which has delimited the possibilities to handle the disturbance risks.

6.3 MINI-CASES

6.3.1 **Selection principles**

A total of six interviews have been conducted within four different companies during the last part of 2003 and first quarter of 2004. Each interview has taken about 1 hour, and all interviews except one have been recorded. A simple interview guide consisting of four figures and eight questions has been presented to the interviewee at the beginning of the interview (see Appendix 2). Focus has been on *disruption* risks in the supply chain flow, consequences of such disruptions and how those risks are handled.

Criteria for the selection of companies and individuals to interview are:

- to cover the whole supply chain i.e. both supply, internal and demand part;
- to choose companies from different industries;
- to choose companies that are in the forefront within the area of supply chain risk management;
- to choose persons who have been reflecting on supply chain risk management issues; and
- to select persons on different levels and with different responsibilities related to supply chain risk management.

And the categories of persons to interview were:

- purchasing managers, production managers and sales/marketing managers (responsibility for a special function);
- transportation managers and the like (responsibility for a certain part of the supply chain); and
- risk managers (total responsibility for risk issues).

6.3.2 Case descriptions

All the companies sell their products worldwide, and components and raw materials are bought from all over the world although Europe tends to dominate.

Company A
Company A is a mechanical engineering company with a production that can be characterized as assembly of components. The final products are customized for a certain customer in a certain market and adapted to the laws and regulations in that country as well as the wishes of the individual customer. Only production-to-customer order. Very small inbound buffer stocks and no outbound. Company A has not been outsourcing to any great extent and is still doing a large part of the total value adding itself. It has several factories spread all over the world. The company has no agreements with their suppliers that give them full compensation for possible disruptions. They have therefore to identify and analyse possible risks in the supply flows themselves. One way is

through quality assurance of the suppliers of critical components. Risks in the production are handled by traditional methods like fire equipment and insurances. If there is a protracted production break in one factory, production can partly be taken over by other factories elsewhere within the company. The customer can often accept a certain delay, and if it cannot there is always a possibility to offer a slightly different product. No special disruption risks seem to exist within distribution. Demand is affected by the activity in the world economy, but the basic trend is a moderate and steady increase in demand.

Company B
Company B is also a mechanical engineering company with a production that can be characterized as assembly of components. Only production-to-customer order. Very small inbound buffer stocks and no outbound. All products are unique, i.e. produced according to the specification of a certain customer. The company has a number of factories in different parts of the world. Some of the machines that are used in production are quite specialised and advanced. Outsourcing has taken place. Close co-operation (partnership) with the suppliers of critical components but no contracts that fully cover the negative consequences of disruptions. Quality certification like ISO 14000 is required by the critical component suppliers. Delays in inbound deliveries can partly be handled through re-planning and overtime work in production. Production risks are handled by traditional methods. The company keeps, as backup planning, a register of which products can be produced in which machine and where, so that in case of production problems in one factory they quickly and easily can create a new global production planning. Distribution risks exist since each delivered product is unique and it takes some time to produce a new one. There is a steady, moderate increase in demand.

Company C
Also company C is a mechanical engineering company. It is producing components for other mechanical engineering companies, and its product is a critical component for their customers. Outsourcing has been practised. Special agreements giving full compensation for disruptions do not exist, either on the supply side or on the demand side.

The change of some of the main suppliers from Europe to the Far East has made it necessary to also move the quality check of the supplied components to the Far East. Several factories spread over the world. Very small buffer stocks except for the spare parts business, where some stocks exist out in the different distribution warehouses. The biggest experienced disruption risk is that supplied components do not maintain the required quality standard and therefore cannot be used in production. A failure of the company to deliver would hit their customers very hard, because it would be difficult for them to find another supplier and they would thus not be able to complete their products. Demand is affected by the activity in the world economy, and the basic trend is a moderate but steady increase in demand.

Company D

Company D, finally, is also a mechanical engineering company producing and selling machinery and material to be used by that machinery. Each piece of machinery is produced according to the individual demand of that customer, i.e. production-to-customer order. No stocks of ready-made products and only small stocks of components. Several factories around the world. A number of critical components. Close co-operation with the most important suppliers but no contracts that fully compensate for disruptions. On the other hand, the company does not give any guarantees to its customers about full coverage of their negative effects of a disruption in their supply. The same is the case for inbound and outbound transports. Standard rules are valid for the agreements with the logistics providers. Those standard rules usually only cover a small part of the negative consequences of a disruption. The company only contracts large logistics providers like Danzas and DHL, which can always put in spare capacity if anything should happen. Transport insurance is always taken for each transport. A disruption is in most cases taken care of before it hits the customer. This means that a disruption normally does not affect revenues negatively, only the costs and perhaps also the capital bound.

6.3.3 <u>**Commenting on the mini-cases**</u>

- For all the mini-case companies the basic trend is steady, moderate growth.
- All the companies are mechanical engineering companies.
- All the companies produce customized products.
- Some of the companies had a stock of finished products – others not.
- All the companies are aware of the disruption risks.
- In all the companies it was possible, in case there was a production breakdown in one factory, to transfer production to another factory.
- The four companies are basically using standard contracts in relation to their supply chain partners, but since standard contracts are used both on the supply side and the demand side there is a certain balance. On one hand, the company is not compensated fully for the negative consequences of a disruption in their supply deliveries, but on the other hand the company does not have to fully compensate their customers for the harm that missed deliveries might cause.
- The agreements with the logistics service providers are based on standard contracts which give very little compensation for the negative supply chain consequences of a transport disruption.
- Since the compensation from a supplier for a delay is rather low the company has to handle the risks in other ways than through contracts. One way is to only buy from suppliers that have a quality certification like ISO 14000. Another one is that the company itself conducts a quality check of the supplier.

6.4 CONCLUDING REMARKS

The findings from this chapter as well as from the previous three chapters will be summed up and commented upon in the next chapter, chapter 7.

7 STATE OF THE ART AND NEED FOR RESEARCH

The aim of this chapter is to sum up the knowledge, in the form of the theories and models presented in Chapters 3 to 5 and the empirical experiences from Chapter 6, about disruption risks in supply chains and related areas. At the end of the chapter, the need for more research, specifically on how to manage supply chain disruption risks, is discussed.

7.1 INTRODUCTION

This study has two objectives, which were presented in section 1.2.2. The first objective is *"to identify, structure and summarize the state of the art on supply chain disruption risks"*. In Chapters 3 to 5, theories within different relevant areas have been discerned, and in Chapter 6 empirical experiences from a couple of case studies have been presented. These findings will now be summarized and reflected upon. They will also be used as a basis for formulating needs for more knowledge – both general knowledge and specifically supply chain risk management theories and models. Thereby, objective number one of the study will be fulfilled.

The second objective of the study is *"to develop and test a generic, aggregate model for managing disruption risks in supply chains"*. This is treated in Chapters 8 and 9 and will take its starting point from the identified need for more research.

7.2 CURRENT KNOWLEDGE

7.2.1 Empirical experiences

In the *Marsh cases* the focus was very much on internal risks in production, especially risks caused by fire, and those risks were covered by traditional property insurances. Risks related to events outside the company premises tended to be given less attention. The full consequences of single sourcing of critical components and material in combination with JIT deliveries and reduced or even eliminated buffers were not realised. The existence of clear dedication of responsibility for risk issues to some specific person or department in the organisation differed greatly, and so did the existence and scope of written business continuity plans. Especially in the Andersson case, the strategy seemed to be: Start bothering if and when there is a disruption.

In the *mini-cases,* which were all mechanical engineering companies producing customized products, only one had a stock of finished products. The companies were aware of the disruption risks, and since they all had several production units they had the possibility to transfer production, at least partly, to another factory, if there was a production breakdown in one of the factories. The four companies basically used standard contracts in relation to their supply chain partners. Standard contracts give limited compensation for delays, but since they used standard contracts on both the supply side and the demand side, there was a certain balance. The fact that compensation for a delay was low meant that the companies had to handle the risks in other ways than through contracts. One such way was to buy only from suppliers that had a quality certification like ISO 14000. Another was to themselves conduct the quality checks of their suppliers.

In all the presented cases there were supply chain flow-related risks, but the risk sources could be of different kinds, and the disruptions could have more or less serious consequences. The way the risks were handled also differed considerably, as well as the degree to which the company was acting proactively. The rapidly increased importance of integration risks in the supply chain flow did not seem to have been matched by an equal increase in awareness, and definitely not in risk handling actions and risk management. There still seemed to be much focus on separate, limited risks, and they were handled with traditional risk handling methods. This behaviour was also supported by the tendency to split the risk responsibility between different individuals and departments – no one really had the responsibility for the integrative risks, since they tended to cross-existing organizational boundaries.

7.2.2 Theoretical knowledge

Risk and risk management

Risk is a construct with many meanings and also a big variance in the meanings (Risk: Analysis, Perception and Management, 1992; Mattson, 2000; Grimvall et al., 2003). It seems to be of relevance in more or less all human activity, and as can be illustrated by the "circle of risk" (Hamilton, 1996) in more or less all organizational activities as well. Different definitions of risk exist (Risk: Analysis, Perception and Management, 1992; Hamilton, 1996; Kaplan, 1997; Deloach, 2000), but they tend to have certain common characteristics that are well covered by Kaplan (1997) with his three questions; What can happen? How likely is it, and What are the consequences? To be able to give meaningful answers to those three questions, we have to be very precise about in what sense we use the concept *risk*, and we also need to provide a description of the "risk setting" in general.

The scope of risk can differ from narrow to wide, from precise to vague. Vagueness can also be linked to *risk perception* (Risk: Analysis, Perception and Management, 1992) – the fact that different individuals can perceive the same risk very differently (Renn, 1998; Pidgeon, 1998). This is an important aspect particularly for *public risks* (Viscusi, 1998). *Human error* (Reason, 1990) is one important *risk source*, *nature* is another and *antagonists* a third. Some risks have only a negative side (static risks) while others have both a negative and a positive side (dynamic risks). *Risk assessment* (Risk: Analysis, Perception and Management, 1992) is necessary to be able to take suitable actions – that is, to manage the risks.

No human activity can be considered to be totally risk-free, but the risk situation can often be changed in one way or another and thus affect the size and character of the risk. How to do it is treated in *risk management* (Risk: Analysis, Perception and Management, 1992; Borge, 2001), which by Borge (2001) has been described as taking deliberate actions to shift the odds in your favour. Risk management is often conducted as a process with a number of steps (IEC, 1995). One important part of this process is *risk analysis,* which could be based on different methods. They can be divided into three main groups: quantitative, qualitative and semi-quantitative methods (Nilsson, 2003). One or more risk management *strategies* (Rasmussen & Svedung, 2000; Borge, 2001) can guide the risk management process. Once you have collected the information, then it is time to decide – which is dealt with in *decision theory*.

Managing risks in organizations

Organizational risks (Reason, 1997) often differ from other risks in the sense that they are often linked to some opportunity – otherwise the organization would not expose itself to that risk. Business decisions are further often taken under *time-pressure* and the risk situation is often *complex* since it has to be taken into account what can happen in other parts of the organization and in other parts of the supply chain. Of special interest in this study are the disruption risks, and they tend generally to receive increasing attention (Brannen & Cummings, 2005). A special theoretical area called "business continuity management (BCM)" has developed to deal with the questions of how to prevent serious disruptions and how to get back to normal business procedures again as quickly as possible (if they in fact exist) (Hiles & Barnes, 2001). It is claimed both within BCM and in other connections that risk management in an organization needs to become more holistic and integrated, and one concept here is "enterprise-wide risk management (Deloach, 2001)".

Supply chain management

To be able to consume, four utilities have to exist; *form utility*, *possession utility*, *place utility* and *time utility.* Logistics can be described as the art of finding the best alternative for the creation of the needed place and time utilities (Lambert, Stock & Ellram, 1998). The basic mission of supply chain management then, which has its origin in logistics, which in turn has developed from transportation and warehousing, is to, besides the creation of place utility and time utility, also assist in the creation of form utility and possession utility (Cooper, Lambert & Pagh, 1997). By using the concept of *supply chain* (Beamon, 1998; Aitken, 1998), we indicate that our interest is not in the individual company/link but in the chain of links/companies. *Supply chain management* then is an integrating philosophy to manage the total flow of a supply chain from first supplier to ultimate customer (Coyle, Bardi & Langley, 1996; Cooper et al., 1997; Christopher, 1998; Paulsson, Nilsson & Tryggestad, 2000), and the aim is to deliver superior customer value at less cost to the supply chain as a whole (Christopher, 1998).

Competition is a constantly present driver for increased efficiency and effectiveness in the supply chain (Christopher, 1998). A number of *actions* are taken to deal with new competitive situations. Examples of such actions or trends are; agility, higher delivery service, customized products, shorter lead times, leanness, outsourcing, single sourcing, shorter product life cycle and shorter time-to-market. But those actions have also affected the risks in the supply chain. This has changed the risk "picture" and in many cases increased the risks as well (Zsidisin & Ellram, 1999; Ritchie & Brindley, 2000).

Supply chain risk

A search and review of journal articles (Paulsson, 2004) showed that *supply chain risk* is an area of increasing importance with a growing production of knowledge. The focus was on disruption risks, and the articles showed that there is a spectrum of possible events that might cause a disruption. The disruption risks could be everything from ordinary disturbances (Boronico & Bland, 1997; Owens & Levary, 2002) to international diseases and to terrorism (Sheffi, 2001; Martha & Sunil, 2002; Lee & Wolfe, 2003). The supply chain risks need to be *structured* in one way or another (Johnson 2001, Peck et al., 2003; Gaudenzi ,2005). The risks also need to be *analysed* and *evaluated* (Gaudenzi, 2005; Kleindorfer & Saad, 2005), and they need to be *dealt* *with* (Johnson, 2001; Peck et al., 2003, Kleindorfer & Van Wassenhove, 2004; Gaudenzi 2005; Kleindorfer & Saad 2005). Finally, it must be stressed that different researchers include more or less within the concept "supply chain risks" (Johnson, 2001; Peck et al., 2003; Kleindorfer & Van Wassenhove, 2004; Kleindorfer & Saad, 2005).

Supply chain risk management

Particular interest in this study is paid to *supply chain risk management,* i.e. how to handle the flow risks in the supply chain. A first step is to identify the risk sources. Here Johnson (2001) stresses the importance of looking at both the supply side and the demand side, and Peck el al. (2003) propose five different risk sources: environmental risk, supply risk, process risk, demand risk and control risk. Risk handling strategies and methods are treated by among others Lindroth & Norrman (2001) and Jüttner et al. (2003). The supply chain risk management *process* is dealt with by Kleindorfer & Saad (2005) and Asbjörnslett & Rasmussen (2005). They both present an overview, step-wise model to guide this process. Another process model is the ARM-method, presented in Säkra företagets flöden! (1999), which is a detailed step-wise model that has been in practical use for several years.

Findings

Risk and *risk management* seem to be theoretical areas within which there is solid knowledge within a number of applied fields. There could be rather large differences between the different fields, but within each there is a consensus about how to define, identify, assess and manage the risks. Risk management *in organizations* has of tradition mainly concentrated on individual, separate risks, and suitable methods for dealing with each risk have been developed. But an interest for integrative risks and collaborative risk handling has been raised over time, and theories covering such risks have now been developed. *Supply chain management,* which stresses integration between the different links in the chain, is a rather new but currently well-established theoretical area within which there exist a number of separate knowledge "pieces" as well as a core of established knowledge. Within the theoretical area of *supply chain risks,* separate and clearly definable risks are still very much in focus. However, an increasing interest can be noticed to study the risk consequences of the increased integration in today's society, not least in the supply chains.

Finally, *supply chain risk management* can be seen as a new, theoretical area under rapid development. Kajüter (2003) has summarized the state of the art concerning theory within supply chain risk management in the following way:

> *"To conclude, research in the area of managing risks in supply chains is still in its very early stages. From an empirical point of view, only a few exploratory case studies have been conducted to date. Most of them describe company-specific approaches to risk management from a purchasing perspective. Little empirical evidence exists on collaborative risk handling in supply chains, though. In addition, there is also a considerable lack of conceptual research providing a framework for interorganizational risk management in supply chains."*
> (Kajüter, 2003, "Risk Management in Supply Chains", in Seuring et al., p. 325)

The above was written in 2003. The production of a number of scientific articles, research reports and a few books from 2003 to 2006 has somewhat improved the theoretical knowledge situation, but not in any way radically changed it. It seems reasonable to describe the theoretical area of supply chain risk management as a promising area with several interesting "islands of theories" but yet without any common, solid foundation of basic concepts and models.

7.3 NEED FOR MORE RESEARCH

General needs

Within the risk area a number of different concepts, theories and models exist side by side. This makes the creation of a common stock of knowledge and comparisons of results more difficult. Kloman (2003, p. 2), commenting at an Enterprise Risk Management Conference, pointed out that *"Most of the speakers agreed that a 'common language' for risk* *is necessary but few reported any progress in reaching this goal"*. There is obviously today a lack of common risk theories and models.

"Compared to the stable conditions of the past, the present dynamic society brings with it some dramatic changes of the conditions of industrial risk management" (Rasmussen & Svedung, 2000, p. 10). Organisations, as well as society as a whole, will therefore in the future need to become more proactive (Rasmussen & Svedung, 2000). To be able to act more proactively *more knowledge is needed*.

This *gap between existing needs and existing knowledge* is accelerated by the rapid development of our modern society, because *"A very fast pace of change of technology is found at the operative level of society within all domains, such as transport, shipping, manufacturing and process industry. This pace of change is much faster than the pace of change presently in management structures"* (Rasmussen & Svedung, 2000, p. 10). Today the risk management methods in use are basically the traditional ones. But in the dynamic and integrated society of today with its new risks, those risk management actions need to be complemented and perhaps even replaced by new ones.

There is also *an increased potential to deal with the risks in new ways*. One example is by using the new information technology: *"On one hand, the present dynamic and competitive society requires new approaches to risk management. On the other hand, the rapid development of information technology offers new opportunities for designing effective decision support tools"* (Rasmussen & Svedung, 2000, p. 9). But to be able to exploit those possibilities fully and manage the supply chain risks more effectively and efficiently, *new risk management theories and models are needed.*

Needs within supply chain risk management

Looking specifically at the area of managing supply chain risks, it can be noted that in a world with increasingly integrated, complex, lean, global and changing supply chains, the need for generic supply chain risk management models has increased. And there is today, as was noticed earlier by Kajüter, "*a considerable lack of conceptual research providing a framework for interorganizational risk management* *focusing collaborative risk handling in supply chains"* (Kajüter, 2003, p. 325). Such generic models could have different scope, structure and ambition level, but that which seems to be especially important will now be discussed.

First of all the generic model ought to be *general,* i.e. useful in many different situations. This means that it ought to be able to include all kinds of disruptions. It is also convenient that the model is flexible and can be used in many different situations by companies, organisations and other stakeholders interested in supply chain flow risk issues.

Then the model ought to have a *pre-perspective* because it is before there is a disruption that the risk situation really can be affected, including its potentially negative consequences. And as Ramussen & Svedung (2000) pointed out there is an increasing need for preventive actions.

The model also needs to be able to include the *total supply chain* and not just two or three links, because the most important risks in the supply chain tend to be the risks following from highly integrated links in the chain, which means that a disruption in one link might spread to several subsequent links and might also create an escalating domino effect. And as Johnson (2001) pointed out, it is important to look at the risks that follow from the integration between the demand side and the supply side.

There is also a need for *assistance in finding new solutions.* Since we are living in a rapidly changing world, the risk situation is constantly changing and we therefore need to repeat our risk analyses frequently. Our present risk handling activities could easily become obsolete. Guidance about what main options are available and how they affect the risks could facilitate the work of managing the risks.

Finally, it should be possible to utilize the model *with limited efforts* in time and other resources. This means that it should be easy to understand and operate and from this follows that it needs to have limited size, a clear logic, and a consequent use of concepts. Supply chain risks can be very complex, but by using models based on criticality the considered complexity can be reduced. *Easy to use* also means that all the different negative consequences ought to be measured with the same scale, which should be one that everyone understands. That makes it easier to compare different risk situations and different risk handling alternatives. But also because supply chain risks not only tend to cross the borders between different links in the chain, they also tend to cross functional specialization borders. This means that managers from different functional areas like purchasing, production, finance, IT, HR, logistics and marketing need to come together with the risk specialists and discuss risk issues. The time they can spend on risk issues is limited, especially when it comes to top management.

So what seems to be especially important, in contributing to the diminishing of the present lack of theoretical frameworks within supply chain risk management, is to develop generic models that are *general, proactive*, that with *limited efforts* can give a "picture" of the supply chain flow risks in the *total supply chain*, and that can assist in *finding new solutions* to the main risk problems.

SECTION III

8 DEVELOPING THE DRISC MODEL

In this chapter the DRISC model is built up step by step. First some points of departure are given, and then the top structure for the DRISC model is developed. After that, the framework for description and analysis is examined and different partial models are developed. Then the same is done for the risk management process. Finally all the developed partial models are summed up and linked together into the complete DRISC model.

8.1 POINTS OF DEPARTURE FOR THE DRISC MODEL[88]

8.1.1 Choice of perspectives and focuses

A systems approach perspective

The systems approach can be described as a way of thinking about total systems and their components. According to Churchman (1968), systems are made up of sets of components that work together for the overall objective of the whole. The environment of the system is what lies outside the system and is made up of things and people that are "fixed" or "given" from the point of view of the system. The environment is something outside the control of the system, but it is also something that partially determines how the system performs.[89]

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[88] An earlier version of the DRISC model was presented in two different papers at the NOFOMA 2005 conference in Copenhagen. Paper 1: Paulsson, Ulf (2005a) *Developing a Supply Chain Flow Risk Model*. Paper 2: Paulsson, Ulf (2005b) *Valuation of Supply Chain Flow Risks by Indexing*.

[89] Churchman (1968) *The Systems Approach*, Chapter 3.

A result-oriented perspective
A result is that which someone or something, such as an organisation or a company, wants to reach. The result might be specified in many different ways/dimensions as e.g.:

- number of successful operations performed;
- number of students examined;
- shareholder value; and
- business profit.

It is up to the user of the DRISC model to specify what kind of result dimension he or she wants to choose and thus what in the specific application is meant by *result impact*.

Generic versus specific
Since the DRISC model is supposed to be a generic model, I will here be talking about result and result impact *without any specification*. In the final chapter, Chapter 10, the generic aspects of the model will be more fully examined.

In the cases and illustrating examples, however, our result dimension will be *business profit* simply because our cases and examples are picked from a business context. The gap between revenues and costs is named net income but more popularly called profit or loss depending on which of the two that is the biggest. Revenues and costs are specified as they traditionally are in financial accounting in the statement of income, but for convenience I will simply talk about business profit and not business profit/loss.

Product flow focus
There are a number of different flows in the supply chain, like product flow, information flow and financial flow. Our focus will be on the product flow, where *product* is **defined** as *something one gets paid to deliver.* It could be a physical product, a service or a mixture of both.

Focal unit perspective
The supply chain is looked upon from the point of view *of an individual unit in the chain*. That particular unit is called the *focal unit* and might be a single company, a group of companies, an organisation, a group of

organisations, a working site, a legal unit or some other specified unit in the supply chain that the users of the DRISC model choose to select as their focal unit. *Focal unit* is thus **defined** as *the individual unit in the supply chain from the perspective of which the supply chain flow risk issues are seen, interpreted and acted upon*.

Focal product perspective
In many cases where the focal unit is producing more than one product, the focal unit is a "member" of several different supply chains where each supply chain is based on a certain product or product group. One has to be chosen. *Focal product* is thus **defined** as *the individual product or product group that the focal unit chooses to study.* So when we talk about "a focal unit perspective" we actually mean from the perspective of a certain focal unit *and* a certain focal product.

Supply chain choice
Since one and the same product can be using different supply chain alternatives, e.g. the product can be distributed through several parallel distribution channels, it may also be necessary to specify a supply chain alternative.

Pre-period time perspective
The perspective is a *pre-period time perspective* where *period* is the chosen time period for the project in question e.g. 1/1 – 31/12 the coming year. This means that we try to act before something happens and thereby eliminate the event or affect the likelihood and/or the negative consequences of the event. When we imagine the negative consequences, we suppose that if an event happens, normal suitable risk handling actions will be taken to mitigate the negative consequences.

Marginal changes in the supply chain
The DRISC model will deal with *marginal changes* in a planned or an already existing supply chain with its current policy for handling disruption risks. The DRISC model assists in the search for alternatives to handle the disruption risks in this supply chain in a more effective and efficient way.

Focus on disruption risk exposure
Since the perspective is a pre-period time perspective, the focus is not on actual disruptions but on *disruption risk exposure*. Given the production of a certain focal product in a certain focal unit in a certain supply chain setting, a disruption risk exposure might exist. A risk exposure exists when there is a possibility that an event with negative result impact is going to happen. In this study the top event is a *disruption in the supply chain*. This means that the focus is on the *negative result impact (NRI) for the focal unit with its focal product of supply chain disruption risk exposure.*

Risk handling
The focal unit reacts to the risk exposure through risk handling. The potential events cause pre-event and post-event handling. The *pre-event handling* could mean that actions are taken, like buying new insurance or building up a buffer stock, to eliminate or mitigate the risk. One could also choose not to act because that is seen as more favourable than acting (we simply accept the risk as it is). But not acting could also follow from a situation where the risk is not affectable. In both cases the disruption is sent on to post-event handling.

Post-event handling could mean taking actions like working overtime or temporarily buying from another supplier. There are two basic ways for the focal unit to handle a disruption that has taken place: to handle the disruption within the focal unit or to let the disruption out of the focal unit by passing it on. Disruptions are passed on for two different reasons. One is that the negative result impact of the disruption will be lower if passed on than if handled internally. The other is that it has to be passed on because it cannot be affected internally. The latter will also be seen as risk handling, since in most situations you have the possibility to eliminate the risk totally by stopping producing the focal product.

Pre-event handling in the form of actions will be called *preventive measures*. Post-event handling in the form of actions will be called *internally handled*, and in the form of not acting *passed on.* There exist in other words three basic ways to handle risk exposure: preventive measures, internally handled and passed on.

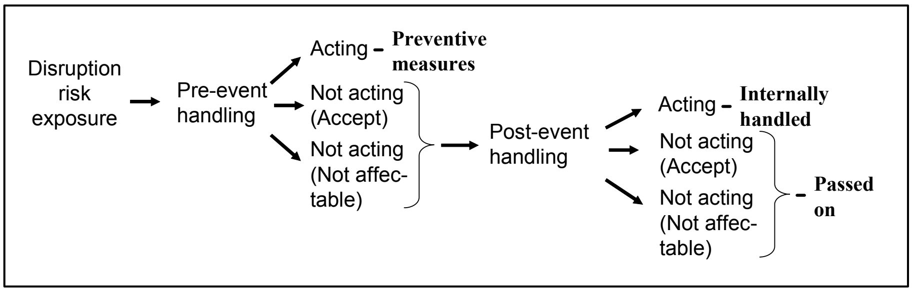

Figure 8.1: Disruption risk exposure and risk handling.

In the individual situation one, two or all three ways of risk handling can be applied (risk handling mix). By making changes in the risk handling mix, the total negative result impact can be affected.

Table 8.1: Some illustrating risk handling mix examples.

Example	**Preventive measures**	**Internally handled**	**Passed on**	***Total NRI***
1	150	0	0	*150*
2	70	40	0	*110*
3	30	10	10	*50*
4	20	20	20	*60*
5	0	50	40	*90*
6	0	0	100	*100*

In example 1 the preventive measures are presumed to take care of the total disruption risk exposure. In examples 2 and 5 a mix of two different risk handlings ways is imagined, and in examples 3 and 4 a mix of all three risk handling ways is supposed to be applied. Finally, in example 6, the only risk handling measure applied is passed on. The best of those alternatives is alternative 3 because it has the lowest negative result impact.

The above six examples are just examples. In reality it might, for instance, not be possible to take care of the total risk exposure only through preventive measures, or it might not be that a mix of all three handling approaches has the lowest negative result impact.

Two kinds of negative result impact

Hamilton (1966, p. 119) says that included in the total negative result impacts are usually costs both from before and after the potential event. From the preventive measures follow future negative result impact (NRI) that we know for certain that we are going to get (deterministic). Those NRI will therefore be called "*known NRI*". We do not know if we are going to get the post-event handling (stochastic), since the likelihood that the event is going to happen is less than 100 %, but we can estimate the expected value. We will therefore consequently call NRI from internally handled and passed on "*estimated NRI*". If the known NRI and the expected NRI are summed up, we will get "*the total NRI from disruption risk exposure*". In a short version: *Total NRI (from disruption risk exposure) = known NRI + expected NRI* (or if you prefer, Total NRI = deterministic NRI + stochastic NRI).

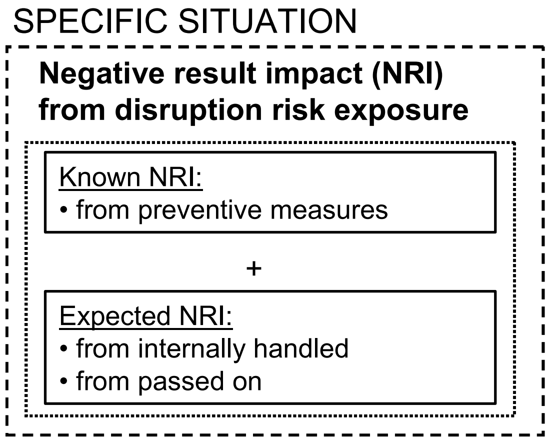

Figure 8.2: The two kinds of negative result impact.

If the focal unit had not been subject to any disruption risk exposure in the supply chain flow, its estimated future result would have been of a certain size. But now since the company is exposed to certain disruption risks, the estimated future result is less favourable. The difference can be regarded as the *total negative result impact from the disruption risk exposure.* The focal unit wants to keep this difference as small as possible.

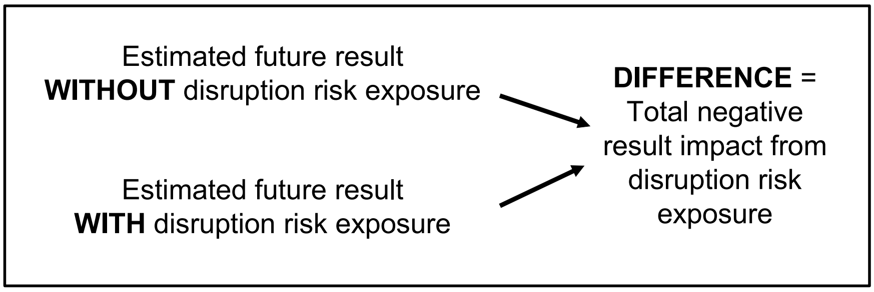

Figure 8.3: Description of total negative result impact.

Supply chain disruption risk categories
Supply chain risks can, according to Peck et al. (2003), be divided into risks that are *external* to the supply chain and risks that are *internal* to the supply chain. In the latter case, risk means a change within the supply chain with negative consequences and in the former case risk means a change in the environment that via changes in the supply chain has negative consequences. Usually the first disruption source category (generated within the supply chain) can be affected by the supply chain participants, but not the second one (see also Churchman, 1968).

Managing disruption risks in the supply chain
Risk management aims at *minimizing the negative result impact* of the risk exposure. Risk management then is a question of finding out if there are any better risk handling alternatives than the ones presently chosen. One important issue here is to find the best mix between pre-event and post-event handling, i.e. between known NRI and expected NRI. To be able to manage the risks you need to be able to identify and describe them in a structured way, to analyse and evaluate them, and to know how they can be handled in alternative ways. This knowledge has to be implemented as well.

8.1.2 **Basic concepts for the DRISC model**

8.1.2.1 Disruption risk

Svensson (2002) discusses the construct of "vulnerability" and identifies two components: disturbance, and the negative consequence of a disturbance. He goes on defining disturbance *"as a random quantitative or qualitative deviation from what is normal or expected"* (Svensson, 2002, p. 3). But most articles within supply chain risk management are not talking about disturbances but rather of disruptions, and this term is also used in this study.

The general meaning of disruption is *"an act of delaying or interrupting the continuity"* (WordNet, http://wordnet.princeton.edu/perl/webwn?s=disruption, 2007-02-08). But here in this study our focus is on the supply chain flow. A number of researchers are using the concept "supply chain disruption" or "disruption in the supply chain", among others Bartholomew (2006), Brannen & Cummings (2005), Chopra & Sodhi (2004), Christopher & Lee (2004), Hillman (2006), Kiser & Cantrell (2006), Kleindorfer & Saad (2005), Rice & Caniato (2003), and Sheffi (2001), but none of them presents a definition of the concept. I have therefore chosen to define the term myself. With reference to WordNet (2007) and to Svensson (2002), *supply chain disruption* will here be **defined** as *an interruption in the continuity of the normal supply chain flow with a negative result impact.*

The normal product flow creates a normal result. A negative impact is then a decrease in this normal result. The normal product flow in the supply chain includes frequent, small disruptions up to a certain level, because it is normal to have such minor disruptions. I can now, for the DRISC model, **define** *negative consequence as a consequence of a disruption in the supply chain product flow that in comparison with the normal result created by the normal product flow has a negative result impact.*

8.1.2.2 Disruption risk linked to Kaplan

Let us now link the disruption risk to the terminology of Kaplan. (See section 3.1.2.2 in Chapter 3.)

According to Kaplan, the basis of a risk analysis is the three questions

- What can happen (scenario)?
- How likely is it (likelihood)?
- What are the negative consequences?

Kaplan calls the answer to these three basic risk analysis questions "*a triplet*". There might be many triplets/answers to those questions, and each answer can be described by using the following formula:

$$<S_i, L_i, X_i> \quad [3.1]$$

where

- S_i is a scenario identification and description;
- L_i is the probability of that scenario; and
- X_i is the consequence or evaluation measure of that scenario, i.e. the measure of damage.

A "set of triplets" could then be described as:

$$\{< S_i, L_i, X_i >\} \text{ where } i = 1, 2,\ldots, N. \quad [3.2]$$

The complete set of triplets, according to Kaplan, is the same as the *risk* (R):

$$R = \{< S_i, L_i, X_i >\}_c \quad c = \text{complete set of triplets} \quad [3.4]$$

I illustrate the risk definition in Figure 8.4

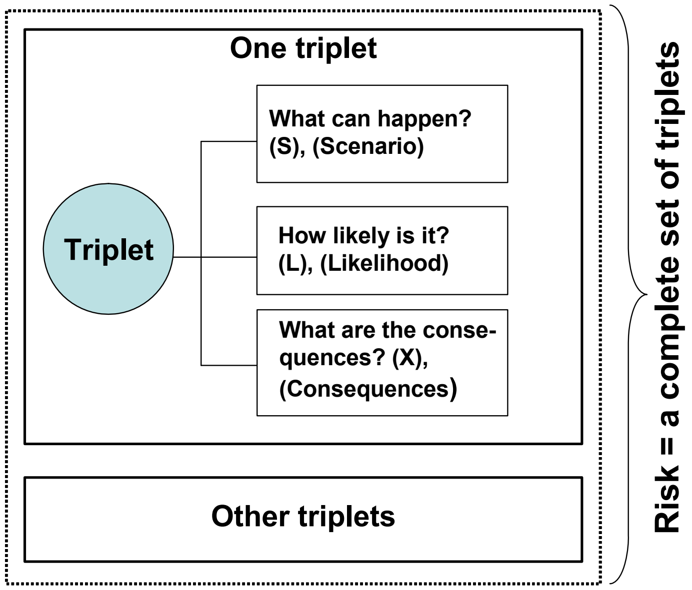

Figure 8.4: Illustration of the general risk definition by Kaplan (based on Kaplan, 1997, pp. 408-409).

To this can be added that it might not be important to know all the possible scenarios. Perhaps only scenarios with consequences of a certain magnitude are interesting. In that case only scenarios with consequences over that magnitude should be included in the complete set of answers. There might consequently be a difference between the theoretically complete set of answers and the for practical reasons complete set of answers.

Added elements

"All risks are conditional, although often the conditions are implied by context rather than explicitly stated" (Risk: Analysis, Perception and Management, 1992, p. 3). To the terminology of Kaplan I would therefore like to add *within the specified system under study*, which I presume Kaplan takes for granted and therefore does not explicitly mention. Without such a specification the concept of risk has no meaning because what is a risk in one specified system situation can be

an opportunity in another. System specification means posing and answering the basic questions: who, what, where and when. The system specification needs to be so detailed that it can judged what is and what is not included in the complete set of answers.

I would further like to add *expected outcome* which in this study is **defined** as *the product of likelihood and consequence.*

8.1.2.3 Risk scenario description

A scenario, according to Kaplan, can be described as a chain of events starting with an "initiating event" and ending with an "end state". In between those there are a number of "middle events".

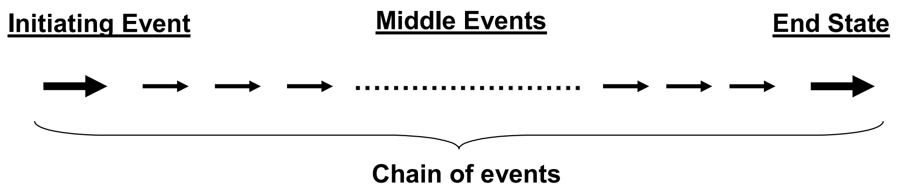

Figure 8.5: Illustration of a general basic description of a risk scenario (based on Kaplan, 1997).

Every risk scenario can only have *one* chain of events. If at any point there is more than one alternative to choose between, then each alternative is treated as an individual scenario, from initiating event to end state, in its own right.

Adopted to the DRISC model
Here our area of study is the DRISC model, and therefore the risk scenario description has to be adapted to that setting through specifications.

It can be that one of the middle events is of special interest. If that is the case that middle event can be called a "critical event". In the DRISC model critical event is specified as "*a supply chain product flow* *disruption which constitutes the first disruption in a risk scenario*". What characterises the "end state" also has to be defined, and the chosen definition is here; when we are "*back to a stable flow again*". Consequently, there is a stable flow, something happens (initiating event) that starts a chain of events, including a critical event, that ends when we are back to a stable flow again.

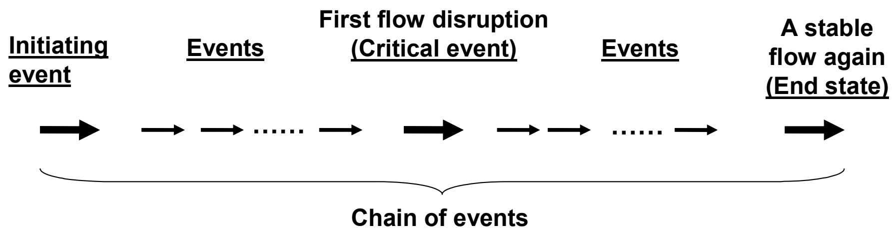

Figure 8.6: Illustration of a scenario with a critical event in the DRISC model setting.

Along the chain of events in a scenario there will be individual events that will have result-related consequences for the focal unit. If the consequences are multiplied with likelihood we will get the expected result impact (RI). The scenario ends when the end state is reached *but the consequences of the scenario can continue* after that. At the point of end state, those post end state consequences are identified and their future expected RI estimated. When estimating the expected RI, *normal actions*, once the disruption is a fact, for limiting the negative consequences are presumed. For instance, if there is a small fire one will not just stand by passively but use the fire extinguisher if there is one.

A scenario can lead to a number of events with result-related consequences. Some of those events may have positive consequences, but it is only called a *risk scenario* if the whole *bundle* of events in a certain scenario taken together has an expected *negative* result impact (NRI).

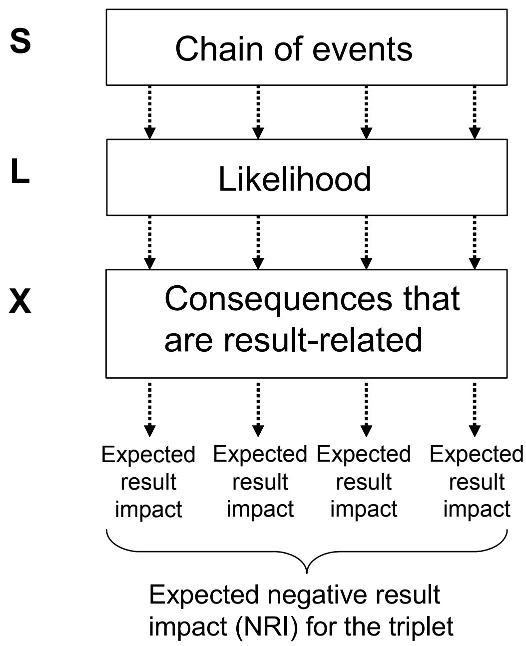

Figure 8.7: Illustration of a risk scenario.

Illustrative example of result impact
Suppose that the initiating event is a breakdown of a machine at a second tier supplier.

Alt. 1:
After *one hour* the machine is mended and up and running again. The sub-supplier uses 1 hour overtime the same day to make up the lost production.
Flow disruption with negative consequences? Yes, for the sub-supplier, but not for the focal unit. Consequently it is not a risk scenario for the focal unit.

Alt. 2:
Suppose instead that after *one day* the machine is mended and up and running again. Deliveries to customers are delayed. The sub-supplier uses re-planning and overtime, and after 2 weeks has made up the lost

production. Its customer, the supplier, also has to do some re-planning of its production, but can deliver to its customer (the focal unit) on time.
Flow disruption with negative consequences? Yes, for the sub-supplier and the supplier, but not for the focal unit. Consequently it is not a risk scenario for the focal unit.

Alt. 3:
Now suppose that it takes *a week* to mend the machine. The focal unit will therefore not get its deliveries on time and will have to buy from another supplier at a higher price.
Flow disruption with negative consequences? Yes, for the sub-supplier, the supplier and for the focal unit that has to buy its components at a higher price. Consequently this is a risk scenario for the focal unit.

Scenario space and outcome space
A chain of events can be described in a *scenario space,* and the outcomes from the chain of events from initiating event to end state can be described in an *outcome space*. A dot in the scenario space represents a certain scenario and an area in the outcome space represents the specific outcomes linked to a certain scenario. This is illustrated, by the help of Paper Clip Limited, which was presented earlier in section 3.1.2.2, in the figure below. In the example two different risk scenarios were presented; Thunderstorm leading to electricity break-down and congestion leading to lack of wires.

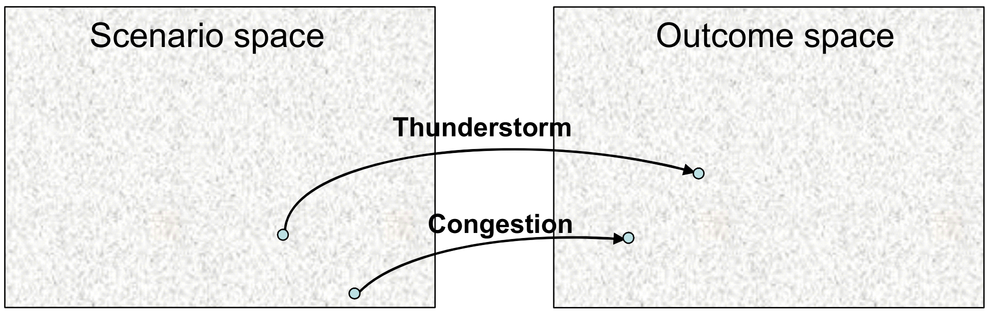

Figure 8.8: Illustration of scenario space S and outcome space X with the help of the Paper Clip Limited example.

The outcome space may consist of several dimensions, e.g. number of production units that could not be delivered, number of people killed, and number of lost lorries. If only one type of outcome is of interest, e.g. lost production in units, the outcome space can be reduced to a single *outcome dimension* which is done in Figure 8.9 below.

It could also be the case that we are interested in dividing the scenario space into different *scenario "groups*" based on some common characteristics. In the figure below (Figure 8.9) the two scenario groups "no electricity" and "no wires" have been introduced. Besides thunderstorm there are many other different possible scenarios, like a digging caterpillar damaging the electricity cable, which will lead to an electricity disruption, and there are also, many other different scenarios besides congestion, like a stolen loaded lorry, that will lead to lack of wires.

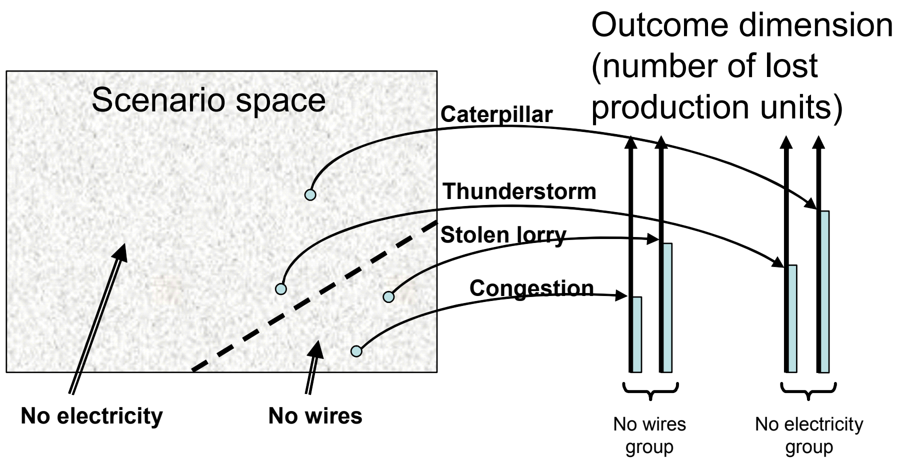

Figure 8.9: Illustration of one outcome dimension and scenario space "groups" with the help of the Paper Clip Limited example.

8.1.2.4 <u>Preliminary risk definition in the DRISC model</u>

Kaplan's risk definition, which was presented in the beginning of section 8.1.2.2 and illustrated in Figure 8.4, has been complemented and specified in different ways in sections 8.1.2.2 and 8.1.2.3. Summed up, this will be used as a preliminary risk definition for the DRISC model.

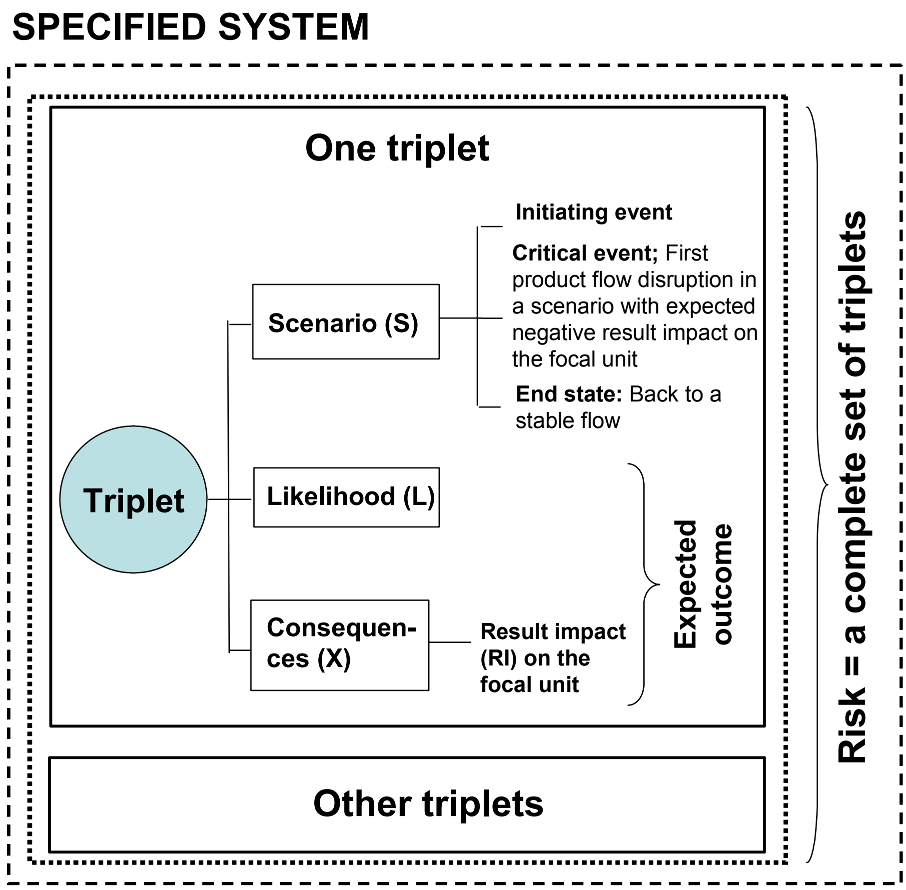

Figure 8.10: Preliminary risk definition in the DRISC model.

Included in the risk under study are all risks linked to disruptions in the supply chain product flow, including market reactions to such disruptions. Examples of risks that are *not* included are bad debt losses, bad contract terms, misjudgements of market demands and unattractive product design.

8.1.2.5 <u>Some illustrative disruption risk examples</u>

In the scenario examples below, likelihood will be indicated by the help of the scale very low, low, medium, high and very high. Focal unit is here specified as focal company and result impact specified as business profit impact.

Table 8.2: Some illustrative disruption risk examples (with F as our focal company).

Ex	**SCENARIO**			**LIKE-LI-HOOD**	**CONSE-QUENCES for F**
	INITIATING EVENT leading (sooner or later) to a	**CRITICAL EVENT leading in its turn (sooner or later) to an**	**END STATE**		
1	A LORRY with standard component X from supplier S CRASHES and all the components are destroyed. The transport insurance covers the value of the components.	DISRUPTION IN THE INBOUND FLOW OF COMPONENT X at company F. The disruption is taken care of internally by: - express delivery with new components payed for by F - working overtime to catch up	Back to normal flow again.	High	Higher freight costs. Higher labour costs in production.
2	LACK OF MAINTENANCE at supplier S of machine K causes inadequate quality in a batch of component X. The quality problem is identified at the arrival checking at F.	DISRUPTION IN THE INBOUND FLOW OF COMPONENT X at company F. The disruption is taken care of internally by; - express delivery with new components payed for by S - working overtime to catch up	Back to normal flow again.	Low	Higher labour costs in production.
3	LACK OF PROPERLY TRAINED STAFF at supplier S leads to a wrongly	DISRUPTION IN THE INBOUND FLOW OF COMPONENT X at company F. The disruption is taken	Back to normal flow again.	Medium	Higher labour costs in production.

	adjusted machine K, which leads to production of a batch of component X with inadequate quality. The quality problem is identified at the arrival checking at F.	care of internally by; - express delivery with new components paid for by S - working overtime to catch up Since there have been quality problems before with supplier S the company decides to change over to another supplier.	Completed the change over to a new supplier.		Changing over to a new supplier means initially increased administrative costs.
4	A LORRY with the unique component Y from supplier A is HIGHJACKED and all components are stolen. The transport insurance covers the value of the components.	DISRUPTION IN THE INBOUND FLOW OF COMPONENT Y at company F. There are no buffer stocks and the component is unique, so the disruption spreads to demand side. After two weeks a new delivery arrives.	Back to normal flow again.	Very low	Lost sale means lower revenues but also some smaller material costs.
5	A LORRY loaded with the unique component Y and the standard component X, both from supplier S, CRASHES and all components are destroyed.	DISRUPTION IN THE INBOUND FLOW OF COMPONENT Y at company F. There are no buffer stocks and the component is unique, so the disruption spreads to demand side. DITTO OF COMPONENT X. The disruption might be taken care of internally by; - express delivery with new components - working overtime to catch up But if this will be done it or not depends on how long it will take to get a new delivery of component Y.	Back to normal flow again. Back to normal flow again.	High	Lost sale means lower revenues but also some smaller material costs. If we choose to take risk handling actions then there will be higher freight costs and higher labour costs in production.
6	A MACHINE BREAKDOWN in production hall 1 at F causes the production flow in that hall to stop for at least two weeks.	DISRUPTION IN THE INTERNAL FLOW OF PRODUCTION HALL 1 at company F. The buffer stock of finished products takes care of some of the disruption but not all.	Back to normal flow again.	Low	Lost sale because of failure to deliver means lower revenues but also some smaller material costs.

		Some customers cancel their orders because of the uncertainty of how long it will take for F to be back producing again. The reputation of F on the market as being a reliable supplier is somewhat damaged.			Lost sale because of lower demand means lower revenues but also some smaller material costs. Lost future market shares.
7	A FLOODING in the production hall of customer D, which is the biggest customer of F, leads to a one week order stop from D.	DISRUPTION IN THE ORDER FLOW to company F. Increase in the stock of finished products.	Back to normal order from D flow again.	Low	Lost sale because of lower demand means lower revenues but also some smaller material costs.

<u>Comments</u>

- In the examples above it can be seen that an initiating event can lead to more than one consequence. Since these consequences are linked to the same initiating event, they cannot be separated and are therefore to be regarded as a "bundle of consequences".
- In examples 4 to 7 it can be seen that some of the consequences in the bundle might have a positive impact. The total impact must however be negative – otherwise it is not regarded as a disruption risk.
- In examples 1 to 3 and 5 it can be seen that different initiating events can lead to the same critical event (multi-finality).
- In example 5 it can be seen that one initiating event can lead to several different critical events.
- In example 6 it can be seen that one part of a disruption can be handled internally and another part passed on.
- In example 6 it can also be seen that a disruption can have long-term consequences. The business profit impact (BPI) of lost future market shares tends to be very high and might in this case outweigh the short term consequences of the actual machine breakdown a number of times.

8.2 A BASIC STRUCTURE FOR THE DRISC MODEL

8.2.1 **Top level structure**

The object of our interest is the *potential disruptions in the supply chain product flow*. These are affected by the supply chain itself and how its risks are managed. Those two – the *supply chain* and the *risk management process* – are in constant interaction. The supply chain with its product flow creates risks. Some of those risks are handled in the risk management process by finding and implementing certain risk handling actions. Those actions change the supply chain in one way or another. A changed supply chain creates a new risk situation to which risk management might then react with new risk handling actions, and so on.

These three basic elements – the supply chain, the risk management process and the potential disruptions in the supply chain product flow – and their interaction can be identified, described and analysed in a number of ways. It is, however, advisable to have certain fixed structures that govern how these three basic elements and their interaction are identified, described and analysed. Those fixed structures will be called the *framework for description and analysis*, which is the fourth basic element of the DRISC model. Changes in the supply chain (and, as a consequence, also changes in risks) can be internally generated within the supply chain but can also come from outside the supply chain – from its *environment*. Therefore the environment of the supply chain is included in the model as a fifth basic element.

The basic structure model is on Level 1 – the top level. Some of the individual elements will be deepened one level or more further on in the study. The top level structure model will thus be developed into the final complete DRISC model.

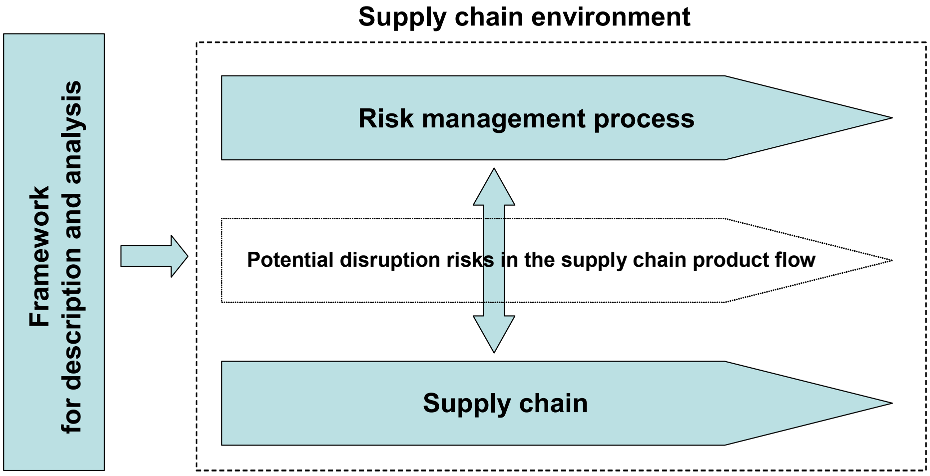

Figure 8.11: The top level structure for the DRISC model – Level 1.

The DRISC model that will be developed here might, if the user of the model wishes, include all disruption-related supply chain flow risks in the total supply chain. In the literature the importance of having a supply chain risk perspective and including the supply chain from nature to market is often stressed, but few examples of models exist that really do this, at least when it comes to supply chain flow risks. Here, however, the ambition is to really make it possible to include the whole supply chain, when suitable.

8.2.2 Basic risk management process model

The risk management process, one of the basic element in the top-level structure for the DRISC model, will be studied more closely.

The risk management process can be described in many different ways. The International Electrotechnical Commission (IEC) has developed a general model for the risk management process and its different parts, which was presented in Chapter 3 as Figure 3.7. This model is frequently used also within other areas than electro technology, and is one of the few that has been internationally accepted and used for description and analysis of the risk management process.

In the following figure the model is rotated so that the risk management process goes from the left to the right instead of from top to bottom (as in Figure 3.7).

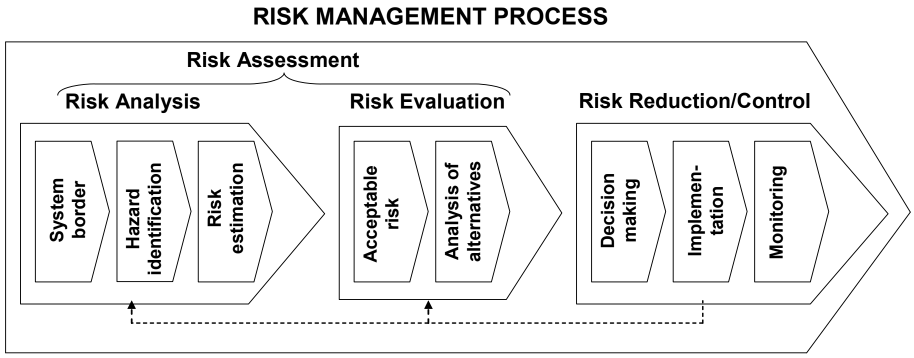

Figure 8.12: The rotated IEC risk management process model.

This model will here be used as the *theoretical starting point* for the creation of a *supply chain risk management process model* for this study. Risk assessment will not be explicitly mentioned – otherwise the model is identical with the original one (except for rotating it). The model includes three different risk management "phases" – risk analysis, risk evaluation and risk reduction/control – where each phase includes two or three different "steps". In total there are 8 different steps.

Issues of how to manage supply chain flow disruption risks are of relevance to *any company* in the chain but *the more exposed to disruption risks* in the supply chain a company is and *the more it could affect those risks* the more reason to spend time and effort on risk management issues.

8.2.3 **More to come**

In section 8.3 the framework for description and analysis is developed. In sections 8.4 to 8.6 the three risk management phases – risk analysis, risk evaluation and risk reduction/control – are further developed. Finally in section 8.7 the results of the different developments are summed up and linked together into the complete DRISC model.

8.3 FRAMEWORK FOR DESCRIPTION AND ANALYSIS

Since the supply chain is supposed to consist of a number of interrelated links – often described as a "network" – a *supply chain network structure* has to be elaborated. There is also a need to decide what from a risk point of view is interesting to identify and describe in the supply chain, i.e. a *supply chain risk essentials* model has to be established. Finally the different types of disruptions and different ways to handle them have to be structured and combined. That structure will here be called *disruption source and handling way* structure. Since the framework model is a partial model in the total DRISC model, the framework model presented below is on Level 2.

Framework for description and analysis

- **Supply chain network structure**
- **Supply chain risk essentials**
- **Disruption source and handling way structure**

Figure 8.13: Framework for description and analysis model – Level 2.

8.3.1 Supply chain network structure with specifications

Johnson (2001) stresses the importance of focusing on how to manage both *supply risks* and *demand risks* simultaneously. Sheffi suggests a division of the supply into three different parts: the *inbound* or supply side, the internal processes or *conversion* part, and the *outbound* or customer-facing side. (Sheffi, 2005, p. 28). Peck et al. (2003, p. 44) are talking about five different risks in the supply chain: supply risk, process risk, demand risk, control risk, and environmental risk. The first three (supply risk, process risk and demand risk) will here be used as a basis for the network structure model (but process risk will be called production risk). The last two (control risk and environmental risk) will not be individually treated. They are instead included in the first three .

The network structure model is based on the following specifications:

- Focus is on the *supply chain product flow* including its input and output.
- The everyday, "undisturbed" supply chain flow following the plans will here be called the *normal flow*. In the normal flow, normal disruptions are included, i.e. small, frequent disruptions that are handled through established routines.
- It is all seen from the perspective of a single unit, here called the *focal unit*, in a single supply chain during a specified time period.
- The focal unit is supposed to produce a *product* and to be a link in a *supply chain.*
- If the focal unit produces several products, one product or product group has to be chosen.
- If the focal product is included in two or more principally different supply chains, one has to be chosen.
- It is the focal unit that chooses the product to study, here called the *focal product*. This choice also determines the internal structure of and interrelations in the supply chain.
- The supply chain can be regarded as starting where the *natural resources* in *nature* are picked up, and ending where the *end product* is handed over to the end customer in the *end market*.

- It is the focal unit that defines what is meant by *nature*, *natural resources*, *end product*, and *end market* and thus decides where the supply chain borders are (what is inside the supply chain and what is outside it?).
- *Only the main flow direction* is indicated in the model. There will probably also be flows in the opposite direction, e.g. different kinds of reverse logistics, and they will also be regarded (although not indicated in the network structure model).
- A supply chain has as its "assignment" to produce and deliver a certain end product that totally or partly serves a specific need for a certain end customer or end market.
- The supply chain consists of a number of more or less independent links, each with its own special *value adding* to the end product.
- A supply chain can thus be defined as all the individual links that are engaged through their value adding in *transforming and moving in space and time* natural resources from nature into an end product delivered to an end market.
- Each supply chain has a certain link *structure* and certain *interrelations* between the links. But all this is of no interest to the end customer as long as it does not affect delivery, quality and price of the end product.
- The needed components for the production of the focal product are together called the *focal components*.
- The supply chain is regarded as being constituted of *three* principally different *"parts"*: supply side, production and demand side.
- *Supply side* is defined as all the activities that help to transform the natural resources into the needed focal components for the production of the focal product and move them to production.
- *Production* is defined as all the activities, like assembly and testing, which help to transform and move the focal components into a focal product.
- *Demand side* is defined as all the activities that help to transform and move the focal product from production into an ordered and delivered end product at the end customer.

- Each “part” (supply side, production, and demand side) can consist of one, two or more *parallel links* like several suppliers of the same component or several similar production sites.
- Each “part” (supply side, production, and demand side) can also consist of one, two or more *sequential links*. For instance, the supply side can consist of first tier suppliers, second tier suppliers etc.
- If the focal unit is the first link in the supply chain there will be no supply side, and if it is the last link in the chain there will be no demand side.

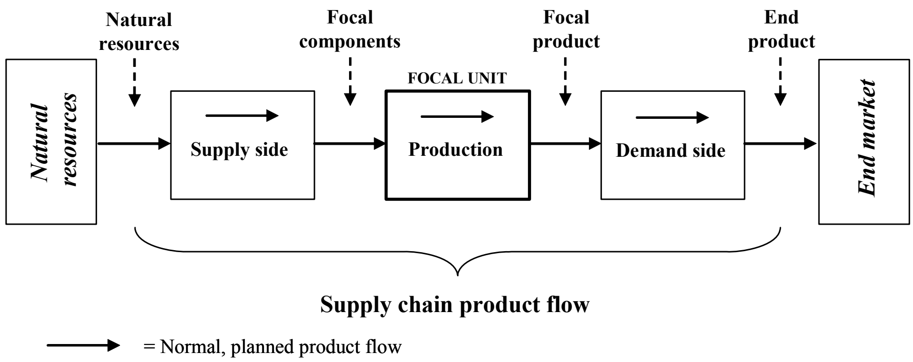

Figure 8.14: Supply chain network structure model – Level 3.

8.3.2 <u>**Supply chain risk essentials**</u>

Choosing important risk essentials

The supply chain risk essentials model identifies what in the supply chain is of special significance from a disruption risk point of view.

<u>Product design</u>
The product itself is one important element. It defines what customer needs could be fulfilled and what markets could be served. It also defines what components and other supplies are necessary for its

production and thus what kinds of supply markets are relevant. The product also defines what kind of production equipment is needed.

Often the same basic product can be constructed in different ways concerning e.g. kind of material used, kind of technical solution applied, number of components, and mixture between unique components and standard components. All this also has importance for the supply chain risks. It will therefore be called *product design* and not just product.

Production process design

Another important element is all the production processes that are necessary to be able to transform and move natural resources into a delivered end product. Those processes can be constructed in different ways, and the choices are of importance for the supply chain risks. This is why it will be called *production process design* and not just process.

Product flow design: structure and volumes

One and the same flow from natural resources to market can be designed in many different ways depending on e.g. the number of suppliers, transportation routes, storing and volumes – factors that are affected by decisions like single or dual sourcing, make or buy, and buffer stocks or not, all of which have relevance for the supply chain risks. To underline this, *structure* and *volumes* will be added as a specification to *product flow design*.

Product flow supporting systems

There are also a number of *product flow supporting systems* like production planning systems, financial systems, and general management systems that in different ways support the product flow. If those supporting systems do not function well, the product flow will become less efficient and risks may increase.

Risk management systems and actions

All the information needed for risk management cannot be gained through the general management systems. Therefore special management systems designed specifically for risk purposes have to be created and maintained. Together they will be called *risk management* *systems*. Also the different risk handling *actions* that already have been taken, like the existence of buffer stocks or excess capacity, are of interest here.

Human resources

Finally *human resources* are needed to keep the product flow running. Their knowledge, skills and motivation are of prime importance when managing disruption risks.

By summing up the discussion above, the supply chain risk essentials model can now be constructed.

SUPPLY CHAIN RISK ESSENTIALS

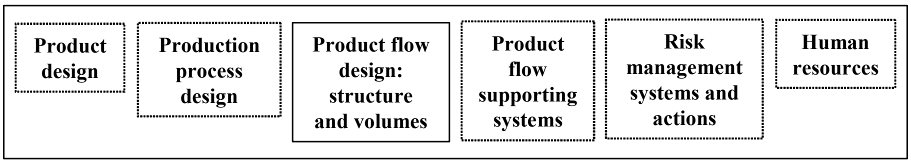

Figure 8.15: Supply chain risk essentials model – Level 3.

8.3.3 **Disruption source and handling way structure**

Modelling is here carried out in *four steps.* First the handing over of the product at a transfer point is discussed. After that the concept of disruption sources is introduced and a limited number of categories for them are identified. Then different ways to handle risks are discussed. Finally disruption source categories and handling way categories are combined into a disruption source and handling way structure model.

8.3.3.1 Handing over at a transfer point

By definition every part in the chain, except the first one and the last one, is both consuming and producing. For instance production is consuming what the supply side has produced. But the product has to be handed over before it can be consumed.

Transfer points
A transfer point is a location in the supply chain where an earlier part in the supply chain hands over what has been decided/ordered to a later part in the chain. One such point is where the supply side is handing over the focal components to production, and another where production is handing over the focal product to demand side. There is also a transfer point where natural resources are handed over from nature to supply side and yet another where the end product is handed over from demand side to end customer. Also within each supply chain part a number of transfer points between different links can be identified, and within each such link in turn still more transfer points can be identified etc.

Ways of describing the handing over
Gaudenzi (2005) refers to a successful handing over as the fulfilment of the four perfect order objectives; on time delivery, order completeness, order correctness and damage/defect free.

Another way of describing the conditions for handing over is by referring to the traditional four utilities that have to be fulfilled before consumption can take place. Those four utilities are: *form utility*, *possession utility*, *place utility* and *time utility* (see e.g. Lambert, Stock & Ellram, 1998, p. 11). To these four utilities is often added a note that they have to be produced at a competitive cost. Form utility is the product with its specific look and qualities. This utility is created through production activities. Possession utility is created through purchasing and sales activities. Place utility is created through transportation activities, and time utility finally through storing activities. A successful handing over means that the delivered utilities are the ones that are demanded by the receiving unit. It is worth noting that through delivery terms of different kinds responsibilities linked to the goods and consequently also the disruption risk can be moved upstream and downstream from the transfer point. Responsibilities/risks can also through contracts be split in different ways between supply chain members.

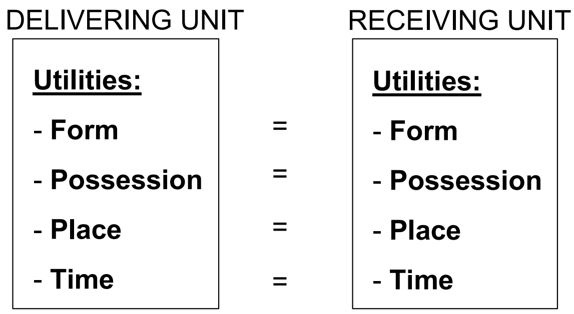

Figure 8.16: A successful handing over.

Handing over failures
Sometimes consumption as planned is not possible because transfer has failed. All necessary conditions have not been fulfilled. There is thus a handing over failure. If this failure is expected to have negative consequences it will be called a disruption. In this study focus is on disruptions in the normal flow. The developed transfer point concept with its four utilities makes it possible to describe a disruption as a lack of one or more utilities in a transfer point leading directly or indirectly to negative consequences for the focal unit.

8.3.3.2 Post-event handling split on disruption source

We are also interested in *where* in the total supply chain the scenario starts i.e. where the *initiating event* took place. This will be called the *disruption source*. The total supply chain has therefore been split in three parts: within the supply side, within the focal unit, and within the demand side. The initiating event in each individual scenario belongs to one and only one of those three. If the original initiating event takes place outside the supply chain, when classifying we will consider where *inside* the supply chain it first had an effect: supply side, focal unit or demand side.

8.3.3.3 Post-event handling split on way of handling

One way to handle a disruption is to let the disruption out of the focal unit by passing it on to the supply side, the demand side and/or the end market. Those supply chain parts will react in one way or another to the disruptions that are passed on to them.

A passed on disruption can influence the focal unit directly or indirectly. *Direct relation* means that only two links in the supply chain are involved. *Indirect relation* means that more than two links in the supply chain are involved. I have earlier chosen only to have three disruption sources in the DRISC model, and they do not distinguish between direct and indirect market relations. It is, though, when looking for possible scenarios, extremely important not to look only at the direct market relations but also at the indirect ones.

The Royal Society in Britain defines risk as *"The probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge"* (Risk: Analysis, Perception and Management, 1992, p. 5). This definition clearly underlines that risks are linked to a certain time period. This is also stressed by Deloach, who says *"We define risk as the distribution of possible outcomes in a firm's performance over a given time horizon due to key underlying variables"* (Deloach, 2000, p. 48).

The consequences of a disruption can often spread over long times. Another aspect is that they can unfold over time from local to widespread. And finally the consequences can change character over time. It is therefore important to split up the consequences into sub-groups. This has been stressed by different sources, among others The Royal Society in Britain that mentions two different approaches to structuring. One is in primary, secondary and tertiary consequences. Another is in immediate, short-term and long-term consequences (Risk: Analysis, Perception and Management, 1992). Deloach (Deloach, 2000, p. 119) stresses the importance of splitting up time in different intervals and proposes; short, medium and long term.

Those aspects seem to be especially relevant for the passed on disruptions. It is therefore suitable to split up the market reactions on several periods of time. Taking the critical event (disruption) as the starting point, the following three periods of time are chosen; *until back to a stable flow*, *short run*, and *long run*. Consequently there are *four ways of post-event risk handling*: internally handled, passed on-until back to a stable flow, passed on-short run, and passed on-long run.

That the flow is *back to a stable situation again* could mean that it is back to what it was before the disruption. But it could also mean that a new stable flow situation has been reached, because it was not possible or desirable to go back to the old situation again. This is the same description as was presented for *end state* in the scenario description. A scenario starts with an initiating event, and when a stable situation is reached that is the end of this scenario (end state). But the consequences can go on much longer. Those consequences are divided into short run and long run.

For *back to a stable flow again* it is reasonable to believe that if you do not deliver you will not get paid, and that if you do not order you will not have to pay. Besides this, other reactions can exist, but if the disruption isn't too long it is reasonable to believe that the above-mentioned reactions are the dominant ones for market reactions.

Markets with a direct relation to the focal unit as well as those with an indirect one can, after the disruption has ended, react in a way that *in the short run* will diminish or enlarge the impact of the disruption or leave it unaffected. The "patience" of the market decides what the negative economic consequences of a passed on disruption will be in the short run. In some markets, such as the market for fast food meals like hamburgers, practically no delay can be accepted, while in other markets, like the market for exclusive sports cars, delays of several months can be accepted. Another word for further market reactions in the short run that will be used here is therefore *market patience*.

The market reactions in *the long run* can differ from those in the short run. The customers' opinions about the long-term ability of the supply chain to deliver on time are reflected in their confidence in the supply chain. How does a disruption affect this confidence? Do the customers dare to continue to do business with that supply chain or will they change to another supply chain as soon as they get the opportunity? And if they choose to continue the relationship, will they demand a price cut to compensate for the diminished confidence and the risk handling actions they may have to take, like increasing their own buffer stocks? Another word for market reactions in the long run that will be used here is therefore market *confidence.* A study by Hendricks and Singhal of nearly 800 instances of supply chain disruptions showed that the companies on average had a drop of 107 % in operating income, 7 % lower sales growth and 11 % growth in cost in the year of the disruption, and continued to operate for at least two years at a lower performance level (Hendricks & Singhal, 2005, p. 4)

A special case is hidden quality problems. Such problems tend to have serious consequences, especially if a product with inadequate quality has reached the market and the consumers do not experience the quality problem until some time has passed. Such problems are of special relevance for the food industry and the pharmaceutical industry, where market confidence can easily be lost.

Delivery problems caused by a disruption do not necessarily lead to a negative market reaction. If the supply chain manages to handle an actual disruption satisfactorily, showing the market that the supply chain has a good general awareness of disruptions and is well prepared to handle them, that could in fact lead to an increase in market confidence. On the other hand, as the example with Nilsson (the steel producer) illustrated, a disruption that never harms the customer can nevertheless hurt market confidence. And even a disruption within the supply chain that does not reach the market can nevertheless in some situations annoy the market.

8.3.3.4 Post-event handling split on disruption source and way of handling

In the previous section the focus was the individual triplet, but Kaplan defines risk as a complete set of triplets. Since our interest is in risk, focus will now be shifted from the individual triplet to the complete set of triplets. If we then split past-event handling on disruption source and way of handling we will get the following figure (Figure 8.17).

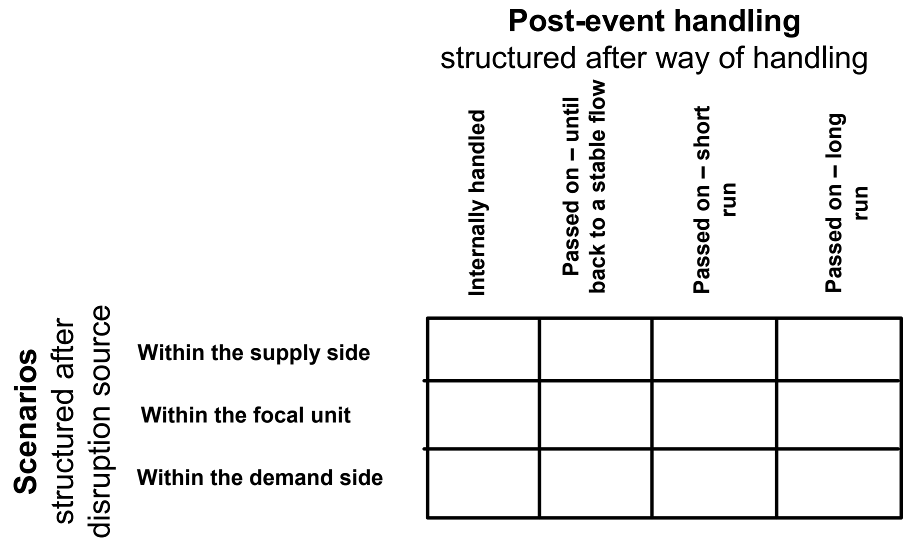

Figure 8.17: Disruption source and handling way structure model for post-event handling.

There are in all 12 combinations (boxes) of disruption sources and handling ways.

8.4 RISK MANAGEMENT PROCESS: RISK ANALYSIS

Risk analysis (Level 3) is the first of three phases in the risk management process (Level 2) and includes three steps (Level 4); system border, hazard identification and risk estimation. Those three steps will be discussed below, and the models developed are then illustrated in section 8.4.4 with the help of three different cases named Alfa, Beta and Gamma.

8.4.1 **System border**

The frames of the "project" are set in the system border step. The user of the model first has to decide *who is the stake holder and who is judging*. The answer to this question influences the answers to other questions, because what one stake holder regards as a risk might be seen as an opportunity by another stake holder. Different individuals also tend to have different utility functions in one and the same situation. Then the *focal unit* has to be specified and, as was discussed earlier, focal unit doesn't have to be a legal unit but could in principle be any unit that the user of the DRISC model finds interesting to define as the focal unit. Then the *focal product* has to be defined and it could be a single product or a group of products with to a large degree common supply chain. *Project goals* also have to be specified as well as *measure dimension for result impact*. Also the *time period* (from xx to yy) that should be considered needs to be specified. Since risk consequences could be spread over a long period of time, the *time horizon* also has to be specified – and of course the *ambition level*. *Other specifications and/or limitations* may also be needed.

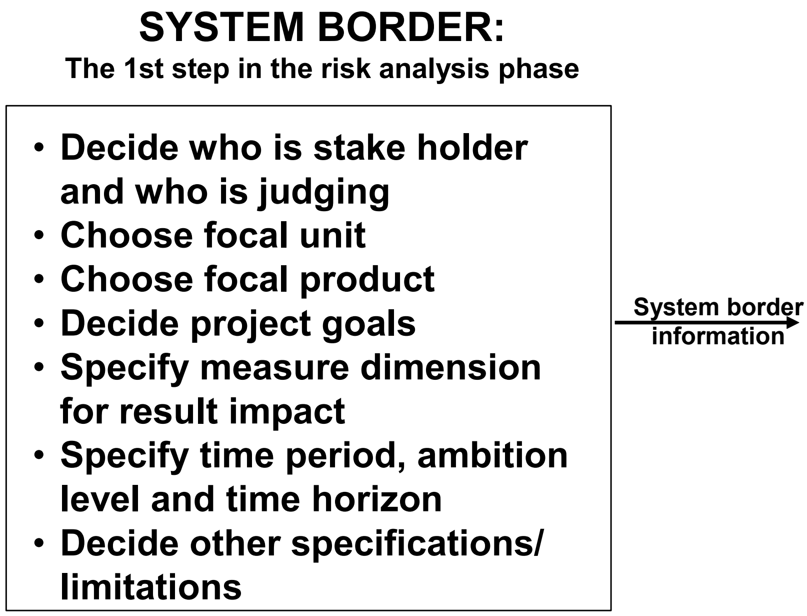

Figure 8.18: System border model – Level 4.

8.4.2 <u>Hazard identification</u>

When the system border has been settled, as a consequence the “look” of the supply chain also has been specified. In the second step, the hazard identification step, facts about the supply chain based on the system border setting are collected and the potential risk sources identified. And the present risk management activities also need to be identified. Only *criticalities* are regarded. The hazards are mapped within a structure that is a combination of two models presented earlier; the *supply chain network structure model* (Figure 8.14) and the *supply chain risk essentials model* (Figure 8.15). The output from the hazard identification model is information about potential vulnerability sources and about present risk management activities.

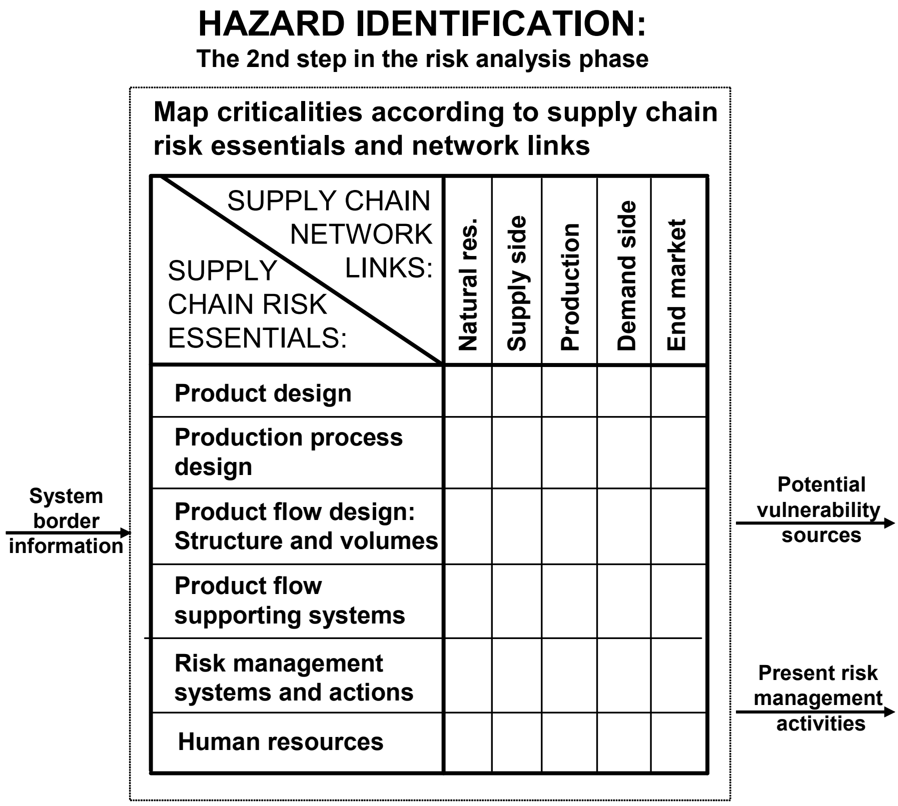

Figure 8.19: Hazard identification model – Level 4.

8.4.3 <u>Risk exposure estimation</u>

So far the issue of potential *post-event* handling, i.e. risks, has been dealt with. But since the DRISC model is a proactive model, *pre-event* handling is also of great interest. So what we are really interested in is the *risk exposure* and how to estimate (and handle) it, and we will get the risk exposure if we include both pre-event and post-event risk handling (see Figure 8.1). The post-event risk handling will below be split on 12 different risk boxes, and the pre-event risk handling on 3 different boxes. Together these 15 boxes will include the total risk exposure. Finally, different estimation methods are briefly examined and the discussions in section 8.4.3 are summed up into a risk exposure estimation model.

Risk is defined by Kaplan as "a complete set of triplets" (Kaplan, 1997). Below, first a look at the individual triplet will be taken and then at the risk, i.e. the complete set of triplets.

8.4.3.1 The individual triplet: Linked to risk handling and negative result impact

It is possible, after the chain of events in a scenario, to sum up all scenario events that have a result impact and thus get "the expected total negative result impact from the triplet". If we split this total on the individual risk handling methods, some of them may have an expected *positive* result impact. We will therefore, when dealing with the individual risk handling way linked to a certain scenario, drop "negative" and just talk about "expected result impact".

Illustrative example (continuation)
Let us now suppose that there is a 3-week disruption in deliveries from the supplier of the critical component X.

1. The company manages to buy one week of supply of the component X from another supplier but at a higher price. No more components can be bought on the spot market.
2. Since there are no deliveries for 3 weeks of component X from our usual supplier, we will not have to pay them during this period.
3. Of the 3-week disruption, 2 weeks will be passed on and we will lose sale revenues for those two weeks.
4. In the short run our customers, because of the 2-week disruption in deliveries, will buy some more from us than usual and our sale revenues will consequently increase.
5. In the long run, though, our revenues will fall because the market no longer regards us as an equally reliable supplier as before the disruption.

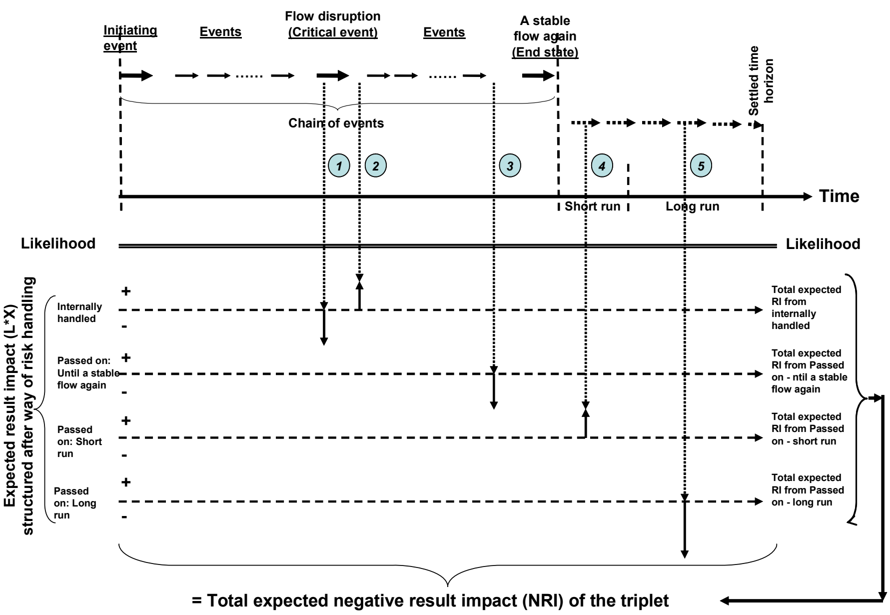

Figure 8.20: The individual triplet linked to way of handling and result impact.

See also Table 8.1 in the beginning of the chapter, where a number of different mixes of negative result impact from different approaches to risk handling were presented.

The dynamic aspect
During the chosen time period, e.g. a calendar year, circumstances may change including risk handling actions, and this affects the triplets. If for instance halfway in the calendar year a buffer stock of components is created, this means that instead of having just one triplet for the whole year we need to have one triplet for the first half of the year and another for the second half.

8.4.3.2 The individual triplet: Expected negative result impact structure

In section 8.3.3.4 a structure for splitting post-event handling on disruption source and way of handling was presented in Figure 8.17.

Each scenario can just belong to one disruption source, but it can have an expected result impact on one, two, three or all four risk-handling ways. In that way the expected result impact of a specific scenario can be estimated, as illustrated in Figure 8.21. For an individual box the impact can be positive, but when all the boxes are summed up at the bottom row, the total expected result impact (RI) must be *negative*, following from the definition of a risk scenario.

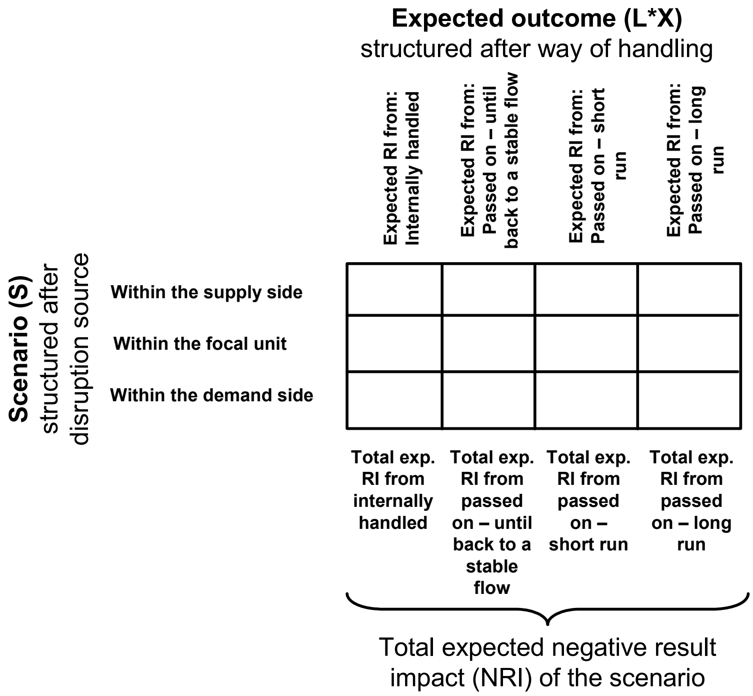

Figure 8.21: Expected negative result impact of one scenario linked to disruption source and way of handling.

Since our interest is in risk, focus will now be shifted from the individual triplet (scenario) to the complete set of triplets.

8.4.3.3 Risk: Final definition for the DRISC model

Based on Kaplan's general risk definition with "triplets", a preliminary risk definition for the DRISC model was developed and presented in section 8.1.2.4 as a figure (Figure 8.10). Now this preliminary risk definition will be developed into the final risk definition for the DRISC model by being made more precise in some aspects. The specifications are:

- *Initiating event* will be split on three alternatives depending on, seen from the point of view of the focal unit, the source of the disruption i.e. where the initiating event takes place: within the supply side, within the focal unit, or within the demand side.
- To *critical event* will be added that it has to take place during the period of time specified in the border step. Added is also the word "total" in connection to the scenario, resulting in "a scenario with negative total result impact".
- *Consequence* has earlier been specified as result impact on the focal unit. Now it will also be linked to the two ways of risk handling: internal handling and passing on. The latter is split on three time intervals: until back to a stable flow, short run, and long run.

The final risk definition can be expressed as a figure (Figure 8.22).

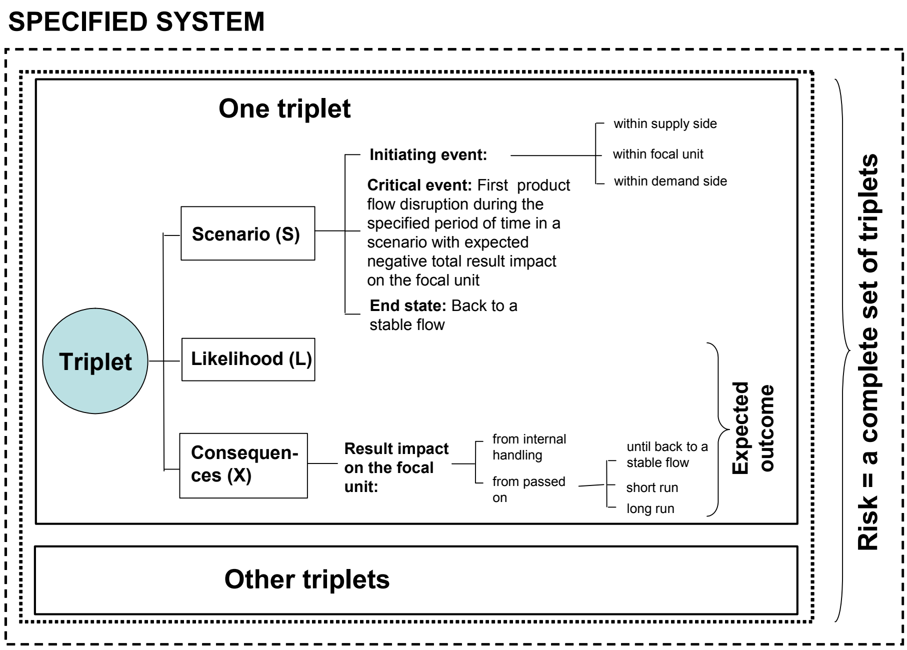

Figure 8.22: Final risk definition for the DRISC model.

The *specification of the studied system* is made in the "risk border" phase when, among other things, one chooses focal unit and focal product. But a number of other specifications might also be suggested there, such as what kind of disruptions should be regarded as everyday disruptions and thus should be included in the normal flow. You can also e.g. specify that only two links backwards and two links forwards in the chain should be included, or that only scenarios with a likelihood of more than 1 % should be considered, or that only initiating events of a certain kind are to be regarded.

8.4.3.4 Risk: Box structure

Back in Figure 8.17, post-event handling was split on three different disruption sources and four different ways of handling, resulting in a "table" with 12 different boxes. Each box will now be linked to the expected result impact of a certain risk. The expected negative result impact of a certain risk can be thus be split on 12 different boxes, which is illustrated in Table 8.3 below.

Table 8.3: Risk; Box structure – Level 5.

	Expected OUTCOME structured after way of handling:			
SCENARIOS structured after disruption source:	Expected RI from *internally handled* disruptions	Expected RI from *passed on* disruptions upstream/downstream with includation of market reaction and considering time dimension		
		until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side				
Initiating event within focal unit				
Initiating event within demand side				
	Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run
	TOTAL EXPECTED NRI			

The result impact for each of the 12 boxes identified in Table 8.3 can be estimated as well as the total expected negative result impact of the risk. It is also possible to estimate only the total result impact from scenarios with a certain disruption source or the total result impact from only a certain way of post-event handling.

8.4.3.5 Risk exposure: Total negative result impact structure

If Table 8.3 above is complemented with the pre-event risk handling, i.e. the preventive measures, we will get the disruption risk exposure.

Each preventive measure can be linked to one or more of the same three disruption sources as the post-event handlings were. We will now get 3 new boxes making a total of 15 boxes. If we complement the above table for the expected NRI with the known NRI from preventive measures, we can then sum up known NRI and expected NRI and get the *total NRI from disruption risk exposure* (Table 8.4).

Table 8.4:Risk exposure; Box structure – Level 5.

DISRUPTION SOURCE:	Known NRI from preventive measures		Expected OUTCOME structured after way of risk-handling:					*NRI FROM DISRUPTION RISK EXPOSURE*
			Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension				
				until back to a stable flow	in the short run (market patience)	in the long run (market confidence)		
Initiating event within supply side		AND					EQUALS	
Initiating event within focal unit		AND					EQUALS	
Initiating event within demand side		AND					EQUALS	
			Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run		
	TOTAL KNOWN NRI	AND	TOTAL EXPECTED NRI				EQUALS	*TOTAL NRI*

Below you will get one or more examples of result impact for each of the 15 risk exposure boxes.

Table 8.5: Examples of result impact for the different risk exposure boxes.

DISRUPTION SOURCE:	Known NRI from preventive measures		Expected OUTCOME structured after way of risk-handling:			
			Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension		
				until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side	S1: The costs for inbound buffer stocks of components and for outbound buffer stocks of ready-made products.	AND	S2: The costs for changes in production planning.	S3: Lost revenues from DM because of failed deliveries.	S4: Additional lost revenues from DM because of decreased market share of the EM in the short run.	S5: Additional lost revenues from DM because of decreased market share of the EM in the long run.
Initiating event within focal unit	P1: The costs for outbound buffer stocks of ready-made products	AND	P2: The costs for using overtime.	P3: Lost revenues from DM because of failed deliveries.	P4: Additional lost revenues from DM because of decreased market share of the EM in the short run.	P5: Additional lost revenues from DM because of decreased market share of the EM in the long run.
Initiating event within demand side	D1: The costs for the preparedness to produce alternative products.	AND	D2: Lost revenues from DM because of less orders. Unchanged purchasing costs from SM.	D3: Lost revenues from DM because of less orders. Lower purchasing costs from SM.	D4: Additional lost revenues from DM because of decreased market share of the EM in the short run. Lower purchasing costs from SM. Less quantity discount on purchased items from SM.	D5: Additional lost revenues from DM because of decreased market share of the EM in the long run. Lower purchasing costs from SM. Less favourable purchasing prices since the company has become a less attractive customer.

Abbreviations:
S = from supply side, P = from production, D = from demand side, DM = Demand side market. SM = Supply side market. EM = End market, RI = risk impact.

8.4.3.6 Estimation methods for risk exposure

In theory the complete result impact for each of the 15 risk exposure boxes can be estimated. They can then be summed up into a complete total negative result impact. *In practice* this is seldom done because it is practically impossible, or because such exact information is, from an action perspective, not necessary. A possibility is to use *a set of risk levels*. For instance five levels can be chosen, e.g. very low, low, medium, high and very high. If we want to be able to sum up the total result impacts, then we can e.g. let each level represent a certain result impact size like very low = up to 1 million, low = 1-10 million, medium = 10-20 million etc., and then use the middle value for each group, that is ½, 5, 15 etc., when we sum up. We will then acquire a rough estimate of the *result impacts*. This is a timesaving method, and if the aim is to gain a quick overview of the risk situation in a supply chain, using risk levels is probably a practicable method.

Another dimension is that of *objectivity*. Objectivity is desirable but could be difficult to reach. In some situations, risks are well defined and we have accurate data for both comsequences and likelihood. The calculated expected value of the risk in those situations can be said to be objective or reasonably objective. But there are also many situations where information is insufficient or lacking and we have to rely on *subjective* estimations.

The estimations ought to made by *experts* either within the focal unit, such as risk managers, production managers and others within the company, or external experts, like risk consultants. Each estimation should be accompanied by *motivations*. The motivations can be as interesting as the estimation itself.

8.4.3.7 The risk exposure estimation model

Input to the risk exposure estimation model is the information about potential vulnerability sources and present risk management activities generated in the hazard identification step – step 2.

In section 8.4.3.5 a box structure for the total negative result impact of the risk exposure was presented (Table 8.4). The structure included three boxes for known result impact and twelve for expected result impact.

The result impact estimations are conducted by internal and/or external *experts*. The expert estimations are *a mixture of objectivity* (preferable) *and subjectivity*. Each estimation has to be *motivated*. Output from the model is information about estimated risk exposure.

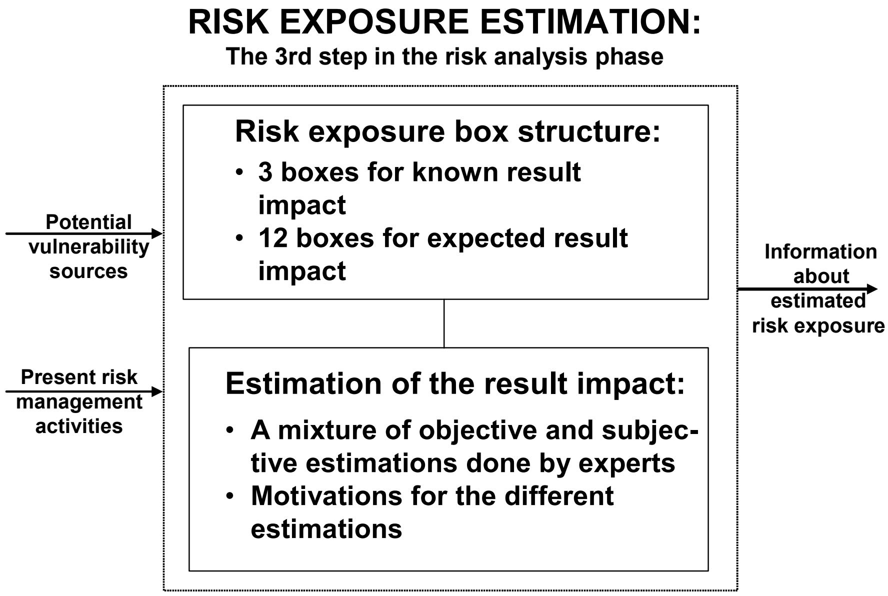

Figure 8.23: Risk exposure estimation model – Level 4.

8.4.4 <u>Descriptive cases</u>

8.4.4.1 Method for choosing cases

When choosing industries and case companies, mainly two dimensions are considered: vulnerability and influence on the supply chain. *Vulnerability* is chosen because it has been considered as the main factor affecting the risks in the supply chain flow. *Influence* is chosen because different companies have different possibilities to affect the supply chain and need to adapt their risk handling accordingly.

The three descriptive cases have been chosen so that they represent different degrees of vulnerability. I have thus chosen one industry with high vulnerability (information technology), one with low vulnerability (chemical) and one with medium high vulnerability (electronic consumer goods). All three cases have a high degree of influence on “their” supply chain, especially the high tech company and the chemical company.

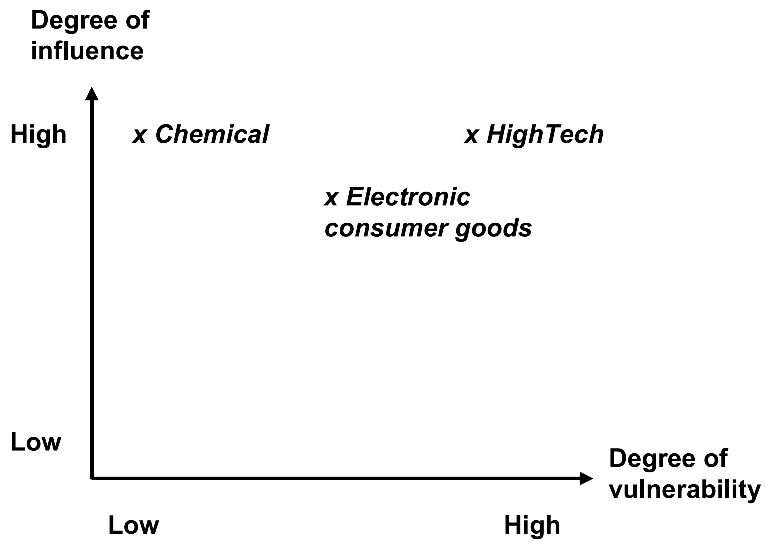

Figure 8.24: Chosen cases positioned according to degree of influence and degree of vulnerability.

The companies are in existence at present. They are, however, anonymous. No facts have been changed, but some facts have been omitted.

The three cases presented below will be illustrating the possible use of the *risk analysis models* but have no ambition to reflect the actual supply chain risks in the cases in detail. Each case starts with a short description of the *system border* of the company, then comes *hazard identification* and after that *risk exposure estimation*. Finally the case is *summed up* and *commented* upon. In the system border step, no exact project goals, ambition level, time horizon or other limitations are specified. Furthermore, the judgements are mainly made by myself. In the hazard identification step, the network structure and the main direction of the product flow are used for deciding the presentation order of the information (starting with natural resources and ending in end market).

8.4.4.2 Case Alfa

System border
Alfa is a big international company operating on a world market with advanced high tech-based products for industrial use. The rate of change in its environment is high. A number of different products are produced, but one is economically dominant, and that product, here called product x, will be focused on. Input to product x is a number of very advanced components, some of which are produced at different supply units within the company group, while others are bought from outside. Several parallel production units exist, but most of the production of product x takes place in one of the production sites. Alfa also takes care of all the marketing of the product and of its distribution.

Hazard identification
Natural resources: The natural resources necessary for producing the components are practically unlimited. They are also geographically distributed over many locations. Access can sometimes be a problem, but only temporarily.

Supply side: Some of the needed components are standard components, but most of the components are specially developed for product x. To produce them at the suppliers is dangerous since highly specialised equipment is used, and if there is a breakdown it will take considerable time to get back to normal volume again. Several of those unique components are also single sourced. Some buffer stocks exist at the suppliers. For the standard components the risks are moderate. But several of the unique components are single sourced and no parallel suppliers exist. This constitutes a clear risk.

Production: Quite large buffer stocks of components exist at the main production site. All copies of product x are produced according to customer order specification and are more or less unique. The production process can be divided into assembly, downloading of software and testing. Assembly uses standard equipment, but the other two production steps need unique, advanced equipment. No buffer stocks exist of ready-made x-products simply because you cannot have a buffer of final products in a situation where each product unit is tailor-made.

Demand side: On the demand side there are certain product assortment links, meaning that the effects of a disruption passed on to the demand side will be increased because other products in the product mix will be affected as well. Almost no buffer stocks exist.

End market: There are several other manufacturers of product x on the market, but for technical reasons it is not so easy for a customer to change over to another manufacturer (or to change back), so in the short run the customer is locked in to a certain manufacturer. Since product x is quite expensive and the investment has long-term consequences, it is very important for the customer to have confidence in the manufacturer's ability to deliver.

Risk exposure estimation

Initiating event within supply side

Quite large buffer stocks of components exist in the main production unit. There is also a certain overcapacity in the production. The security level is generally high, with a number of different security actions. The total *known result impact* for *preventive measures* is estimated to be *high*.

The preventive measures will take care of many disruptions. But for the remaining disruptions the possibilities of internal handling are limited – mainly working overtime. The *expected result impact* for *internally handled* disruptions is thus estimated to be *low*.

Disruptions that are not taken care of by preventive measures or internally handled are *passed on*. Concerning the passed on disruptions, the *expected result impact* for *until back to a stable flow* is estimated to be *medium*. Certain product assortment links exist, meaning that the effects of a passed on disruption will be increased since the demand for other products will be reduced as well. In the *short run* the customers are locked to the manufacturer and the *expected result impact* is estimated to be *low*. In the long run perspective the situation is quite different. Since a customer is locked to its supplier and since product x is quite expensive it is very important for the customer to have confidence in the supplier's ability to deliver. If this is not the case the customer will not dare to choose the supplier next time there is a big strategic investment. *Expected result impact* for passed on disruptions, *long run,* has therefore been estimated to be *very high*.

Initiating event within focal unit

The production process can be divided into assembly, downloading of software and testing. Assembly uses standard equipment, but the other two production steps need access to unique, advanced equipment. There is presently an overcapacity in production and consequently there is also a surplus of the unique, advanced equipment. The security level is also high. But there is no buffer stock of finished products, and almost all the production is concentrated to the main production site – no money is thus spent on spreading the risks on several locations. The total *known result impact* for *preventive measures* has been estimated to be *low*.

Overcapacity and possibilities for overtime exist and will lead to higher costs when used – at least the overtime. There are also some possibilities to use other production units than the main one, which will also lead to increased costs. The *expected result impact* for *internally handled* disruptions has been estimated to be *medium*.

Expected result impacts for *passed on* disruptions vary considerably. Since preventive measures and internal handling of the disruptions are limited, many of the disruptions will be passed on. Because of the assortment links the *expected result impact* for "until back to a stable flow" is estimated to be *medium*. Since the customers are locked to the manufacturer in the short run the expected result impact for *short run* is *low*. But the *expected result impact* for *long run* is estimated to be *very high* since, as mentioned earlier, it is extremely important that the customers have confidence in the manufacturer's ability to deliver as ordered, and disruptions can easily damage this confidence.

<u>Initiating event within demand side</u>
Product x is partly sold as a separate unit and partly as a part of a bigger "package" including other products as well. In the latter case a disruption in the production of some of the other products can lead to disruptions in the order flow of product x. My knowledge about those facts is however too limited for an estimation of the result impact levels. The disruptions that are imported from demand side are therefore *not estimated*.

Table 8.6: Case Alfa; Risk exposure levels.

	Known NRI from preventive measures	Expected OUTCOME structured after way of risk-handling:			
		Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension		
DISRUPTION SOURCE:			until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side	S1: High	S2: Low	S3: Medium	S4: Low	S5: Very high
Initiating event within focal unit	P1: Low	P2: Medium	P3: Medium	P4: Low	P5: Very high
Initiating event within demand side	D1: Not estimated	D2: Not estimated	D3: Not estimated	D4: Not estimated	D5: Not estimated
		Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run
	TOTAL KNOWN NRI	**TOTAL EXPECTED NRI**			

<u>Abbreviations:</u> S = from supply side, P = from production, D = from demand side, RI = risk impact, NRI = negative risk impact

<u>Risk exposure levels;</u> Very low, Low, Medium, High, Very high and Not estimated.

Commenting and summing up

Disruptions with initiating event within demand side were not estimated and can therefore not be commented upon. For the other two disruption sources the result impact levels seem generally to be low or medium with one exception, and that is the *market confidence related risk exposure levels*, which are very high. The explanation is the fear of the customer being technically locked to a manufacturer that cannot fulfil his deliveries as agreed. For *disruptions with initiating event within supply side* the main individual risk source is that the unique components customized for the Alfa company are single sourced. For *disruptions with initiating event within the focal unit* the most critical individual risk source is that almost all production is concentrated to just one site, and that this production unit contains unique equipment that it would take considerable time to replace if the production site were to be totally destroyed by e.g. a big fire. *Summing up* the discussion it can be concluded that *Alfa is exposed to serious risks*.

8.4.4.3 Case Beta

System border
Beta is a big international company operating on the European market within the chemical-technical industry. It has a number of production units around the continent. Input to its product is different types of basic chemicals. The product and the production process are relatively simple. The rate of change in the environment is moderate. The market consists of both industrial buyers and private households. Here, only that part of the company serving private households (the consumer market) is considered. Beta is mainly engaged in the production part of the supply chain, but to some extent also in the distribution and selling of the product.

Hazard identification
Natural resources: Input to production is different types of basic chemicals based on natural resources like oil and timber. The natural resources necessary for producing the needed basic chemicals are practically unlimited and distributed over many locations, but access can change somewhat. Events like flooding or strikes, for example, can cause temporary disruptions and make it necessary to change location.

Supply side: Some of the produced chemicals are flammable and there is a constant risk of fire in the factories of those suppliers, although the suppliers have taken various fire protection measures. But since there probably are several other suppliers of the same chemical, the disruption can be handled within the supply side. The suppliers also have some buffer stocks of the basic chemicals that they produce. Single sourcing is frequently used by Beta, but it is not very risky as potential alternative suppliers exist in most situations. Costs will however become higher. But Beta has deals with their suppliers based on Vendor Managed Inventory (VMI) and full economic compensation for potential shortages. VMI means that the supplier administrates the stock and assumes responsibility that the right items or raw materials are there when needed in production. So if there should be a shortage of some chemical, Beta will be compensated by the supplier for all the negative economic consequences that this shortage might have on Beta.

Production: Beta has a number of production units around the continent. Production means mixing different chemicals according to a certain prescription, tapping the mixture in cans and labelling it. The product and the production process are relatively simple. The same or similar type of product is produced at several sites and normally in 1-shift. No unique, advanced machineries or specially designed premises are needed. Some of the chemicals are highly flammable, however, and have to be treated with great care. A fire starting in one part of a production unit can also easily spread to other parts of the unit. Fire is a real danger, and some production units even have their own fire brigade. The knowledge of the personnel of how to handle input goods as well as the product itself in order to avoid fire is important, as well as knowing how to extinguish a fire.

Demand side: The products are sold through big retailer chains as well as a number of local retailers. Distribution is carried out by the help of trucks for the transportation part and warehouses at the different local retailers for the storing part. Each transport unit has limited size, and storage is done in many premises.

End market: The products are standard consumer products, where the same product is bought by a number of different customers. The different products can be sold and used more or less independently of each other, but in practice they are partly dependant on each other (assortment links). There are a number of similar, competing products on the market. Customers could easily change over to another supplier.

Risk exposure estimation is presented in Appendix 3, but the result of that estimation is presented below in Table 8.7.

Table 8.7: Case Beta; Risk exposure levels.

	Known NRI from preventive measures	Expected OUTCOME structured after way of risk-handling:			
		Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension		
DISRUPTION SOURCE:			until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side	S1: High	S2: Very low	S3: Very low	S4: Medium	S5: Low
Initiating event within focal unit	P1: High	P2: Medium	P3: Low	P4: Low	P5: Very low
Initiating event within demand side	D1: Very low	D2: Very low	D3: Very low	D4: Very low	D5: Very low
		Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run
	TOTAL KNOWN NRI	TOTAL EXPECTED NRI			

Abbreviations: S = from supply side, P = from production, D = from demand side, RI = risk impact, NRI = negative risk impact

Risk exposure levels; Very low, Low, Medium, High, Very high and Not estimated.

Commenting and summing up

For disruptions *with initiating event within supply side* the known negative result impact is high. This can be explained by the fact that Beta has chosen to have several parallel production units and also some overcapacity in the factories. Beta also has VMI agreements with its suppliers. The VMI explains why the expected negative result impacts for internally handled disruptions and for passed on disruptions-until back to a stable flow – are very low. The considerable preventive measures that are taken also explain why the expected negative result impacts for passed on disruptions are limited. For disruptions *with initiating event within focal unit* the known negative result impacts are high mainly because of the parallel factories and overcapacity created. Parallel factories and overcapacity make it possible to handle most disruptions internally, but those activities create increased costs and that it is why internal handling has been estimated to be medium. Efficient internal disruption handling means that there are few passed on disruptions, and consequently those result impacts are low or very low. We can finally note that all result impacts linked to disruptions *with initiating event within demand side* are very low. *Summing up* it can be concluded that Beta spends *a lot of money on preventive measures* and as a result enjoys *low expected negative result impacts*.

8.4.4.4 Case Gamma

System border
Gamma is a medium-sized company producing high-priced electronic consumer products of good quality with an advanced design. Input can be divided into electronic components and design-related components. Production consists of assembly and testing. The electronic components in the product have a high rate of change, while the design components change much more slowly. The market consists of a number of countries primarily in Europe. The products are sold through special shops that only sell Gamma products and have exclusive selling rights within a local area. Gamma is engaged in designing, producing and marketing their products.

Hazard identification
Natural resources: The natural resources necessary for producing the components can be regarded as unlimited and almost always accessible.

Supply side: The components related to the design are unique but not particularly difficult to produce. All the electronic components are standard components of good quality and alternative suppliers can be found. Gamma is a small buyer of electronic components, but since they are prepared to pay well for those components the supply is ensured as long as there are any on the market.

Production: The production is concentrated to only one big production site operating in 1-shift, with normally a great deal of spare capacity. In the production process, standard equipment for assembly and testing is used, and the premises are normal factory premises. If the factory were to be totally destroyed, production could therefore be started up in another site after a few weeks.

Demand side: The products are sold on many markets and through a number of retailers in each market. The sales of the different products are more or less independent of each other.

End market: Most products are built to customer order and are more or less unique. The customer probably already has an old, similar product that provides the same basic function as the one he/she has ordered.

Risk exposure estimation is presented in Appendix 3 but the result of that estimation is presented below in Table 8.8.

Table 8.8: Case Gamma; Risk exposure levels.

	Known NRI from preventive measures	Expected OUTCOME structured after way of risk-handling:			
		Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension		
DISRUPTION SOURCE:			until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side	S1: Medium	S2: Low	S3: Very low	S4: Very low	S5: Low
Initiating event within focal unit	P1: Low	P2: Low	P3: Very low	P4: Very low	P5: Low
Initiating event within demand side	D1: Very low	D2: Very low	D3: Very low	D4: Very low	D5: Very low
		Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run
	TOTAL KNOWN NRI	TOTAL EXPECTED NRI			

Abbreviations: S = from supply side, P = from production, D = from demand side, RI = risk impact, NRI = negative risk impact

Risk exposure levels; Very low, Low, Medium, High, Very high and Not estimated.

Commenting and summing up

It can be noted that all risk exposure levels with one exception are low or very low. The exception is known result impacts linked to preventive measures for disruptions imported from supply side, which is estimated to be medium. The main explanation for this estimation is the overcapacity in production. But the overcapacity mainly has to do with the existence of an annual peak in demand. So perhaps the estimation here should be low rather than medium. *Summing up* Gamma it can be concluded that *the result impacts are between low and very low*.

8.4.4.5 Concluding remarks

The three cases have illustrated that *the risk "picture" is very different* in different supply chains both when it comes to the total disruption risk exposure in the supply chain and to the risk exposure for individual boxes. The cases have also shown that the balance between known and expected result impact could vary a lot. And we have, through the production overcapacity example in Gamma, obtained an illustration of the difficulty in estimating known result impact: How much of the cost for this overcapacity is to be regarded as known result impacts for preventive measures and how much as ordinary production costs?

It can also be noticed that Gamma is exposed to quite large risks, they are though not related to the supply chain flow but to design. Advanced, bold design is the prime competitive advantage of the company, and every introduction of a new product assortment based on a new design idea is critical because Gamma can never be sure of market reaction. This illustrates that *considerable risks exist outside the supply chain* product flow. Another example of this is Beta's dependency on the weather, since this affects demand substantially.

The cases have shown that the developed risk analysis models are *useful* in mapping and estimating disruption-related supply chain risks.

8.5 RISK MANAGEMENT PROCESS: RISK EVALUATION

Risk evaluation is the second phase in the risk management process and consists of two steps: acceptable risk and analysis of alternatives.

8.5.1 **Acceptable risk**

Acceptable risk is the fourth step in the risk management process and the first in the risk evaluation phase. Now that the risk analysis phase is completed and the system borders are set, the hazards identified and the risk exposure estimated, it is time to decide which risks are acceptable and which are not.

If a specification of the level of acceptable risk has already been set in the system border step, that specification is to be applied. If not, it is time to draw up the specification now. Then we compare the set level with the estimated result impacts in order to find out which risks are not acceptable and where we thus have to search for better alternatives. The output from the model is a list of the non-acceptable risks and the information about estimated risk exposure from the previous step.

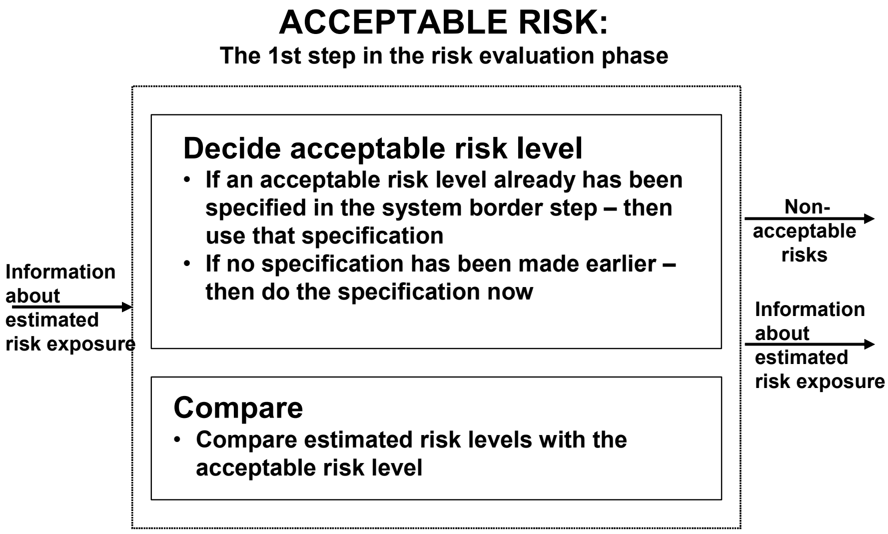

Figure 8.25: Acceptable risk model – Level 4.

8.5.2 Analysis of alternatives

After having identified what specifies the non-acceptable risks, we now try to find new acceptable alternatives by choosing one or several risk handling methods and applying them on one or more supply chain risk essentials.

8.5.2.1 Identify what is critical

Looking more closely at the risks, we often find that a few scenarios represent almost all the total negative result impacts. This means that if those scenarios can be identified, our efforts can be concentrated on them, thus substantially reducing the complexity of the problem without losing too much accuracy. Approximately how many alternatives should be considered also has to be specified.

8.5.2.2 Generate alternatives

Introduction

To generate a new alternative means to choose a risk handling method to use and a (or several) supply chain risk essentials to change. The different supply chain risk essentials were presented in Chapter 8 in the supply chain risk esentials model (Figure 8.15) and will not be further commented upon here. A number of risk handling methods will be presented below.

In the literature, the way to handle a risk is sometimes called strategy and sometimes method. The concept of strategy is however a difficult one, as it is used in so many different ways, and will therefore not be used here. Instead the concept of generic risk handling methods will be used. But inspirations for those generic risk-handling methods are *general risk strategies* that could be practised in more or less all risk situations. Each *generic risk handling method* could include a number of *individual risk handling methods* and they in their turn include a number of *specific risk handling methods*. This can be described as a supply chain risk handling hierarchy (Table 8.9).

Table 8.9: Supply chain risk handling method hierarchy.

ALL SETTINGS	**SUPPLY CHAIN DISRUPTION RISK SETTING**		
General risk strategies	***Generic risk handling methods***	***Individual risk handling methods***	***Specific risk handling methods***
An illustrative example			
Insuring	Insure	Business disruption insurance	Business disruption insurance for company x

Generic risk handling methods

Earlier in the thesis, risk strategies of three different kinds have been presented. In section 3.2.4 *general strategies,* i.e. strategies for managing risks of all kinds were presented. The main source here was Borge (2001) with his 10 general strategies. In section 3.3.6 *company risk strategies* was presented, and here the main source was Deloach (2001) who proposed five main strategies, and a number of sub-strategies, for business risks (Figure 3.17). Finally *supply chain risk strategies and methods* were discussed in section 5.5. One interesting source here is Jüttner et al. (2003), who propose four main risk mitigating strategies including a number of sub-strategies. Another interesting source is Lindroth & Norrman (2001) who identify 12 different examples of categories for risk handling in supply chains (Figure 5.12) and also give examples of individual risk handling methods for most of the categories.

Table 8.10: Overview of different risk strategy sources and their proposed risk strategies/methods.

SOURCE: RISK STRATEGIES:	**Borge (2001)**	**Deloach (2001)**	**Jüttner et al. (2003)**	**Lindroth & Norrman (2001)**
General risk strategies	Identifying Quantifying Preventing Creating Buying and selling Diversifying Concentrating Hedging Leveraging Insuring			
Company risk strategies		Avoid Retain Reduce Transfer Exploit		
Supply chain risk strategies			Avoidance -dropping… Control -vertical integration -increased stock… -maintaining excess capacity... -imposing contractual obligations … Co-operation -joint efforts for increasing supply chain visibility -joint efforts to share risk-related information Flexibility -postponement -multiple sourcing -localised sourcing	Trust Information Insurance products Futures & options instruments Sourcing strategies Allocation rules Inventory Joint investments Buy back agreements Flexibility Minimum purchase commitment Pricing

Working method

First some general strategies are presented. Here the ten general strategies for managing risks presented by Borge (2001) will be used as a starting point. The next step is to decide which of those general strategies can be of relevance to handle disruptions in *a supply chain setting with a focal unit perspective.* The result for the individual general strategy is either that it is dropped or that it is transferred and accepted.

In the latter case it is renamed to "generic risk handling method". To those transferred methods some new methods are finally added. One source of inspiration here are the sources mentioned earlier in this section dealing explicitly with supply chain risks. Finally the discussion is summed up.

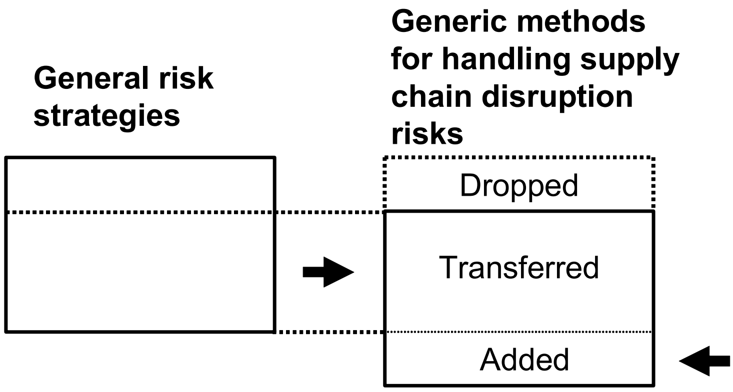

Figure 8.26: The process of creating the generic risk handling methods.

The transferred general risk strategies will eventually be renamed so that they get "labels" that cover the use of the strategies in this special setting. In one case it will also be split into several generic risk handling methods.

<u>Transferred general risk strategies</u>
To invest effort in *identifying* risks is definitely of relevance in a supply chain setting. One example could be to monitor the inbound flows to the focal unit. To *quantify* an identified risk is also relevant. In the focal unit, for example, there could be special routines for assessment of inbound flow risks. *Preventing* a risk is also relevant. For example, if the risk is related to a certain unique component, the company could redesign the product so that it includes a standard component instead of the unique component. In that way the risk is avoided. This strategy will be called *avoiding*. *Creating* risks is also of relevance. It could be the creation of a quite new risk, but it could also be an increase of an already existing risk. If e.g. the company thereby can reduce some other risk

then this might be of interest. *Buying and selling* is also definitely relevant, but it may be better to call it *transfer through contract changes* as the risk is normally linked to a business transaction the terms of which are specified in a contract. This contract also specifies how the risk and its handling should be shared between the business parties. One party may be willing to accept a bigger risk if he gets compensation for it. The other party may be willing to pay for getting rid of some of the risk. The original contract is adjusted with transfer of risks as a result. *Diversifying* is also a relevant strategy. One example is to spread production on multiple production facilities. *Concentrating* the risk is also of interest. If, for example, you have products or components that are very attractive to steal, you could concentrate storing into one warehouse and protect it very carefully instead of having several less protected warehouses. When *hedging* is mentioned one normally thinks of financial risks. Hedging means taking actions that offset the risk. Such *counterbalancing* can be found in several variants in a supply chain setting. One is *backup plans*, e.g. alternative sourcing plans for a critical component. Another one is *buffers*, e.g. a buffer in inbound stock of a critical component. Still another one is *flexibility*, e.g. in the production equipment. Also *overcapacity* could be regarded as a counterbalancing action, e.g. in production. *Insuring* finally is also of relevance, e.g. in the form of a transport insurance policy.

Dropped general risk strategies

Leveraging: Since the focus is on reducing bad outcomes and not on maximising the good, leveraging is not relevant.

Added generic risk handling methods

Accept: The most commonly used strategy is to accept the risk, which could be the effect of not being aware of the risk, not caring about the risk or, after careful consideration, accepting the risk. In the first case it is hardly a strategy but in the last case it definitely is. *General reserves*: It can be difficult to identify the risks, their consequences and ways to handle them, but we do know that when there is a disruption it will call for more resources. To build up general reserves in human and economic resources therefore creates increased possibilities to handle a disruption when there is one. *Good relations*: To build and maintain good and close relations to other partners in the chain could be regarded as a strategy because it increases the possibilities to handle the risks in the supply chain. *Organize*: Finally one could organize, e.g. give existing or new organizational units responsibility for supply chain risk issues and create suitable risk management systems and routines, which could be seen as a risk management strategy. *Protect*: Since this study is dealing with risks related to disruptions in the physical flows, it means that there is something physical like a component or a product that can be damaged or stolen. Protecting must therefore be one of the strategies. *Replace*: Sometimes replacing with something similar could be a useful strategy. A missing component, for instance, could be replaced with a similar component, especially if it is a component with higher performance characteristics. *Secure supply chain partners:* The supply chain flow is dependent on its links. From a focal unit perspective, probably some of the partners in the supply chain are critical. The potential loss of such a partner therefore constitutes a risk. Those supply chain partners have to be secured in different ways. *Training:* Risk management actions are carried through by human beings and their ability to analyse and handle different risk situations and risk events is of critical importance. *Quality assurance*: Quality assurance of processes means that it becomes more likely that those processes will run smoothly and produce material, components and products of high quality. *Quality check:* Checking the quality of material, components and products is also an important risk management strategy.

The discussion above is summed up in Table 8.11 below.

Table 8.11: General risk strategies and the generic risk handling methods.

General risk strategies (Borge 2001)	Actions	Generic risk handling methods
Identifying	OK	Identify
Quantifying	OK	Quantify
Preventing	RENAMED	Avoid
Creating	RENAMED	Create/increase
Buying and selling	RENAMED	Transfer through contract changes
Diversifying	OK	Diversify
Concentrating	OK	Concentrate
Hedging	RENAMED AND SPLIT	Counterbalance/Backup plans
		Counterbalance/Buffers
		Counterbalance/Flexibility
		Counterbalance/Overcapacity
Leveraging	DROPPED	
Insuring	OK	Insure
xxxxxxxxxxxxxxxxxx	xxxxxxxxxxxxxxxxxx	xxxxxxxxxxxxxxxxxxxxxxxxxxxx
	NEW	Accept
	NEW	General reserves
	NEW	Good relations
	NEW	Organize
	NEW	Protect
	NEW	Replace
	NEW	Secure supply chain partners
	NEW	Training
	NEW	Quality assurance
	NEW	Quality check

<u>Generic risk handling methods; a summing up</u>

The above selected generic risk handling strategies are presented below in alphabetical order. For each method, one or more practical implementations of that method are shortly discussed in a supply chain flow setting.

Accept: Accepting a risk can be done without assessment if for instance it is just a minor risk. But it could also be done after an assessment where it has been estimated that to accept the risk is the best way to handle it.

Avoid: A risk is always linked to a certain activity. The risk is avoided if you discontinue the activity. This could mean that the product is dropped, i.e. not produced. It could also mean a redesign of the product so that a critical component is excluded. Finally a redesign of the supply chain flow could also mean avoidance of a risk.
Backup plans: To have ready-made alternative sourcing plans, production plans and/or distribution plans makes it possible for the company to take quick and efficient actions if there is a disruption.
Buffers: Buffer in stock is a traditional way to handle disruption risks in supply chains. It gives the company a chance to decrease or even eliminate the consequences of a disruption. In a corresponding way, slack in lead times can be used to meet delays in the flows.
Concentrate: By concentrating your flows you can also concentrate your attention and gain more knowledge about the risks. It will also be possible to use superior solutions for risk handling. When flows are concentrated, they can be protected more efficiently when it comes to transportation, storing and production.
Create/increase risks: Creating a risk is the opposite of avoiding (see avoid) a risk; risks can be created by starting production, redesign of the product or redesign of the supply chain.
Diversify: By having multiple supply channels, production facilities and/or distribution channels the consequences of a disruption are lowered. At the same time there are also more alternatives to handle the disruption.
Flexibility: Flexibility in production mixture means the production mixture can easily be changed (but total production capacity remains the same). Flexibility in production capacity means that over time you can produce more (by the help of e.g. overtime) or less than normal.
General reserves: Building up economic and human reserves is always helpful when handling risks; this also applies to flow-related risks.
Good relations: By creating close and trustworthy relations with key supply chain customers and suppliers it can become easier to handle a disruption, and also easier to work proactively. It could also be a good idea to build good relations with different authorities.
Identify: By monitoring critical inbound, internal, and/or outbound flows you get up-to-date information about those flows and also early warnings of eventual disruptions. By regularly supervising the

surrounding world you can gain access to information of events, changes and trends that might disturb your supply chain flows.

Insure: Basically three different types of insurances are of interest: Equity insurance, e.g. fire insurance for a factory, transport insurance to cover the value of goods in the event of loss, and finally business disruption insurance, which covers the economic consequences of the company's business activities after a disruption.

Organize: Different administrative units with their staffs are probably responsible for certain aspects of disruption risks and also have certain authority concerning the handling of such risks. To reorganize units and staff and to reorganize their responsibility and authority could therefore be one method to handle the risks. Those units and staff members are dependant upon risk management systems and routines for the collection, processing, storing and distribution of risk-related information. Making changes in those systems and routines is therefore also a risk management method.

Overcapacity: Overcapacity in production means that there is a constant overcapacity in production that will make it easier to make up for a disruption, e.g. caused by a delay in inbound transport. Likewise, overcapacity on the supply side or demand side can make disruptions easier to handle.

Protect: The flow consists of assets that are transported or stored, including water, electricity, oil, telecommunications etc. They need to be protected against theft, especially if they are attractive to steal. They must also be protected against damage such as shock, water, pressure, manipulation, heat, and fire. Protection also involves other assets: buildings, machinery, information, information systems, etc.

Replace: In some instances a missing component can be replaced with another, similar component without affecting the product negatively. In such cases the replacement component often has higher performance (which is why the customers do not mind) and is therefore more expensive. Another case is when one product is replaced with another similar product with higher performance. If performance is affected negatively by the replacement, the customers may refuse it or at least ask for a price reduction.

Secure supply chain partners: Some of the business partners in the supply chain are critical for the focal unit. It might therefore be a good

idea to regularly check the financial status of those supply chain partners and assess their chances to remain in business. It might also be a good idea to consider the risk of takeovers, perhaps by one of the competitors, of critical supply chain partners or even dropouts. The disruption risk also has to be controlled.
Training: Training in how to analyse and handle different types of risk situations and critical events.
Transfer through contract changes: In a standard contract, risk is normally shared between supply chain partners in some standardized way by reference in the contract to some general terms of delivery. Transfer of risk to other links in the chain can be done by adjustments in those contracts. If e.g. there is a company buying components from a supplier and the terms of delivery are changed from Ex works (EXW) supplier's factory to Cost, insurance and freight (CIF) buyer's factory, the risk is transferred from the buyer to the supplier. Another variant is when there is a clause in the contract about supplying spare capacity i.e. the right for the buyer to buy more than normally needed and an obligation for the supplier to deliver up to the limit decided in advance. The same method can be used for production and distribution capacity. Other variants of risk sharing contracts also exist.
Quality assurance: Quality assurance of internal processes diminishes the risks and their consequences. In the same way, quality assurance of key suppliers and also customers/distributors can be a good idea. Multiple link quality assurance means that the company is executing quality assurance on more links than just first tier suppliers or customers.
Quality check: Checking the quality of input material and components is an important risk management strategy. So is the checking of product quality. Another possibility is to make the quality checks at an early stage in the supply chain. Quality checking early in the chain means that quality checking is moved upstream the chain compared to what was earlier the case. It could mean, for example, that instead of doing quality checking of components at arrival to the factory store you do it before the components leave the supplier's warehouse.
Quantify: Quantified assessment of the inbound, internal, outbound and/or total flow risks does not eliminate the risks, but it does create

better possibilities to handle them efficiently by other risk management methods.

Linked to affected risk element

Chapter 3, section 3.1.2 referred to a triplet defined by Kaplan (1997) as the answer to the three questions; What can happen?, How likely is it?, and What are the consequences? The first question was called "scenario", the second "likelihood", and the third "consequences". They will here be called triplet elements. Each one of the generic methods identified is listed below and linked to one or more of the triplet elements. The links proposed in Table 8.12 should be seen as examples of possible links.

Table 8.12: The generic risk handling methods linked to affected triplet element.

Generic riskhandling methods	
	Affected triplet element/s
1. Accept	
2. Avoid	Scenario
3. Back-up plans	Consequences
4. Buffers	Likelihood
5. Concentrate	Scenario and Likelihood
6. Create/increase	Scenario
7. Diversify	Consequences
8. Flexibility	Consequences
9. General reserves	Consequences
10. Good relations	Consequences
11. Identify	Consequences
12. Insure	Consequences
13. Organize	All three
14. Overcapacity	Consequences
15. Protect	Scenario
16. Replace	Consequences
17. Secure supply chain partners	Likelihood
18. Training	All three
19. Transfer through contract changes	Consequences
20. Quality assurance	Scenario
21. Quality check	Scenario
22. Quantify	Consequences

A short description of risk handling methods 3–4 in Table 8.12 by way of illustration:

- *Back-up plans* could mean that the consequences of a potential disruption become less severe.
- *Buffers* could mean that fewer disruptions than before will lead to negative consequences.

The different individual risk handling methods presented above are all proactive in the sense that they can be decided upon before there is a disruption. In Appendix 4, examples of individual risk handling approaches are given for each of the generic risk handling methods.

8.5.2.3 The analysis of alternatives model

Input to the model is information about *estimated risk exposure* and the *non-acceptable risks*. Output from the model is information about *considered risk handling alternatives*.

When considering if the risks could be handled in a better way in the future, we first need to decide what is critical and approximately how many alternatives should be considered.

A risk-handling alternative is presumed to consist of two parts; a chosen risk handling method and chosen element/s to change.

Each method affects one or more of the risk elements. In total, 22 generic risk handling methods and three affected risk elements have been identified. Summing up the discussion above ends up in the following analysis of alternatives model (Figure 8.27).

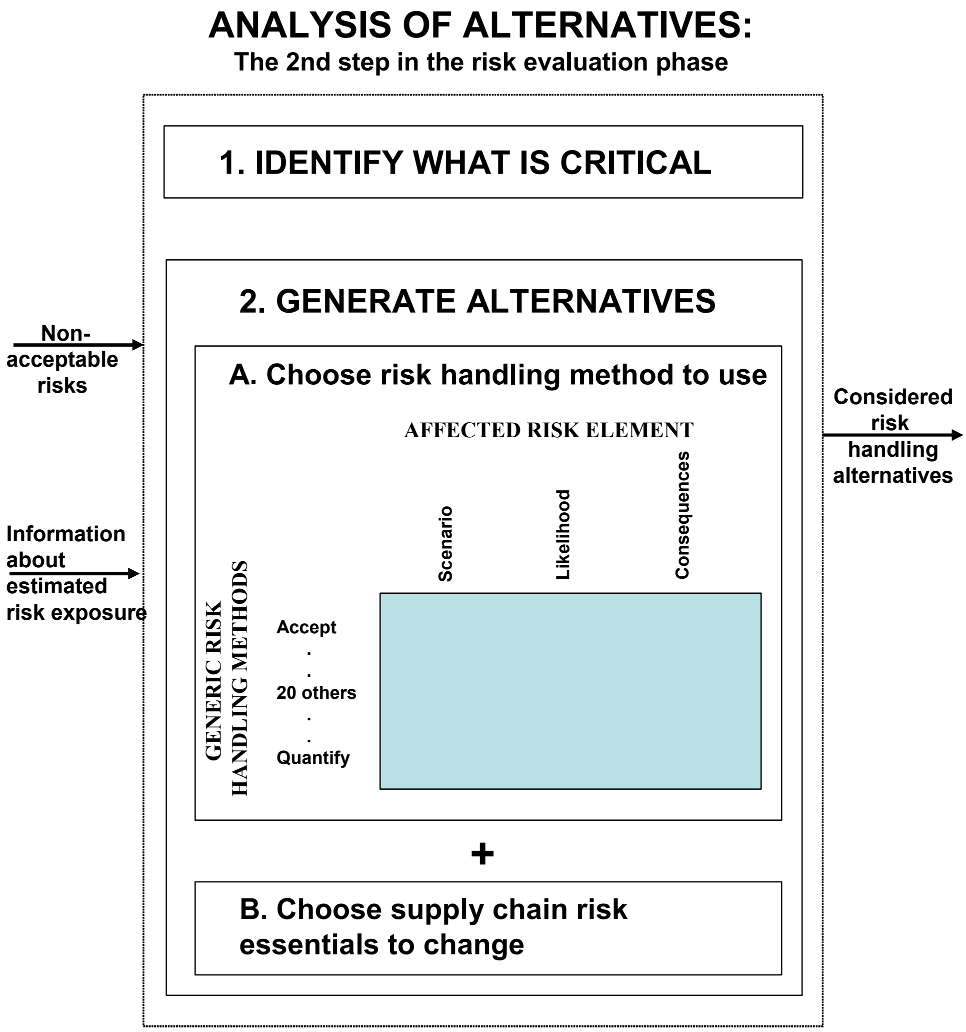

Figure 8.27: Analysis of alternatives model – Level 4.

8.6 RISK MANAGEMENT PROCESS: RISK REDUCTION/CONTROL

The risk reduction and risk control phase (Level 3) consists of the following three steps: *decision making*, *implementation*, and *monitoring*. The last two steps will not be further dealt with.

8.6.1 **Decision making**

The risk handling alternatives that have been considered are *catalogued*, and the ones that are regarded as having the best potential are selected for futher analyses. For each of those, *the marginal impact* on the expected result is estimated. O*ther aspects* that need to be regarded are here identified and also considered. Finally, the alternative that best fulfils the project goals is *chosen*.

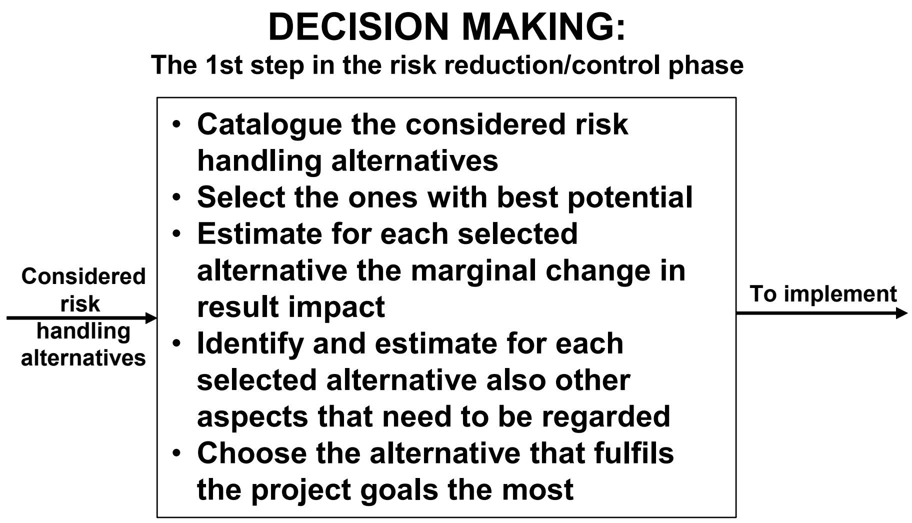

Figure 8.28: Decision making model – Level 4.

8.6.2 **Implementation and monitoring**

Implementation is the second step and monitoring the third step in the risk reduction/control phase. These steps are also important but are not treated here.

8.7 THE COMPLETE DRISC MODEL

The starting point for the model building was the top level structure for the DRISC model (Figure 8.11) presented in section 8.2, which had the following five basic elements: supply chain, supply chain environment, risk management process, framework for description and analysis, and potential disruption risks in the supply chain product flow.

Two of the basic elements – the framework for description and analysis, and the risk management process – have now been developed on one or several levels. The *framework for description and analysis* consists of supply chain network structure, supply chain risk essentials, and disruption source and handling way structure. Based on a model from IEC (1995), a *risk management process* model with three phases – risk analysis, risk evaluation and risk reduction/control – and eight individual steps has been developed. Each of the steps, except for "implementation" and "monitoring" has been elaborated on at least one further level.

When all the steps in the risk management process have been carried through and, as a result, the supply chain has been changed in some way, it has to be considered whether the risk situation is now good enough or if further efforts are needed. If the answer is no, a new risk management process "round" is initiated.

Taken together, the above constitute the complete DRISC model (Figure 8.29).

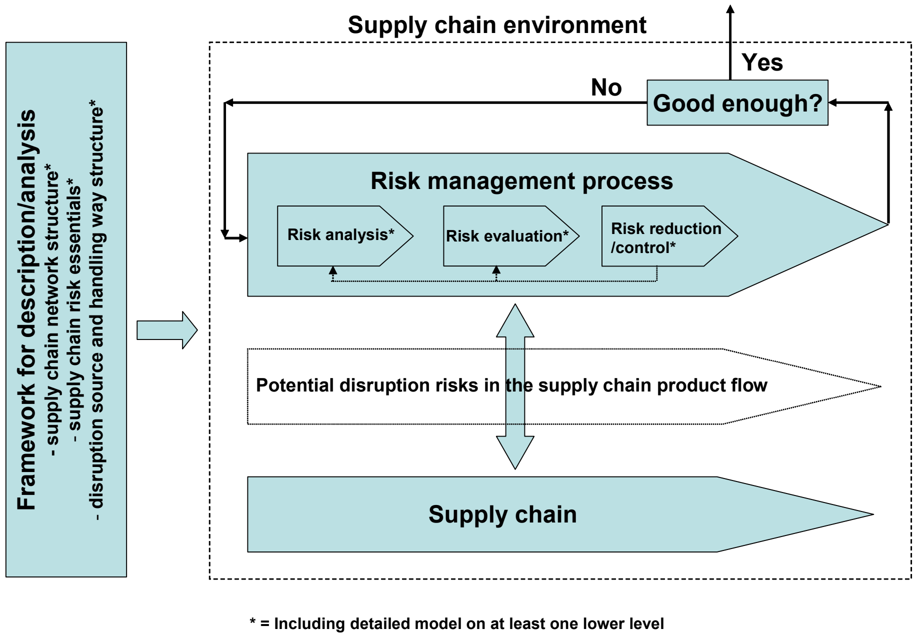

Figure 8.29: The ending DRISC model at its top level – Level 1.

It includes the following partial models;

Framework for description and analysis; Figure 8.13 (Level 2)

- Supply chain network structure; Figure 8.14 (Level 3)
- Supply chain risk essentials; Figure 8.15 (Level 3)
- Disruption source and handling way structure; Figure 8.17 (Level 3)

Risk management process; Figure 8.12 (Level 2)

- Risk analysis (Level 3)
  - System border; Figure 8.18 (Level 4)
  - Hazard identification; Figure 8.19 (Level 4)
  - Risk exposure estimation; Figure 8.23 (Level 4)
- Risk evaluation (Level 3)
  - Acceptable risks; Figure 8.25 (Level 4)
  - Analysis of alternatives; Figure 8.27 (Level 4)

- Risk reduction/control (Level 3)
  - Decision making; Figure 8.28 (Level 4)

In Appendix 5 the complete DRISC model, including all its partial models, is presented in concentrated form.

9 ***TESTING THE DRISC MODEL***

In this chapter the DRISC model is tested in two different ways; by being applied on a live case and by a survey to risk managers. The results of those testings are then discussed. Finally reflections on the usefulness of the DRISC model are made, including a critical look at the use of the model.

9.1 TESTING METHODS

There are two different testing methods; application of parts of the DRISC model to a case (Brämhults) and a survey sent to a group of risk managers presenting the complete DRISC model.

In *case Brämhults* the risk analysis phase with its three steps/models (system border, hazard identification and risk estimation) is applied on the situation before and after the installation of a pasteurizer, and changes in "risk pattern" are described and analysed. Finally the changes are also briefly described by the help of the risk essentials model (Figure 8.15).

The *survey of risk managers* includes a short presentation of the total DRISC model, illustration of the use of the model by the help of the Brämhults case and a questionnaire.

9.2 BRÄMHULTS JUICE

The substance of this section is based a visit to the premises, including an interview with the quality manager in August 2006 supplemented with information from a Master's thesis[90], the website of the company[91] and a PowerPoint presentation of the company and its risks[92]. The situation first described below is the one that existed before the installation of the pasteurizer in May 2005.

9.2.1 **Before the pasteurizer**

9.2.1.1 Basic facts

The company

Brämhults started at the end of the 40s as a small company producing freshly squeezed carrot juice for the local market. The juice was not chilled and had very limited shelf life. At the beginning of the 70s, Brämhults started to chill the juice to just a few degrees Celsius immediately after squeezing it. This increased the shelf life to about 5 days. From the mid-90s, the company also produces other juices than carrot juice in the only squeezing machine for citrus fruits in Sweden. But no matter what kind of juice, the philosophy is "as fresh and as natural as possible".

The company is very keen on keeping a high and even quality of their products. Within a few hours from squeezing, the fresh juice is delivered by the company's own refrigerated trucks to the different stores and their refrigerated display cabinets.

The company has a turnover of about 170 million SEK (about 20 million Euros) and, until a few years ago, was family-owned but is now part of Mellby Gårds Industri AB – a middle-sized conglomerate. The company

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[90] Ohlsson, D. & Svensson, S. (2005) *DOSS – Värderingsmodell för riskerna vid tillverkning av flytande livsmedel*. Master's Thesis in Technology Management. Lund University.
[91] www.bramhultsjuice.se. 2005-08-25.
[92] Tylestrand, Ulf (2005-02-05) PowerPoint presentation of Brämhults and its risks at a SIK meeting in Lund.

has about 100 employees, most of whom are employed within sales and distribution.

The products

The products are freshly squeezed juices that do not contain any preservatives, most of them in 1 litre bottles. Carrot juice was the original offering and, for some decades, the only kind of juice. It is still in the assortment, which now also includes a number of other juices and products:

- Freshly squeezed juices: Made from fresh fruits. The temperature to be kept is between zero and 5 degrees. Shelf life up to ten days.
- Healthy liquids. Made from fresh fruits (juices) with a natural additional healthy contribution like ginseng. The temperature to be kept is between zero and 5 degrees. Shelf life up to ten days.
- Smoothies: Made from four different kinds of fresh fruit that are crushed and mixed. The temperature to be kept is between zero and 5 degrees. Shelf life up to ten days.
- Fruit liquids: Made from fresh frozen juices. The temperature to be kept is between zero and 5 degrees. Shelf life up to ten days.
- Fresh frozen juice: Made from fresh fruits; the juice is frozen immediately after it has been squeezed. The temperature has to be kept at minus 18 degrees or lower. Shelf life up to one year.

The product flow

In Chapter 8 a figure (Figure 8.14) of the supply chain network structure was presented. This figure will be used here as a basis for the presentation of the supply chain flow for Brämhults.

Natural resources

Nature in the sense of natural resources is here mainly the land and the soil producing the fruits.

Supply side
The fruits are mainly bought from traders and to some extent also directly from producers that are located both within Europe and outside it. The freight is paid by the supplier, and the transport is also arranged by the supplier. For a number of reasons the quality of the fruit can change in an unforeseeable way. One factor is changing weather conditions, which can affect the accessibility and the quality of the fruits.

Production
The company has in its premises a small stock of fresh oranges and other citrus fruits covering a couple of days' need. The juice is squeezed during night time and chilled and distributed early in the morning. Production is customer driven, and no stock of finished products exists. This means that everything that is produced during the night has already been sold and will be distributed during the day.

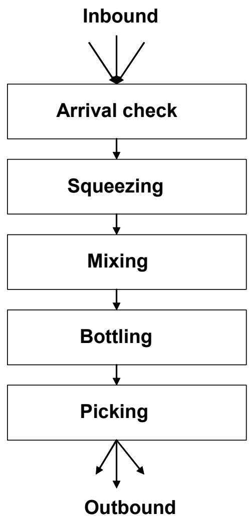

Figure 9.1: Brämhults; Production flow with internal activities (Based on a PowerPoint-presentation by Ulf Tylestrand, dated 2005-02-04).

In the figure above, production is described as consisting of five different production steps; arrival control, squeezing, mixing, bottling (bottle) and picking.

Demand side (distribution)
The company sells its products in Denmark, Finland, Norway and Sweden. The fresh juice is delivered to the different stores and their refrigerated display cabinets by Brämhults' own refrigerated trucks driven by their own drivers (except on the Finnish market, where distribution is bought from a third party). The products have to be kept cool during the whole chain from production to consumption, because the juices are not pasteurized, which means that they might contain bacteria that could easily multiply if the temperature rises too much. If the juices are kept at the right low temperature, between zero and 5 degrees, they are guaranteed to stay fresh for 10 days. Within this period of time, the bottles should be distributed to the shop, stored at the shop, bought by an end customer, brought to the home of the end customer, stored again and finally consumed. This is the main reason why the company only sells its products in geographically nearby markets (i.e. the Scandinavian countries).

End market
End customers are mainly the different individual consumers (private households) that buy the juice in the shop, but there are also a few big customers (e.g. an airport) that get the juice directly delivered to them.

9.2.1.2 Risk analysis

The risk analysis phase consists of the three steps – system border, hazard identification and risk exposure estimation. For each step a model has earlier been developed.

System border

The system border model was specified in Figure 8.18 and will now be applied on Brämhults.

The *focal unit* is Brämhults and the *focal product* the fresh juices produced by the company. The *time horizon* is 2005 up to the installation of the pasteurizer in May 2005. The *project goal* is to map and evaluate the risks before the pasteurizer was installed. One *limitation* is that the fresh frozen juice will not be included, as its risks probably differ considerably from the other products in the assortment. Nor will carrot juice be included, because it remains un-pasteurized and has very short shelf life. The Finnish market will not be included in this study due to the use of a quite different distribution mode in that country than in the other Scandinavian countries. Finally it should be mentioned that I, in collaboration with the company, have made the *judgements*.

Hazard identification

Hazard identification was summed up in Figure 8.19. That model is now applied here. The aim of the mapping is to collect information about potential risk vulnerability and to identify present risk management activities. The vulnerability sources and risk management activities identified are presented below in a compact version. A more complete version can be found in Appendix 6.

Potential sources of vulnerability
Changing weather conditions like heat, cold or an unusually dry period can drastically reduce the supply of citrus fruits, and so can natural disasters like flooding and hurricanes. Wrong deliveries and late arrivals could also cause problems. The fact that the bottle is unique and single sourced is another cause of vulnerability. There is only a small buffer stock of packages and an almost non-existent one of citrus fruits. Moreover, there is just one production unit with one production line. A disruption in production could not be mitigated by buffer stocks of finished products, since there are none at the factory and only a limited stock of juice covering a couple of days' demand at the shops. If Brämhults juice is not on the shelf, there is a risk that the customer will buy a competitor's product instead — and like it.

The risk of spoiled juice is a special case. Not only will the quality of the product be affected if mistreated, but there are also contamination risks meaning that people actually could get sick, although the risk is very small. If a shipment containing bad fruit is not discovered on arrival, it might enter production and cause contamination problems since the juice is not pasteurized. But the major problem is the cold chain, which has to be maintained from production throughout the whole distribution. There are a number of risk sources. One is that the shops may not pick up the delivered juice immediately and place it in refrigerated display cabinets. Another risk source is that the temperature may be too high in the refrigerated display cabinets in the shops. Yet another one is that customers may regret buying the product while they are still in the shop and just put it back on an ordinary shelf or leave it at the cashier's counter. Then it might occasionally take some time until the juice is put back in the refrigerated cabinet. Spoiled products might thus be on the shelves in the shops and be bought by customers.

There are also a number of risk sources after the product has been sold in the shop: too high temperature during the end customer's (consumer's) transport from the shop to the refrigerator in his/her home, too high temperature in the end customer's refrigerator or in another place where the customer leaves the juice for a period of time, e.g. on the kitchen table.

The customer's personal experience of the spoiled juice means that s/he might hesitate to buy the product in the future even if s/he likes it. Information about spoiled juice from external sources like newspapers or television might also mean that customers feel apprehensive about buying the product in the future even if they have not had any problem with bad juice themselves.

Risk management activities
Brämhults tries to buy all their fruit from certified producers. They also have specific routines for the arrival check of the fresh fruits, e.g. visual control of the fresh fruit and returning those fruits that do not live up to the required quality level, or occasionally taking a sample of the fruit and sending it to a test laboratory for analysis.

In production, Brämhults has specific routines for sorting away those fruits that do not live up to the required quality level. There are also specific routines for the cleaning-up of the machines (but no central cleaning-up function). There are also certain routines for handling customer complaints, which can provide indications of quality problems in production.

On the demand side, there is direct distribution from factory to the individual shop with Brämhults' own trucks driven by their own drivers. There are also routines for the drivers to check the quality of the products on the shop shelves and, finally, routines for picking up and taking back bad products belonging to batches that do not live up to the quality standard.

Risk exposure estimation

Risk exposure estimation was discussed in section 8.4.3 and the discussion was summed up in a risk exposure estimation model (Figure 8.23). The result impacts at Brämhults will now be estimated by means of a five-level ranking (very high, high, medium, low and very low) and the motivations for each estimation are given.

Initiating event within supply side (S)

Facts

- Electricity is bought from the ordinary local distributor. Brief disruptions can occur, but since Brämhults is situated in a middle-sized town, disruptions longer than a couple of hours are very unlikely.
- Water is bought from the local water authorities, who test the quality of the water regularly. A pipeline might break, but delays longer than a day or two are unlikely.
- The citrus fruits are bought from a number of different suppliers, and alternative suppliers are always at hand.
- The bottles are unique and of Brämhults' own design. They own this design as well as the unique forms that are used to produce the bottles. There is only one supplier of the bottles, which are

produced in Ullared about 100 kilometres away. If the production facilities in Ullared were destroyed, it would take considerable time to start up a new production – about six months. It would take about as long to change over to another supplier. By outsourcing the bottling step, however, it would be possible to change over to ordinary Tetra Pak packages much faster.

- Juice is the only product produced by Brämhults, and they cannot easily change over to another kind of production.
- Fresh juice is a sensitive product, especially since it could easily get spoiled.

<u>Estimations with motivations</u>

Preventive measures (S1)

There is a buffer stock of bottles for some weeks' need. The small buffer stock of citrus fruits covers just a couple of days' need. There are also specific routines for the arrival check of the citrus fruits. There are, however, no reserve alternatives for water supply or electricity supply and no buffer stock of finished products (juice), and there is just one production site and one production line. The total *known result impact* for preventive measures has therefore been estimated to be *low*.

Internally handled (S2)

The buffer stocks of juice and bottles deal with some of the disruptions, but far from all of them. Certain minor disruptions in the magnitude of a couple of hours can be handled internally through overtime work. But since there is just one production unit and one production line and no buffer stocks of juice, there are, in other words, almost no possibilities to deal with incoming disruptions internally. They have to be passed on to the demand side. The total *expected result impact* has consequently been estimated to be *very low*.

Passed on; until back to a stable flow (S3)

Since the preventive measures are limited and the possibilities of handling disruptions internally are small, the disruptions from supply side will to a considerable extent be passed on to the demand side. In the case of non-deliveries, there will, of course, be no revenues. The fleet of trucks and drivers will also become idle, because it cannot so easily be used for other purposes in the short run. In the case of a delivery of spoiled juice and subsequent complaints, the cost for taking back the product also has to be added. The expected result impact is estimated to be *medium*.

Passed on; Short run (market patience) (S4)
If Brämhults juice is not on the shelf in the shop, there is likely to be a category of customers who will postpone their purchase of juice until Brämhults juice is back again. But most of the customers will probably temporarily choose another brand instead, and it might be a while before they change back to Brämhults juice again, even though Brämhults is the only fresh, un-pasteurized juice on the market. So sales will be lost, and there will be a partly idle truck fleet as well. If the juice is spoiled and the customer finds out about it only after the purchase, s/he can go back to the shop and return the product. But the customer might instead simply throw away the spoiled juice. In both cases, the customer will probably avoid buying the product for a period of time. Also, the supply market (the supply side) can react in a way that makes the economic consequences of a disruption worse by e.g. giving Brämhults a lower quantity discount than otherwise. Considering all the factors mentioned above, the expected result impact has been estimated to be *high*.

Passed on; Long run (market confidence) (S5)
If Brämhults juice is not on the shelf, there is a risk that the customer will buy a competitor's product instead and find that s/he prefers it, which means that Brämhults will lose that customer permanently. In the case of spoiled juice, there are different alternatives. The customer's personal experience of spoiled juice means that s/he might avoid buying the product in the future. Other people's bad experiences can have the same effect, even if the customer likes the product and has not had any problem with bad juice personally. Another alternative is the negative consequences of information from external sources like newspapers or television about spoiled juice. The resultant anxiety can become very strong and have a long-lived effect and spread to other juice brands as well. This could mean that the Brämhults brand is severely damaged with a considerable drop in sales on a long-term scale, and Brämhults is

the only brand of the company. The supply side can also have an impact on the consequences in the long run by e.g. offering Brämhults less favourable prices in the future, since the company has now become a less attractive customer. The expected result impact is therefore estimated to be *very high.*

Initiating event within focal unit (production) (P)

<u>Facts</u>

- It is a matter of non-advanced products and production.
- There are a few, rather simple, production steps, which are conducted by means of standardised, relatively uncomplicated machines. This makes it possible to handle potential breakdowns rather easily and quickly.
- One production unit with just one production line creates inflexibility and thus vulnerability.
- Wrong handling of the machines and shortcomings in the quality control can lead to contamination of the juice during the production process.

<u>Estimations with motivations</u>

Preventive measures (P1)

There are routines for quality control of the finished product (juice) and routines for introducing and training new staff members, but no other preventive measures. The known result impact has therefore been estimated to be *very low*.

Internally handled (P2)

Re-planning of the production schedule for the day and/or working overtime can handle disruptions of up to a couple of hours – but not more. In other words, the internal risk handling possibilities are very limited. The expected result impact has been evaluated to be *very low*.

Passed on disruptions (P3-5)

The risks costs for the different passed on disruptions (P3, P4 and P5) are the same as for S3 to S5, but since the likelihood is judged to be lower, the estimation of the expected result impact is one step lower.

Initiating event within demand side (D)

<u>Facts</u>

- Fresh juice is a "sensitive" product, and the cooling chain has to be maintained all the way from production site to end customer.
- There are four possible weak links in the chain: distribution from the production site out to the different shops, storage at the shop, the customer's transport of the juice from the shop to his/her home and, finally, storage of the juice at the customer's home.
- The negative reactions to spoiled juice will probably be very much the same no matter where in the total supply chain the juice is spoiled before consumption.
- The accessibility of the product in the different shops can be affected by e.g. a wild strike among transport workers.

<u>Estimations with motivations</u>

Preventive measures (D1)

The fresh juice is distributed from the factory to the different shops by the company's own drivers and refrigerated trucks. The drivers have special competence and interest in maintaining the cold chain. This way of distributing the juice can partly be regarded as a preventive measure. The drivers also check whether the quality of the juice on the shelves in the shops is satisfactory. Finally, the drivers return the juice that shops or customers have complained of. The expected result impact has been estimated to be *low*.

Internally handled (D2)

There is very little that Brämhults can actually do if there is a sudden drop in orders, and consequently the expected result impact is *very low*.

Passed on disruptions (D3-5)
The expected result impact for the different passed on disruptions (D3, D4 and D5) are estimated to be at the same level as for S3, S4 and S5.

Summing up and commenting on the estimations

Table 9.1: Brämhults; Risk exposure levels BEFORE the pasteurizer.

	Known NRI from preventive measures	Expected OUTCOME structured after way of risk-handling:			
		Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension		
DISRUPTION SOURCE:			until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side	S1: **Low**	S2: **Very low**	S3: **Medium**	S4: **High**	S5: **Very high**
Initiating event within focal unit	P1: **Very low**	P2: **Very low**	P3: **Low**	P4: **Medium**	P5: **High**
Initiating event within demand side	D1: **Low**	D2: **Very low**	D3: **Medium**	D4: **High**	D5: **Very high**
		Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run
	TOTAL KNOWN NRI	**TOTAL EXPECTED NRI**			

Abbreviations: S = from supply side, P = from production, D = from demand side, RI = risk impact, NRI = negative risk impact

Risk exposure levels; Very low, Low, Medium, High, Very high and Not estimated.

There are few preventive risk-handling actions, and consequently the known result impacts are low. Since the juice is fresh, the possibilities to handle a disruption internally are nearly non-existent, and therefore the result impacts are very low. Accordingly, almost all disruptions have to be passed on, and this is where the main expected negative result impacts will be found. They are: until back to a stable flow about medium, in the short run about high and in the long run about very high.

In conclusion, it is worth mentioning that two major individual risk sources have been identified:

- one is spoiled juice and, especially, the long-term effects that hidden quality problems can have on market confidence; and
- the other is the unique bottle, which is characteristic of Brämhults juice. Single sourcing in combination with a limited buffer stock of bottles and a long start-up time if the production facilities for the bottle are destroyed can make it necessary to bottle the juice in standard packages, e.g. Tetra Pak packages, for

some period of time. The problem, however, is that the customer might not recognize the product.

9.2.2 After the pasteurizer

The description and analysis below is based on the situation in August 2006 – about 15 months after the installation of the pasteurizer in May 2005.

A pasteurizer is a machine in which the juice in this case is heated to 70–72 degrees Celsius for about 30 seconds, thereby eliminating many of the micro-organisms that might contaminate the product.

9.2.2.1 A short survey of the changes

- The pasteurizer installed by Brämhults eliminates almost all possible bacteria, both those in the incoming fruit and those that might have been added through contamination during the production process.
- This has reduced the number of returns and withdrawals by about 90 %.
- It has also prolonged shelf life from 10 to 18 days.
- The prolonged shelf life has made it possible to change from distribution by the company's own drivers and lorries to all the different shops over to transport to a limited number of DCs (distribution centres) belonging to different retailer chains, which then take care of the distribution to the individual shops themselves.
- There was a change in operating costs for operator, heating, service and other costs related to the pasteurizer that led to a limited increase in the annual operating costs.

9.2.2.2 Changes in risk exposure estimation

Initiating event within supply side (S)

Preventive measures (S1)
The investment in the pasteurizer leads to lower distribution costs and reduced risks of spoiled juice. The latter means that the cost of the pasteurizer is partly to be seen as a known result impact. The pasteurizer takes care of both incoming fruit of bad quality and of the risk of contamination during the production process, or rather reduces them considerably. The estimation of total *known result impact* for preventive measures has therefore gone up one level from low to *medium*.

Internally handled (S2)
It is still only minor disruptions of the magnitude of a couple of hours that can be handled internally (through overtime work). The total *expected result impact is* consequently still estimated to be *very low*.

Passed on; until back to a stable flow (S3)
The risk that the juice is spoiled has been practically eliminated by the installation of the pasteurizer. It eliminates almost all the bacteria that can enter with the fruit, and consequently there is a much lower number of potential disruptions. The expected result impact is therefore estimated to go down one level from medium to *low*.

Passed on; short run (market patience) (S4)
After the installation of the pasteurizer, the likelihood that the juice will be spoiled is now much lower. The expected result impact has therefore been estimated to go down from high to *medium*.

Passed on; long run (market confidence) (S5)
Since the risks of spoiled juice formed a considerable threat to the Brämhults brand and the attractiveness of its products, there is now, after the installation of a pasteurizer, a considerable change downwards in the result impacts related to market confidence. The expected result impact is therefore estimated to go down two levels, i.e. from very high to *medium.*

Initiating event within focal unit (production) (P)

Preventive measures (P1)
The pasteurizer also eliminates potential bacteria that have entered during the first part of the production process. Consequently, there will be considerably fewer potential disruptions. The cost of the pasteurizer is thus partly to be regarded as a preventive measure and some of its costs as known result impact. Some of the costs for training the staff to operate the machine also have to be included. The known result impact has therefore been estimated to go up two levels from very low to *medium*.

Internally handled (P2)
The possibilities of internal risk handling are still very limited, and the expected result impact has been estimated to be unchanged, i.e. *very low*.

Passed on; until back to a stable flow (P3)
As S3, but no change in the result impact level, which had already been estimated to be *low*.

Passed on; short run (market patience) (P4)
As S4, but since the likelihood is judged to be lower than for the disruptions imported from supply side, the estimation of the expected result impact is also lower – more precisely one step lower, which in this case means that it is estimated to go down from medium to *low*.

Passed on; long run (market confidence) (P5)
As S5, but since the likelihood is judged to be lower than for the disruptions imported from supply side, the estimation of the expected result impact is also lower – more precisely one step lower, which in this case means that it is estimated to go down from high to *medium*.

Initiating event within demand side (D)

Preventive measures (D1)
Brämhults' own drivers and their own refrigerated lorries no longer distribute the juice to the shops. The result impacts have thus gone down, and therefore the estimated result impact level has been lowered from low to *very low*.

Internally handled (D2)
There is still very little that can be done concerning internal handling, and the result impact level remains *very low.*

Passed on disruptions (D3-5)
The result impacts for the different passed on disruptions (D3, D4 and D5) are estimated to be at the same level as for S3 to S5.

Summing up and commenting on the estimations

Table 9.2 presents the estimated risk exposure levels after the installation of the pasteurizer. The estimations before the installation are given within brackets.

Table 9.2: Brämhults; Risk exposure levels AFTER the pasteurizer (before within brackets).

	Known NRI from preventive measures	Expected OUTCOME structured after way of risk-handling:			
		Expected RI from *internally handled* disruptions	Expected RI from passed on disruptions upstream/downstream with includation of market reaction and considering time dimension		
DISRUPTION SOURCE:			until back to a stable flow	in the short run (market patience)	in the long run (market confidence)
Initiating event within supply side	S1: **Medium** (Low)	S2: **Very low**	S3: **Low** (Medium)	S4: **Medium** (High)	S5: **Medium** (Very high)
Initiating event within focal unit	P1: **Medium** (Very low)	P2: **Very low**	P3: **Low**	P4: **Low** (Medium)	P5: **Medium** (High)
Initiating event within demand side	D1: **Very low** (Low)	D2: **Very low**	D3: **Low** (Medium)	D4: **Medium** (High)	D5: **Medium** (Very high)
		Total expected RI from internally handled	Total expected RI from passed on; Until back to a stable flow	Total expected RI from passed on; In the short run	Total expected RI from passed on; In the long run
	TOTAL KNOWN NRI	**TOTAL EXPECTED NRI**			

Abbreviations: S = from supply side, P = from production, D = from demand side, RI = risk impact, NRI = negative risk impact

Risk exposure levels; Very low, Low, Medium, High, Very high and Not estimated.

The investment in a pasteurizer is partly to be seen as a risk handling action – a preventive measure. The known result impacts are therefore now medium for two of the three disruption sources. The result impacts for internally handled disruptions are still very low. Almost all the result impacts that are linked to passed on disruptions have decreased and are now low for "until back to a stable flow" and about medium for the rest.

There are still two major individual risk sources, but one of them is new:

- The first risk source is the unique package – *the bottle* – where nothing has changed.
- Since the juice is now pasteurized, the risk of spoiled juice causing a drop in market confidence has been more or less eliminated under the condition that the pasteurizer is properly operated and maintained. If this is not the case, the consequences could be even more severe than before, since e.g. the best-before date has been prolonged by eight days and their own drivers and lorries no longer carry out distribution. Hence, pasteurizer *maintenance and operation* has become a new major risk source.

9.2.2.3 <u>The changes linked to the supply chain risk essentials model</u>

In Chapter 8, Figure 8.15, a supply chain risk essentials model, including six different risk essentials, was presented. This model will be used here to describe the consequences of the installation of the pasteurizer.

First of all, the *product design* has changed from fresh, un-pasteurized juice to pasteurized juice with a number of new qualities. The taste is different, shelf life is longer and sensitivity to contamination is considerably lower. The *process design* has also been changed, since a pasteurization step has been added to the production process. The prolonged shelf life has made it possible to gradually change distribution from direct distribution to the shops over to distribution to a limited number of DCs. Another consequence is fewer returns and withdrawals. The *product flow design* has thus been changed. Instead of a large number of small customers, Brämhults now has mainly a few big ones, which has consequences for invoicing, for example. Thus the *product flow supporting* systems have also been affected. Since the juice is now pasteurized, the number of products that are spoiled has decreased considerably, and the potential returns are carried out by the big food chains themselves. On the other hand, routines for the handling and maintenance of the pasteurizer have been introduced and added. The pasteurizer has to be cleaned in the correct way. The right temperature, flow and detergent concentration in the cleaning system are necessary when tanks, pipes and pump station, bottle machines and pasteurizer are cleaned. Consequently, the *risk management systems and actions* are also affected. It is of great importance that the personnel that handle the pasteurizer have the right competence for that task. On the other hand, the company has almost no need for drivers any longer. The effects on the *human resources* are considerable.

It is thus worth noticing that, at a closer look, a change that was initially regarded as a change in product and process design turns out to have *affected all the six different supply chain risk essentials.*

9.2.3 **Comments on Brämhults**

Different changes in the risk "picture".

- Changes in both known result impacts and expected result impacts.
- Changes in all three disruption sources: initiating event within supply side, initiating event within focal unit, and initiating event within demand side.
- An increase in two result impact levels and a decrease in nine.
- Before the installation of the pasteurizer, the risk levels related to market confidence were high or very high, whereas after the installation they are all medium.
- There has been a change towards comparatively more known result impacts and less expected result impacts, since all the increased cost levels concerned known result impacts and all the decreased cost levels concerned expected result impacts.

- However, since there is no "weighting" of the different result impact boxes and their different levels, we cannot say whether the total result impacts in the supply chain have increased or decreased.
- The investment in the pasteurizer paid for itself already during the first year through the substantial drop in returns of spoiled juice. This is reflected in Table 9.2 in the change in result impact levels from medium to low in boxes S3 and D3 (*until back to a stable flow*). The risk levels for the *short run* and for the *long run* have also been lowered.

Economic consequences

- The investment in the pasteurizer was about 2 million SEK.
- There was a limited increase in the annual operating costs of about 800.000 (400.000 operator, 120.000 heat, and 280.000 service and other related costs)
- The costs for returns and withdrawals caused by spoiled juice were before the pasteurizer about 6 million SEK annually. After the installation of the pasteurizer they dropped by about 90 % to about 0,6 millions annually.
- The pay-back time for the investment was thus about 5 months (2 millions/4,6 millions per year).
- But the pasteurizer also prolonged shelf life from 10 to 18 days, thereby making it possible for Brämhults to change from distribution by the company's own drivers and lorries to all the different shops over to transporting to a limited number of DCs (distribution centres) belonging to different food chains.
- If we split the investment 50/50 on risk and on distribution we will get a pay-back time concerning the risk part of the investment of only 2 to 3 months.
- Included in the costs for returns and withdrawals are only the direct, immediate costs. If the negative effects of disruptions on future sales are also considered the pay-back time will be even shorter.

Observations of special interest

- This case/case study has stressed the importance of "hidden" disruptions, i.e. the fact that the initial disruption in the form of a deviance in quality is identified only in a later link in the chain, which leads to more serious consequences than would otherwise have occurred. The worst case is when the quality problem is discovered only after the end customer has used the product for some time.
- This case/case study has also stressed the importance of market confidence for products that are directly linked to people's well-being but where there are other alternative products that could fulfil the same basic needs.

Further possible risk management improvements

- Develop a contingency plan for the unique bottle, probably including copies of the unique bottle form kept in a safe place away from the supplier's production site.
- Add more brands so that Brämhults juice is not the same as the company Brämhults. That will make the company Brämhults less vulnerable especially to market confidence-related disruptions.

9.2.4 **Model adjustments**

When the risk exposure levels before and after the pasteurizer were presented to the company in August 2006 the *passed on disruptions* were split on the three time dimensions "until back to a stable flow", "short run" and "long run", but not on the three disruption sources "supply side", "focal unit" and "demand side". The company stressed though that it was of interest to be able to see the passed on disruptions split up *both* on the three different time dimensions *and* on the three different disruption sources. So this adjustment of the model was made, and it meant an increase in the number of risk exposure boxes from 9 to 15.

9.3 SURVEY TO RISK MANAGERS

9.3.1 Survey method

In 2007, towards the end of the research project, a survey of 20 selected risk managers was conducted. The survey included a one-page introduction letter, a questionnaire with 12 questions (Appendix 7) and a 13-page DRISC model presentation (Appendix 8). In the beginning of the DRISC model presentation was an executive summary that shortly reflected on the needs and the aims of the model given. At the end of the presentation a summary of the application example Brämhults juice was given.

The purpose of the survey was to get a limited test of the usefulness of the model and indications of possible adjustments of it. To reach that goal it was enough to get the opinions from just a handful of risk managers. To this can be added that the DRISC model is quite complex and therefore each respondent needed to spend some effort to understand it before all the questions in the questionnaire could be answered. If each of the selected risk managers knew that they were one in a very limited group of respondents and their opinion mattered a lot, it was regarded as much more likely that they would spend time and effort on analysing the DRISC model and answering the questions. Consequently only 20 risk managers were selected.

The risk managers were chosen in such a way that there were representatives from companies, organizations and authorities. Examples of these areas are IT, pharmaceuticals, medical service, logistical service, insurance, and consultancy.

9.3.2 Survey results

Six risk managers answered the questions. Some answers were short and some were comprehensive. Most answers were directly addressed to each individual question, while one answer was inspired by the questions but more general and not directly linked to the individual question. The answers were treated anonymously.

One of the respondents said that the DRISC model was of limited interest to themselves because of the special kind of activities that they perform, but stressed that the model definitely was of interest to many others.

Another respondent said *"To me the DRISC model appears to be a part of RM! RM is the overall structure – the fundamental framework, not one of five basic elements. The model is though highly applicable on that part of RM that deals with business interruption, caused among other things by disruptions in the supply chain [my translation]".*

A third respondent started by giving some more general comments on the DRISC model. This respondent said *"I see it as a valuable contribution to a structured and consistent way of dealing with this important and difficult area"*. A few sentences later the respondent went on saying *"A general remark is that the term risk now is used in so many meanings, both in layman´s language and in science, that I recommend to use more specific terms to avoid the r-word. Use severity, probability, frequency, exposure, deviation etc. and define your terms".* The respondent also said *"I see this "model" as a tool for the "risk assessment process" in "business continuity management", a part of risk management that seems to have developed as a "stand alone" discipline, which I resent, actually".*

Question 1. When you perform a risk analysis, which models or guidelines do you use?

One respondent said that they were using a model based on a mix between the Australian standard and the FERMA model. Another said that their model was based on a framework for risk handling by COSO, and that most of the risks were identified as obstacles to reach the goals set. A third respondent said that they were not using any specific risk model when doing Supply Chain Disruption risk analysis. Still another concluded that "*A risk analysis focusing interruption risks or business continuity which seems to be the favourite term today must always start with a flow chart. Depending on the scope and objective you go as far upstream and downstream as needed. Interdependencies are of course one area of key interest to identify. In the flow chart or starting from there, there is a multitude of tools that can be used ranging from fire risks to failure in product design or adapting to customers´ preferences"*.

Question 2. What is good and what is less good or missing with these models/guidelines?

One comment was that it was positive that the model was so simple but that it had to be complemented with more specific risk analyses to be complete. Another respondent said that *"The model is quite simple and easy to understand, but as all other models, rather hard to spread and get acceptance for in the organisation"*. A third respondent said that *"it is always good to have a defined and consistent structure. The flow as such is pretty much generic and self-evident. There is a structure suggested and I see it as workable. The point is to define it and use it consistently. It is as much a way of communication as anything else"*. The same person also stressed that it was a good thing that the model distinguished between determinable costs and expected costs, and that the dissolution of each "focus" goes far enough, but also observed that *"I am a bit concerned that completely unrelated events or factors are overlooked"*. Still another respondent stressed that it was crucial to be able to consider changed prerequisites. Those two answers illustrate an imperfection that probably all models have more or less: How do we know in an ever changing world that our model includes all relevant risks?

Question 3. What do you think research and development of supply chain risks should focus on?

One respondent said *"The focus on Supply chain Disruptions Risk is increasing as our company is trying to minimize the lead time to customer, the delivery is more and more to be just in time"*, and went on to say that *"Supply Chain risks is probably considered as one of the top threats as we also have a few key supplier"*. This author also referred to a survey done by FM Global where it turned out that the most significant threats to many UK-based companies were Supply Chain Risks. Another respondent pointed to the fact that there are alternatives to auditing; *"The make sure there are solid processes to evaluate the third party dependence when it comes to all relevant risks that might cause bad impact on our business, e.g. access to a secure raw material process , existing quality system in progress etc. I think it's very common the industry relies on assurances rather than audit them on a regularly basis"*. A third respondent was not satisfied with the concept of supply chain risk management and said; *"Now, what is supply chain risk management?"* And went on to say, *"So it is generally not advisable to invade other professional areas under the label of risk management"*. This person also concluded that *"There are surely models to develop but there are more than enough of those as it is. The key in risk management is to implement rather basic measures, to make things happen. That is management"*.

Question 4. Is there anything in the DRISC model that is obvious and could be deleted?

One respondent simply answered no, and another, *"No the model reminds about the traditional way to work with Risks and risk and threat identification"*. A third one said that *"DRISC is in itself generic and "obvious". One of the points is to explain this specific application, determine the structure and define its terms. Therefore nothing should be deleted"*.

Question 5. Is there anything in the DRISC model that is unclear and should be clarified?

Two of the respondents answered no, and a third suggested that the model is relatively complex and might be possible to simplify. A fourth commentator basically agreed but added, *"But no doubt there seems to be some need for elaboration on the risk assessment bit, for general understanding. If anything seems misty here it is probably the "triplets". I am also critical to the stated elements in table C, that are debatable. The same goes for the "ways" of risk treatment and the various "costs". They are highly interrelated. Anyway it is good to develop such an "account plan""*.

Question 6. Do you feel the lack of anything in the DRISC model that should be added?

None of the respondents had anything to add here, which is reassuring, but the small number of respondents must not forgotten.

Question 7. Is the terminology used in the DRISC model comparable to the terminology that you yourself use? If not, please point out the deviations.

One respondent said a clear yes, and two said yes but had something to add. One added that the concept "system border" was unfamiliar, another that the concept "Back up plans" preferably could be replaced by the concept Business Contingency Plan, as this includes both an Emergency Plan and a Business Recovery Plan. Another respondent said that they were not using the concept "supply". Still another said that *"The language feels in part to be somewhat home-grown. On the other hand, no one can monopolize the terminology, although attempts to do that occur all the time, leading to endless (academic) discussions. The terms are understandable but please not my first remarks. Some terms may should be more 'harmonised' (export vs transfer e.g.)"*.

Question 8. What other similar models or frameworks are you familiar with? Please make references.

One respondent said none. Another said that they *"have adopted a mix between the FERMA RM standard and the Australian ditto. That sets out a strategic process, starting with an organisation's overall objectives and aspirations, through to the identification, evaluation and mitigation of risk, and finally the transfer of some of that risk to an insurer"*. A third respondent pointed to the fact that large consultancies develop their own tools, e.g. SW.IRMA which is a tool for the presentation and monitoring of interruption risks in the process industry. The respondent also mentioned that *"The company Palisade offers a number of sophisticated tools for representation of a business process and probabilistic analysis of events and their impacts on the performance. These models can be used also for intellectual processes"*.

Question 9. How would you like to position the DRISC model in relation to other models within the area? Similarities and differences?

One respondent said *"DRISC is concentration on a more detailed and specified way to identify and handle risks. If you compare with our model that focuses on the company as whole with all our risk categories, they are quite similar"*. Another respondent said that *"There are many models and tools and I would rather describe the model here as follows. It gives a generic but specific structure (a scenario approach) and can be combined with other special tools or models as needed. It can as such be used as a framework in many ways, from quick overall analyses to detailed calculations. It is not per se a numerical computer model but can be developed into or combined with such models"*.

Question 10. How can the DRISC model be useful for you and your company/organisation?

One comment was that the DRISC model could be useful in specific risk audits but not as an everyday tool. Another was that it *"can be helpful in all the ways it is intended to be by the author"*. A third one that *"It would make it possible to do a systematic assessment on risks and it would be helpful when presenting the conclusion"*.

Question 11. How can the DRISC model be useful for your colleagues within the risk management profession?

Here one of the respondents stressed that *"If we use the same tool everybody would understand how it work and what reference that should be used when applying it to different risks"*.

Question 12. What other persons do you suggest we should send these questions (including the presentation of the DRISC model) to?

One respondent suggested that the questionnaire could be sent to Risk Managers in other companies, and another one suggested to a selection of members of SWERMA[93].

9.3.3 Model adjustments

First we have to remember that there were only 6 answers and that even if we had received all the 20 answers we would not have known if those 20 individuals were representative of the risk management profession.

It seemed that the respondents, although they had some criticisms e.g. of the use of certain concepts, all agreed that the DRISC model was an understandable model that could be useful for different kinds of risk

[93] SWERMA stands for Swedish Risk Management Association.

audits. A couple of model adjustments were also proposed, and some of the suggested adjustments have been carried through. One is the recommendation to define the concept "risk" and other critical concepts in the project. Another is to avoid the concept *export*. That concept has now been replaced by the concept *passed on*.

9.4 REFLECTIONS ON THE USE OF THE DRISC MODEL

9.4.1 **A critical look at the model**

The DRISC model is based on a number of *assumptions*. If the supply chain studied does not fulfil those assumptions, the usefulness of the model is reduced accordingly. Clearly stating the assumptions on which the model is based makes it easier for a presumptive user of the model to judge its value in a certain situation. The model is one among a number of risk models that can be used to analyse supply chain risk issues, and it should be seen as a complement to existing risk models. Using a generic model such as the DRISC model can be a way to quickly and with limited resources get a rough idea of the risk situation. The model can also be used for more comprehensive analyses. Whatever the use of the model, it is necessary to be careful because using models creates new risks – for instance the risk that one *believes too much* in the accuracy and usefulness of the model.

9.4.2 **Level of abstraction**

Different levels of risk models can be identified. If risk is studied from the point of view of a single company/organization/unit, as is done in the DRISC model, there are on the top level – level one – "Corporate risk handling models" i.e. models that include *all* kinds of company *risks* like political risks, financial risks, flow risks, market risks. These models are on a very high level of abstraction. Level two can be said to include all company risks of a certain type, e.g. all financial risks. We can go downwards like this until we reach the level where, using Kaplan's risk definition, the risk consists of *just one scenario*. The DRISC model is an example of a model on level two: "Total supply chain product flow risks model", i.e. a model that includes all disruption risks affecting the focal unit in the product flow in the total supply chain of a focal unit.

Not only do the risks differ between different levels; the possibilities to handle them also vary, as the levels are very much linked to the authority levels in the company. An example of this is the risk of having all production concentrated in just one factory. On a higher authority level this risk can be eliminated through the split of production on two or more different factories. On a lower authority level this handling alternative does not exist. We are here restricted to solutions like increased security and better fire equipment – solutions that can decrease the risk somewhat, but only marginally compared to the solution of creating two or more separate production units. Risk handling at the wrong authority level tends to be inefficient.

9.4.3 **Application examples of the DRISC model**

The DRISC model helps to treat supply chain flow risk issues systematically. The human brain has limited capacity to receive, store and process information. The developed model *assists* through its relative simplicity *the decision maker* in grasping the complex, integrated system that most supply chains tend to be today.

The model can help to indicate *where the highest risks* are and where it consequently might be most fruitful for the focal unit to seek more information and probably also to take risk handling actions. The model can also help to stress the *differences in "risk patterns"* between different supply chains. Furthermore the DRISC model can facilitate the illustration that risks that from the *perspective* of a certain single link are limited can be huge seen in a supply chain perspective. This is specially the situation when there is a *multiplier effect* for disruptions passed on from link to link in the supply chain that amplify the consequences.

Aspects that are stressed in the model are *market patience* and *market confidence*. For some products market confidence is of no or very little importance, while for other products it is of huge importance where lost market confidence even could mean the end of the existence of that supply chain.

The model can be useful in many other ways, too. Application of the model can for instance reveal that there is a *lack of information* about the risks in the supply chain and how they are handled. It can also reveal a *lack of awareness* among the supply chain members of the risks and how they are handled, or reveal that there is a lack of responsibility for some of the supply chain risks.

If risk handling actions within the present supply chain structure cannot reduce the risk level enough, it might be necessary to *restructure* the whole supply chain, to *leave* that supply chain for another supply chain or even *to stop producing that product*. Also in this situation the DRISC model can be of assistance.

The DRISC model can be used as a tool *to start dialogues around supply chain risk issues,* dialogues which could yield information of perceived risks and ideas on how to handle those risks. And it can be used as a *conceptual basis* for the long term risk management work in an organization.

Last but not least it should be stressed that the above applications are valid for use by the focal unit both *on its own* and in *co-operation* with supply chain partners.

9.4.4 **Intended users of the DRISC model**

Intended user of the DRISC model is primarily the *individual company/organization/unit* in the supply chain, but it could also be *a supply chain group*, i.e. some of the supply chain members together, or the total supply chain, i.e. *all the supply chain members* together. The last alternative is probably seldom the case unless the supply chain is very uncomplicated with few links. But the second alternative is very relevant, not at least against the background of the ideas of partnership and closer relations between supply chain members. The model could also be used by stakeholders *outside the supply chain* e.g. presumptive investors that want to judge the risk level for different investment alternatives, or authorities e.g. a municipality that wants to judge the risk that the local paper mill, the biggest employer in the area, will have to close down.

9.4.5 **Different application possibilities for the model**

First of all the DRISC model can of course be used in its *original version*. But as will be shown below it can also be applied in *a number of other ways*.

The model is on a high level of abstraction, but the basic concepts and structures in the model can easily be applied on *lower abstraction levels as well*. If one e.g. believes that the risks on the supply side are of special importance, the supply side can be split up into e.g. three sub-parts (1st tier suppliers, 2nd tier suppliers and 3rd tier suppliers) and then the same basic principals can be applied on each of the tiers.

It is also possible to focus on just a certain *part of the supply chain*. For instance to focus on just production, or even just a single production unit (factory). We can then describe the flow within that factory as a number of links (units) with transfer points between them.

Finally, it is also possible to use only *a certain part of the model* (and not the complete DRISC model), as for instance only the hazard identification step.

SECTION IV

10 CONTRIBUTIONS AND FINAL REMARKS

In this final chapter the results of the study are summed up and compared with the purpose and objectives set in Chapter 1. The main results for each of the two objectives are then discussed. After that the development of supply chain risk management as a research area is commented upon. The chapter concludes with some reflections about this study and suggestions for further research.

10.1 CONTRIBUTIONS

10.1.1 Have the research objectives been fulfilled?

The purpose and the two objectives of the study were presented in section 1.2.2.

The *first objective* was to identify, structure and summarize the state of the art on supply chain disruption risks. This was carried out in *Chapters 3 to 7*. The *second objective* was to develop and test a generic, aggregate model for managing disruption risks in the supply chain. This was presented in *Chapters 8 and 9*.

The *purpose* of the study was to contribute to our knowledge on how to manage disruption risks in the supply chain. The purpose has been fulfilled by the achievement of the two objectives.

10.1.2 **The state of the art review**

Empirical experiences

In all the presented cases there are supply chain flow-related risks, but the risk sources are of different kinds and the disruptions have more or less serious consequences. The way the risks are handled also differs a great deal, as well as the degree to which the company is acting proactively. The rapidly increased importance of integration risks in the supply chain flow does not seem to have been matched by an equal increase in awareness, and definitely not in risk handling actions and risk management. The focus appears to be mainly on separate, limited risks, and they are handled with traditional risk handling methods. This behaviour is also supported by the tendency to split the risk responsibility between many different individuals and departments – nobody really has responsibility for the integrative risks since they tend to cross the existing organizational boundaries.

Theoretical knowledge

Risk and *risk management* seem to be theoretical areas within which there is solid knowledge within a number of applied fields. There may be quite big differences between the different fields, but within each field there is a consensus about how to define, identify, assess and manage risks. Risk management *in companies* has by tradition mainly focused on individual, separate risks and presented suitable handling methods for each such risk. But increasingly an interest in integrative risks has arisen, and theories covering such risks are now being developed. *Supply chain management,* which stresses integration between the different links in the chain, is a rather new but today well established theoretical area. There exist a number of separate knowledge “pieces”, but also a core of established knowledge. The theoretical area of *supply chain risks* also deals preponderantly with separate, clearly definable risks, but an increasing desire can be noticed to study the risk consequences of increased integration in the supply chain. *Supply chain risk management*, finally, can be seen as a new, exciting theoretical area under rapid development, at present without any common, solid base of knowledge but with several interesting “islands of theories”.

General needs for new research

Within the risk area, a number of different concepts, theories and models exist side by side. This makes the creation of a common stock of knowledge and comparisons of results more difficult (Kloman, 2003). Today there is obviously a *lack of common risk theories and models*.

The present dynamic society brings with it some dramatic changes of the conditions of industrial risk management compared to the stable conditions of the past. Organisations, as well as society as a whole, will therefore in the future need to have access to more knowledge about risks and methods/strategies to handle them, and they will need to become more *proactive* (Rasmussen & Svedung, 2000). To be able to act more proactively, more knowledge is needed.

This *gap between existing needs and existing knowledge* is widened further by the rapid pace of change of technology in our modern society within all domains, not least at the operative level. This pace of change is much faster than that in management structures at present. Today the risk management methods in use are basically the traditional ones. But in the dynamic and integrated society of today with its new risks, those risk management actions have to be complemented and perhaps even replaced by new ones (Rasmussen & Svedung, 2000). And there are some new and heightened possibilities to handle the risks. One example is by using new information technology. But to be able to exploit those possibilities fully, and manage risks more effectively and efficiently, *new risk management theories and models are needed.*

Need for new supply chain risk management models

In a world with increasingly integrated, complex, lean, global and changing supply chains, the need for *generic supply chain risk management models* has increased. And there is today "*a considerable lack of conceptual research providing a framework for interorganizational risk management in supply chains"* (Kajüter, 2003, p. 325). Such generic models may have different scopes, structures and levels of ambition, and we will now look into what seems to be especially important.

First of all, the generic model ought to be *general* i.e. applicable in many different situations. This means that it ought to be usable for many different disruption risks and in many different situations, and also by different companies, organisations and other stakeholders interested in supply chain flow risk issues. Next, the model ought to have a *pre-perspective* because it is *before* a disruption occurs that the risk situation really can be affected, including its negative consequences. The model also needs to be able to include the *total supply chain* and not just two or three links, because the most important risks in the supply chain might be those following from high integration of links in the chain. There is also a need for *assistance in finding new solutions.* Since we live in a rapidly changing world, the risk situation is constantly changing, and therefore we need to repeat our risk analyses frequently. Our present risk handling activities may easily become obsolete. Guidance about what main options are available and how they affect risks could facilitate the work of managing risks. Finally it should be possible to utilize the model *with limited efforts* in time and other resources. This means that the model should be easy to understand and operate, and from this follows that it needs to have limited size, clear logic, and a consequent use of concepts. “Easy to use” also means that all the different negative consequences ought to be measured with the same scale, which should be one that everyone understands.

So what seems to be especially important in attacking the present lack of theoretical frameworks within supply chain risk management is to develop generic models that are *general* and *proactive* and that with *limited efforts* can provide a picture of the risk situation in the *total supply chain* as well as assist in *finding new solutions* to the main risk problems.

10.1.3 **The DRISC model positioned**

The importance of having a supply chain risk perspective and include the whole supply chain from nature to market is often stressed in journal articles and other literature, but few examples of such models exist – at least when it comes to supply chain flow disruption risks. The DRISC

[Disruption Risks in the Supply Chain] model, including its partial models, developed in this study addresses the whole supply chain from nature to market. It is a model based on the setting of a focal unit with a focal product practising a supply chain perspective. The latter means that the focal unit must regard the optimal performance of the total supply chain, and that risk-handling solutions ought to be developed and implemented in co-operation with supply chain partners.

The DRISC model is thus a *holistic* and *generic model* for managing disruption risks in the supply chain product flow that helps to treat supply chain risk issues systematically. It can be used in a number of different ways and by different users as a tool for *more effective and efficient* supply chain risk management work.

The *test* of the DRISC model on the Brämhults *case* showed that the model was of value for identifying, structuring and estimating the supply chain risks and for giving an overall picture of the risk exposure situation. The *survey* of risk managers confirmed that. It seemed as though the respondents, although they had some criticisms e.g. of the use of certain concepts, all agreed that the DRISC model was an understandable model that could be useful for different kinds of risk audits.

How then is the DRISC model *positioned* vis-à-vis other models dealing with supply chain disruption risk issues? We will take a look at other research contributions and classify them with the help of the two dimensions "supply chain scope" and "risk/opportunity scope".

Since supply chain issues are being dealt with, a triad is the minimum requirement when it comes to supply chain scope. Fahlén (1997) studies triads because his delimitation is from first tier supplier to first tier customer. Svensson (2000) deals here with the whole upstream part of the supply chain. In Svensson (2001), the focus is both upstream and downstream. In Peck et al. (2003) disruption risks in the whole supply chain are studied. The same can be said about the first three parts of the article by Norrman & Jansson (2004). Others that also deal with disruption risks in the whole supply chain are Gaudenzi (2005) and Kleindorfer & Saad (2005).

Some researchers do not restrict themselves to disruption risks but include other types of supply chain risks; see e.g. the articles by Johnson (2001), Lindroth & Norrman (2001) and Kleindorfer & Van Wassenhove (2004).

Finally, there is a group of research contributions that also include other than risk aspects – those aspects will here together be called "opportunities". In the fourth and concluding part of Norrman & Jansson (2004), the discussion is widened to logistics in general, where risk is only one of several dimensions. Asbjörnslett & Rasmussen (2005) also include aspects other than risk in their model – a model that was especially developed for the maritime logistics chain.

Below (Table 10.1) the DRISC model is positioned in relation to those other research contributions within the area of supply chain risk management with the help of the two dimensions "supply chain scope" and "risk/opportunity scope".

Table 10.1: The DRISC model related to other research contributions.

Supply chain scope: **Risk/opportunity scope:**	Triad	Supply side	Demand side	Door-to-door chain	Whole supply chain
Disruption risks in the supply chain	F, 1997	S, 2000 S, 2001	S,2001		Peck, 2003 N&J, 2004 G, 2005 K&S, 2005 **DRISC**
Supply chain risks generally		J, 2001	J, 2001		L&N, 2001 K&W, 2004
Opportunities and risks in the supply chain				A&R, 2005	N&J, 2004

The research contributions that have most similarities with the DRISC model are thus Peck et al. (2003), Norrman & Jansson (2004), Gaudenzi

(2005), and Kleindorfer & Saad (2005). A closer look at each of these will now be taken.

Peck et al. (2003) cover the whole supply chain with the help of four risks, since the fifth risk is the supply chain environment. For each of the risks are discussed what factors are affecting it and how the risk could be handled. No attempt to quantify the risks is made.

Norrman & Jansson (2004) discuss the risk management work at Ericsson. Mapping is done for a number of links upstream and partly also downstream. The company works with the identification of individual risks and tries to grasp their business value impact (BVI). To simplify the analysis, BVI is split into four categories: severe, major, minor and negligible – each category representing a certain economic interval. Also the probabilities are judged by the help of a limited number of classes. Individual major risks are thus categorized according to impact and probability, but no attempt is made to summarize risk values or to cover all risks.

Gaudenzi (2005) stresses the identification of a focal unit as the starting point of risk analysis. The focus is on the handing over (transfer) point and the fulfilment of the perfect order. Different deviance possibilities of the perfect order are discussed, and different risk handling methods presented. Methods for partial quantification are also discussed.

Kleindorfer & Saad (2005) present ten different principles for efficient management of disruption risks in supply chains. No attempt is made to quantify the risks.

The DRISC model is an aggregate model that explicitly includes all product flow-related disruption risks in the total supply chain. The DRISC model also presents a partly new structure for risk analysis and risk evaluation of supply chain flow risks, and suggestions for how to manage them.

10.2 FINAL REFLECTIONS

10.2.1 **Supply chain risk management – an expanding research area**

Reason (1997) stressed the need to have a balance between production and protection. Through single sourcing, for example, you can increase the productivity in the chain but you will probably also increase the disruption risks. An increased focus on production efficiency and effectiveness thus needs to be balanced by an equally increased focus on how to handle disruption risks in the supply chain. Consequently, the more the competition between supply chains increases, the more will *supply chain risk management issues be emphasized.*

> *"They were the effects of a systematic migration of organizational behaviour toward accident under the influence of pressure toward cost-effectiveness in an aggressive, competitive environment. Consequently, the first step toward a proactive risk management strategy will not be to predict and avoid exotic causes of accidents, but to ensure operation within the design envelope".*
> (Rasmussen & Svedung, 2000, "Proactive Risk Management in a Dynamic Society", p. 14)

In Chapter 1 and especially at the end of Chapter 4, a number of trends were mentioned that tend to make the supply chain more vulnerable. The article survey in Chapter 5 added further vulnerability causes like natural disasters, terrorist threats, rapid consumer demand changes, and shorter product lives. Today in many regards we certainly have a more complex and vulnerable society than before. This means that, for different reasons, supply chains and the individual links in those chains now tend to be exposed to new kind of risks. It is therefore reasonable to believe that in the future there will be an increasing interest in supply chain risk management issues, not only regarding practical applications but also as a research area, a conclusion that also is reached by other researchers within the area, like Jüttner et al. (2003):

"…we believe that it is an academic responsibility to establish supply chain risk management as an important, if so far neglected, area of applied research."
(Jüttner et al., 2003, "Supply Chain Risk Management: Outlining an Agenda for Future Research", p. 209)

10.2.2 Suggestions for further research

A new and expanding theoretical area, like supply chain risk management, guarantees the emergence of many interesting research topics. Only a few will be indicated here.

First can be mentioned a more thorough *state of the art* study of supply chain risks. For instance, would it be interesting to update the search for scientific journal articles after 2003. The area is huge and expanding.

The DRISC model has here been presented as a non-mathematical model, but has the potential of being expressed in equations.

There are many possibilities to enrich the DRISC model by *integrating it with models from other researchers.* One such interesting possibility is the four-level model for analysis of the sources and drivers of supply chain risks (Peck, 2005, p. 218), which was presented earlier in section 5.4.1.

Models like the DRISC model can become very complex if you want to have high result accuracy. But the ambition level has to be balanced against the time and resources that management is willing to spend on the application of the model and on the presentation of its results. It would be very interesting to know more about what *variables affect the magnitude of time and resources* that management is willing to spend on supply chain risk management models.

A number of generic *risk-handling methods* are presented in the DRISC model. It would be interesting to discuss for each of them in *what situations* they can suitable be applied.

The integrative risks are stressed in the DRISC model, and at the same time it is noticed that most supply chains and companies are "organized" according to principles that spread the integrative risks over a number of responsibility units, which could in the worst scenario lead to no one really thinking that integrative risks are their responsibility. It would be of great interest to study *which ways of organizing address the integrative risks* the best.

It would also be interesting to know more about the size and the character of *integrative risks in different kinds of industries* and perhaps also link them to different risk handling methods.

Business risks and other organisational risks are in most situations considered in relation to the opportunities with which they are linked. In the DRISC model this is done indirectly and very late in the risk management process through the request "identify and estimate for each selected alternative also other aspects that need to be regarded" in the decision making model (Figure 8.28). It would therefore be interesting to enlarge the present DRISC model into a new one that more explicitly includes *opportunities*. Other researchers like Norrman & Jansson (2004) and Asbjörnslett & Rasmussen (2005) have already included opportunities in their models Legislation is also showing interest in opportunities. Company risks have long been recognized in many laws. For instance, in many countries today it is compulsory to include risk assessment in the annual report of a public company. Germany has had legislation (Kontra G) since 1998 making it mandatory to mention risks. But from January 1, 2005 there is a new law (Bilanzrechtsreformgesetz (BilReg)) in Germany making it compulsory to present *both the risks and the opportunities.*

10.2.3 **Concluding remarks**

A supply chain consists of a number of independent companies/organizations/units, and there is always the question of who is going to do what. Obviously there is a risk that the individual link will take a narrow perspective and expect others in the supply chain to assume the overall perspective and responsibility.

In Chapter 4, section 4.1.3, there was a discussion of the fact that there are situations where it is “natural” for one of the companies in the supply chain to dominate because it has control over some strategic resource like raw material, production technology, brand, or market knowledge. In other situations where there is no natural supply chain leader, there could nevertheless, for one reason or another, be one company that takes most of the strategic and co-ordination decisions. For such situations, models like the DRISC model could be of great interest.

But it could also be valuable in situations where no single company dominates and even for a single company with a very weak position in the chain. There are always actions to take within the company itself to reduce those risks, and if those actions are not enough to create an acceptable risk level, there is in most cases the possibility to change over to another supply chain. And ultimately there is always the option of simply leaving the market.

The link in the chain that has the best possibilities to handle a risk, e.g. by taking preventive measures, seldom has the motivation to fully do so simply because the main negative consequences of a disruption spreading to other links are often taken by other links and not by the link that "caused" the disruption. This *lack of incentive* makes the supply chain more vulnerable and consequently less competitive – at least in the long run – than it would otherwise have been. What is needed is the implementation of a *“disruption causer pays-principle”*, like the “polluter pays-principle” that exists within the environmental area. Implementation of such a principle for the focal unit on e.g. the supply side would mean that there are two equal alternatives. Either the flow of e.g. components is normal and the focal unit can hopefully make a profit on it, or the flow is disturbed and the focal unit can get full compensation from the disruption causer, e.g. a supplier not delivering on time, for the negative economic consequences that the disruption has caused it, including lost profit. The two alternatives would be “equal”, and the focal unit indifferent. This *“indifference principle”* can be said to apply in the case of Beta with its VMI-agreements on the supply side, but that kind of agreement seems to be an exception. The incentives for the individual link in the chain to take fully actions that would reduce the overall supply chain risks are simply seldom present today. This makes it necessary for the individual company itself to pay attention to the disruption-related supply chain risks – both the direct and the indirect ones.

The DRISC model developed here underlines the integrative risks in the supply chain and stimulates the individual link in the chain (the focal unit) to pay attention to and act in the best interests of the total supply chain, and to find and implement risk-handling solutions in co-operation with its supply chain partners while simultaneously looking after its own welfare. The model helps to make risk management holistic, structured and explicit, and is thereby hopefully *contributing to a more efficient and effective managing of supply chain disruption risks.*

And managing risks is of critical importance to our society.

> *"The capacity to manage risk, and with it the appetite to take risk, and make forward-looking choices, are the key elements of the energy that drives the economic system forward."*
> (Bernstein, 1996, "Against the Gods – the remarkable story of risk", p. 3)

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SURVEY ANSWERS
Six different risk managers answered the questionnaire.

INTERVIEWS
About 25 different individual interviews in connection to the different cases (the mini cases, the descriptive cases and the Brämhults case)
.

Appendix

APPENDIX 1: METHOD FOR SELECTING JOURNAL ARTICLES WITHIN SUPPLY CHAIN RISK

Search for articles
Only published scientific journal articles are considered because only they have fully passed the quality control executed by the journal. Only articles written in English have been considered. English is the leading language for international scientific journal articles.

The search for articles has been conducted in several different ways.

1/ Through searches in databases
The searches were carried through in July and August 2003.

1A/ Articles have been searched for in *ELIN@Lund*[94]. The alternative "All fields" has been chosen, which means that the concept/s should exist in the "Title, Journal title, ISSN, Author, Key words or Abstract". No time restrictions (all years). Search in "all" collections i.e. e-Journals, Ebsco Databases, IEE/IEEE Proceedings, e-Print archives, ABI/Inform Database and IEE/IEEE Standards. The searches have been conducted on the concept

- Supply chain risk management *(1 hit)**

And on the following combinations of concepts:

- Supply chain management + Risk management *(20 hits)**
- Supply chain + Risk management *(55 hits)**
- Supply chains + Risk management *(28 hits)**
- Supply chain + Risk *(260 hits)*
- Supply chains + Risk *(156 hits)*

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[94] Elin@Lund is the electronic library information navigator of Lund University in Sweden. In April 2003 ELIN had, via agreements with a very large number of publishers and other information providers, access to about 10 million records.

- Logistics + Risk *(336 hits)*
- Supply chain + Risks *(116 hits)*
- Supply chains + Risks *(67 hits)*
- Logistics + Risks *(123 hits)*
- Business continuity management + Supply chain *(No hits)*
- Business continuity management + Logistics *(No hits)*
- Business continuity planning + Supply chain *(1 hit)**
- Business continuity planning + Logistics *(No hits)*

1B/ A search directly in the database *ABI/Inform*, which seemed to be the most relevant database, was also conducted, on the combination of the two concepts "Supply chain" AND "Risk management" (42 hits).

1C/ A search in *ScienceDirect* (Elsevier database for research journals) on the combination of the two concepts: "Supply chain" AND "Risk management" (31 hits).

1D/ A search in *Scirus* (Elsevier database for scientific information only) on the alternative "journal articles only", "Exact phrases". Search on the combination of the two concepts: "Supply chain" AND "Risk management" (143 hits).

1E/ In the beginning of September 2003 a "My Elin" on the five search profiles marked with an * in search a/ above was created. This means that information about new references in the updated databases that match the search profiles are sent over automatically by e-mail.

These different searches in databases had resulted in October 2003 in more than 1200 hits. Many of them were duplicates.

<u>**2**/ Through searches in journals</u>
The contents of each number of *five central journals within the areas of Supply chain management, Logistics and Purchasing* was looked through for the period 1990 (or if the journals starting year was later, the starting year) - up to August 2003. The chosen journals were:

- European Journal of Purchasing and Supply Management (Started 1994*)*
- Journal of Business Logistics (Started 1990).
- International Journal of Logistics (Started 1998).
- International Journal of Physical Distribution and Logistics Management (Started 1970).
- Supply Chain Management: An International Journal (Started 1996).

3/ Through the ISCRIM network

Articles have *also* been found through the ISCRIM (International Supply Chain Risk Management) network[95]. Partly through their workshops, partly through their newsletter which is distributed four times a year and partly through personal contacts within the network.

All the search activities had resulted in October 2003 in about 400 unique articles.

Selection of articles

Step 1: Trade journals were excluded. And only "hits" with a specified author mentioned were considered.

Step 2: A look at the title and if it seemed as if the article could deal with some aspect of "supply chain risk management" the abstract was looked through. If the abstract also seemed interesting, the full text version was if possible printed out.

After this step 141 articles were still found relevant. 131 of them were printed out in a full-text version. 10 have not been possible to get a full-text copy of yet.

[95] More information about the ISCRIM network can be found at www.iscrim.biz

Step 3: All the 131 full-text articles were assessed on two aspects:

- It must *fit in on the chosen definition* of Supply chain risk management (presented earlier), which meant that logistics related activities or resources had to be treated in the article.
- The issue of Supply chain risk management had to be *central or rather central in the article* and not just marginal.

The articles that did not fulfil those two conditions were sorted out.

Step 4: Only the earliest publication was considered when one and the same article was published in more than one journal.

Remaining were then 80 unique articles. They were all reviewed. A list of the 80 reviewed articles is presented in Chapter 6 in Brindley (2004).

Missed articles

The search for articles has mainly been based on searches in databases, and since many databases have a limit of how far back in time they go this means that a number of older articles probably have been missed. Searches in databases have been based on certain concepts and combinations of concepts that should be present in the title or abstract or be used as a keyword. This means that if the article's author had chosen to use some other concept, like "cost" instead of "risk", that article will be missed although its contents might well fit in.

Finally, although searches have been conducted in a number of important databases, far from all databases that might include relevant articles about supply chain risk management have been included.

APPENDIX 2: INTERVIEW GUIDE FOR THE MINI-CASES

- Which disruption risks in the physical flows of the company do you think exist today? (Vilka störningsrisker upplever ni finns i nuläget i företagets fysiska flöden?)
- Have these risks changed during recent years due to the actions of the company? (Har dessa risker på senare år förändrats genom företagets agerande?)
- Have these risks changed during recent years because of trends/changes in the environment? (Har dessa risker på senare år förändrats genom trender i omvärlden?)
- How are these risks handled today? (Hur hanteras dessa risker i nuläget?)
- Who is/are responsible for the physical flow respectively risk management? (Vem är ansvarig för flödet respektive riskhanteringen?)
- Are there any thoughts about changing risk management? (Finns det några tankar på att förändra riskhanteringen?)
- What kind of relevance does the concept ”lean” have for company risks and risk management? (Vad har begreppet ”lean” för relevans för företagets risker och riskhantering?)
- What kind of relevance does the concept ”agile” have for company risks and risk management? (Vad har begreppet ”agile” för relevans för företagets risker och riskhantering?)

APPENDIX 3: RISK EXPOSURE ESTIMATION FOR CASE BETA AND CASE GAMMA

CASE BETA: Risk exposure estimation

Initiating event within supply side
First of all is there a certain buffer stock of final products. Then there is the existence of several production units and overcapacity in production. Those can partly be regarded as preventive measures. Finally the VMI-agreements that largely can be regarded as preventive risk handling. The total known result impact for *preventive measures* is therefore estimated to be *high*.

Since Beta has buffer stocks, several parallel production units and overcapacity in production a disruption from supply side will in most cases be able to be dealt with within the focal unit and does not have be passed on to the demand side. Since Beta has deals with the suppliers based on VMI and full economic compensation for shortages/disruptions, those internal handling costs (e.g. costs for the re-planning of production or overtime work) will not be paid by Beta but by the supplier. The expected result impact for the *internally handled* disruptions is therefore estimated to be *very low*.

Also for *passed on* disruptions, the VMI-agreements will compensate for the negative consequences of eventual disruptions. The expected result impact for *until back to a stable flow* is therefore estimated to be *very low*. For the *short run* the expected result impact is estimated to be *medium* since the customer might easily change over to another brand with corresponding qualities if the product is not on the shelf . The retailer sells perhaps more than one brand, or the customer might simply go to another retailer. For the *long run* the expected result impact is though estimated to be *low.* Delivery problems would certainly mean lost sales for a period since it is so easy for a customer to change over to another brand, but since it is equally easy to change back, sales might, when the delivery problem is solved, after a while go back to normal again. But there is always the risk that the customer liked the product of the competitor better than Beta's. Delivery problems in one period are therefore likely to have some impact on sales in the following periods, but that impact has been regarded to be limited.

Initiating event within focal unit

Some of the chemicals used in production are highly flammable and have to be treated with great care. A fire starting in one part of a production unit can easily spread to other parts of the unit. Fire is a real danger and different preventive measures have been taken. The existence of several parallel sites within Beta is one. Overcapacity in production is another. Some production units also have their own fire brigade. The total known result impact for *preventive measures* is therefore estimated to be *high*.

Risks linked to disruptions within a single production unit are high. But those disruptions do not have to be passed on because there are other production units within the company with the same or similar product and production equipment that could take over the production – especially since a production unit normally is only running 1-shift. By adding overtime or more shifts, production capacity could rapidly be raised. The production costs and other costs as e. g. transportation costs will increase, however. Since the likelihood of a fire is considered relatively high the expected result impact for *internally handled* disruptions is set to be *medium*.

Concerning the *passed on* disruptions, the expected result impact for *until back to a stable flow* is regarded *low* because the considerable preventive measures in combination with efficient internal handling of disruptions means that very few disruptions will be passed on. The same goes for the *short run* related result impact. For the *long run* consequences can be added the ease for the customer to change between different brands, which means that the long run effects of a disruption tend to be quite low. The expected result impact has therefore been estimated to be *very low*.

Initiating event within demand side
Disruptions from demand side mean that there is a sudden order drop caused by a disruption on the demand side. Unfavourable weather conditions during a certain period could cause a drop in orders but are here not considered as a disruption. The product is a standard product bought by a number of different customers. The product is used independently of other products. Several distribution channels and a great number of retailers exist. The product is stored at many different retailers and distribution centres. Less fire risk than in production because the products are now canned. Risks exist linked to the transportation and storing of the final products, but they are limited since each transport unit has limited size and storing is spread over many premises. *All* the different kinds of *result impacts* have therefore been considered to be *very low*.

CASE GAMMA: Risk exposure estimation

Initiating event within supply side
Buffer stocks of standard components as well as design-related components exist. There is also a considerable overcapacity in production. The total known result impact for *preventive measures* is estimated to be *medium*.

All the electronic components are standard components, and alternative suppliers can be found. Besides, Gamma is a small buyer of electronic components and is prepared to pay well. There is also a considerable overcapacity in production and minor delays in input could easily be handled. The products are normally customized, but if a certain component is missing then in many cases the customer might accept another equal or better component (upgrading). The costs will though become higher. The expected result impact for *internally handled* disruptions is therefore estimated to be *low*.

The design components are not especially difficult to produce, but since they are unique then certain unique forms etc. exist perhaps only in one copy. If destroyed it can take some time to construct a new one. The disruption then has to be *passed on*.

Concerning the *passed on* disruptions, it can be noticed that the customer probably already has a product back home which gives the same basic function as the one he has ordered and is therefore willing to accept some delay. The ordered product is furthermore produced according to customer specifications, which make the customer less willing to cancel the order and buy from another manufacturer. The expected result impact for *until back to a stable flow* is therefore estimated to be *very low*. The end customer tends, as was discussed above, to be rather insensible to late deliveries. The expected result impact for *short run* is therefore estimated to be *very low*. Repeated delivery problems would probably have some, but limited, negative effects on market confidence. The expected result impact for *long run* is therefore estimated to be *low*.

Initiating event within focal unit

The production unit has a considerable overcapacity, but there is only one production site and almost no buffer stock of finished products. The known result impact for *preventive measures* is estimated to be *low*.

Production consists of assembly and testing. Production is concentrated in just one big production site working in 1-shift and usually having spare capacity, so working overtime could take care of some of the disruptions. So could probably also upgrading of the product. If the factory were to be totally destroyed, production could be started up in another site after a few weeks. Another alternative could be to temporarily outsource the assembly. The expected result impact for *internally handled* disruptions is estimated to be *low*.

Expected result impact for the *passed on* disruptions are here the same as for the disruptions initiated within the supply side: *until back to a stable flow = very low,* short run = *very low,* and *long run = low.*

Initiating event within demand side

The products are sold on many different geographical markets; each market has a number of retailers, and the different products are sold more or less independently of each other. To this can be added that the end customer tends to be rather insensible to late deliveries. There are some risks that the products will get destroyed or lost during distribution, but those risks are limited. It has therefore been evaluated that *all* the *five result impacts* linked to events initiated within the demand side are *very low*.

APPENDIX 4: EXAMPLES OF INDIVIDUAL RISK HANDLING METHODS

For each generic risk handling method a number of different individual risk handling methods exist. Below one or more examples of individual risk handling methods for each of the 22 generic risk handling methods will be given.

Table: Examples of individual risk handling methods

Generic risk handling methods (in alphabetic order)	**Examples of individual risk handling methods (in alphabetic order)**
Accept	Accept after assessment
	Accept without assessment
Avoid	Drop product
	Redesign product
	Redesign supply chain
Back-up plans	Alternative distribution plans
	Alternative production plans
	Alternative sourcing plans
Buffers	Buffer in stock
	Slack in lead times
Concentrate	Concentrate production and protect it
	Ditto storing
	Ditto transports
Create/increase	Redesign product
	Redesign supply chain
	Start production
Diversify	Multiple distribution channels
	Multiple production facilities
	Multiple supply channels
Flexibility	Production capacity flexibility
	Production mixture flexibility
General reserves	Economic reserves
	Human reserves
Good relations	Create close and good relations with key authorities
	Create close and good relations with key supply chain partners
Identify	Monitoring inbound flows
	Ditto internal flows

	Ditto outbound flows
	Supervision of the surrounding world
Insure	Business disruption insurance
	Equity insurance
	Transport insurance
Organize	Change risk management systems
	Change risk management routines
	Reorganize responsibility and authority
	Reorganize units and staff
Overcapacity	Overcapacity in distribution
	Overcapacity in production
	Overcapacity in supply
Protect	Protect against damage
	Protect against theft
Replace	Replace with another similar component
	Replace with another similar product
Secure supply chain partners	Check financial status for supply chain partners
	Ditto for dropout possibilities
	Ditto for taking-over possibilities
Training	Fire drill
Transfer through contract changes	Transfer through contract adjustments to other links in the chain
	Right to distribution capacity contract
	Ditto production capacity
	Ditto supply capacity
	Other risk sharing contracts
Quality assurance	Multiple link quality assurance
	Quality assurance of customers
	Quality assurance of internal processes
	Quality assurance of suppliers
Quality check	Early in the chain quality checking
	Quality checking of components and material
	Quality checking of products
Quantify	Quantified assessment of inbound flow risks
	Ditto internal
	Ditto outbound

APPENDIX 5: THE COMPLETE DRISC MODEL

THE DRISC MODEL AT ITS TOP LEVEL

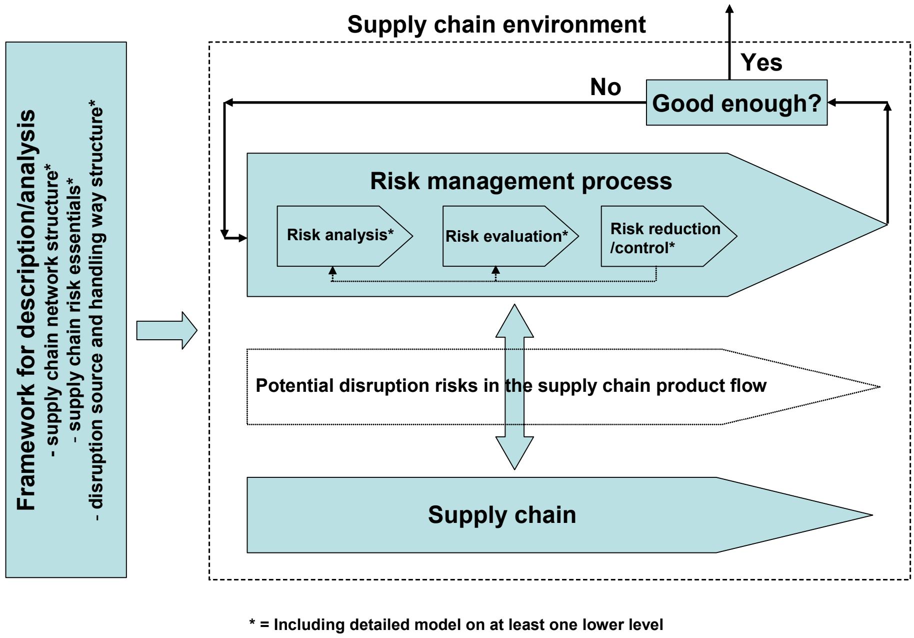

Figure A: The DRISC model at its top level – Level 1

It includes the following partial models;

Framework for description and analysis; Figure B (Level 2)

- <u>Supply chain network structure</u>; Figure C (Level 3)
- <u>Supply chain risk essentials</u>; Figure D (Level 3)
- <u>Disruption source and handling way structure</u>; Figure E (Level 3)

Risk management process; Figure F (Level 2)

- <u>Risk analysis </u>(Level 3)
  - System border; Figure G (Level 4)
  - Hazard identification; Figure H (Level 4)

    - Risk exposure estimation; Figure I (Level 4)
- Risk evaluation (Level 3)
    - Acceptable risks; Figure J (Level 4)
    - Analysis of alternatives; Figure K (Level 4)
- Risk reduction/control (Level 3)
    - Decision making; Figure L (Level 4)

FRAMEWORK FOR DESCRIPTION AND ANALYSIS MODEL

The framework for description and analysis consists of; *supply chain network structure, supply chain risk essentials*, and *disruption source and handling way structure*.

Framework for description and analysis

- **Supply chain network structure**
- **Supply chain risk essentials**
- **Disruption source and handling way structure**

Figure B: Framework for description and analysis model – Level 2

Supply chain network structure model

Seen from the perspective of the focal unit three different relevant supply chain parts can be identified – *supply side*, *production* and *demand side* – in a supply chain product flow going from *natural resources* to *end market*.

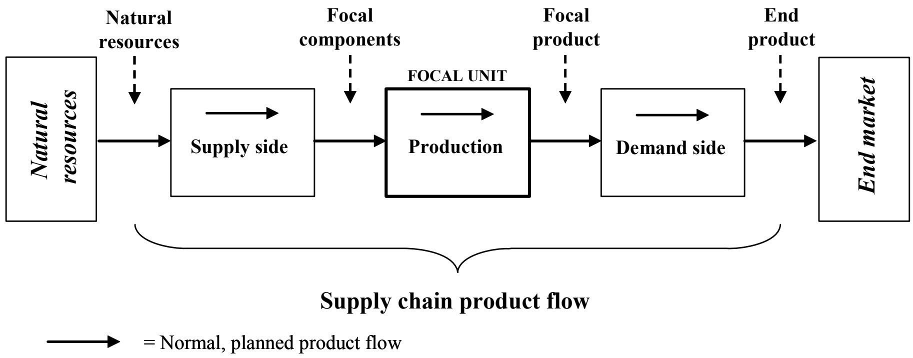

Figure C: Supply chain network structure model – Level 3

Supply chain risk essentials model

The supply chain risk essentials model identifies that in the supply chain which is of special significance from a disruption risk point of view. The model consists of six different risk essentials; *product design*, *production process design*, *product flow design*, *product flow supporting systems*, *risk management systems and actions*, and *human resources*.

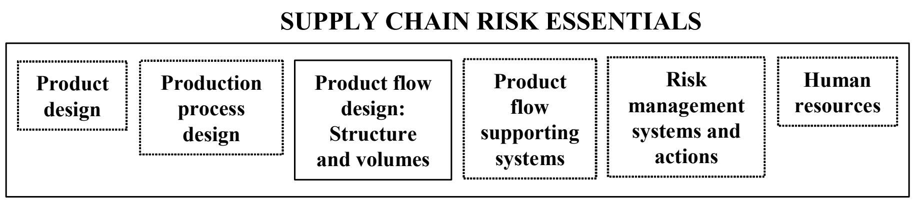

Figure D: Supply chain risk essentials model – Level 3

Disruption source and handling way structure model

Three different *disruption sources* are identified: initiating event within the supply side, initiating event within the focal unit, and initiating event within the demand side. Two principally different *ways of handling disruptions* are identified: internally handled and passed on. The latter is split on: until back to a stable flow, short run and long run. There are thus twelve possible combinations of disruption sources and handling ways.

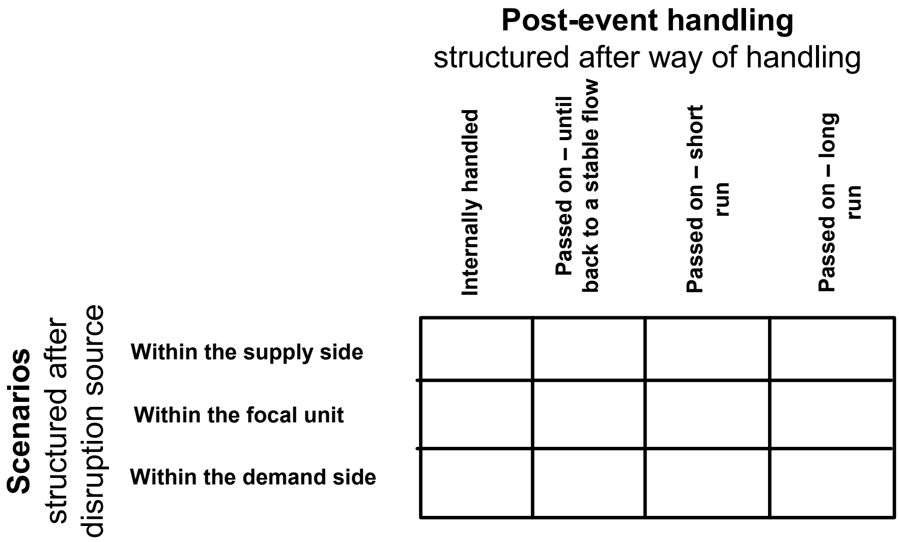

Figure E: Disruption source and handling way structure model for post event handling – Level 3

THE RISK MANAGEMENT PROCESS MODEL

Based on IEC (1995) a risk management process model with three "phases" – risk analysis, risk evaluation and risk reduction/control – with altogether eight "steps", has been identified.

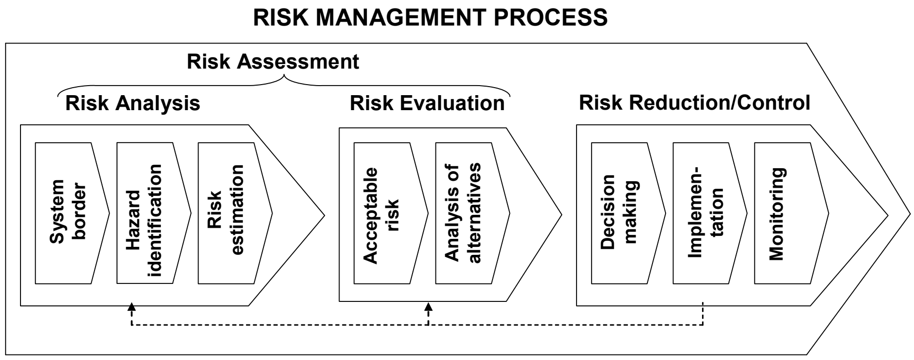

Figure F: The rotated IEC risk management process model (based on IEC, 1995) – Level 2

Each of the eight risk management process steps, except the last two ("implementation" and "monitoring") is elaborated on at least one lower level.

Risk analysis

The risk analysis phase (Level 3) consists of the three steps; *system border*, *hazard identification*, and *risk estimation*.

System border model

The first step when using the DRISC model is to decide upon the setting which means; decide who is stake holder and who is judging, choose focal unit and focal product, decide projects goals, specify measure dimension for result impact, specify time period, ambition level and time horizon, and decide other specifications/limitations.

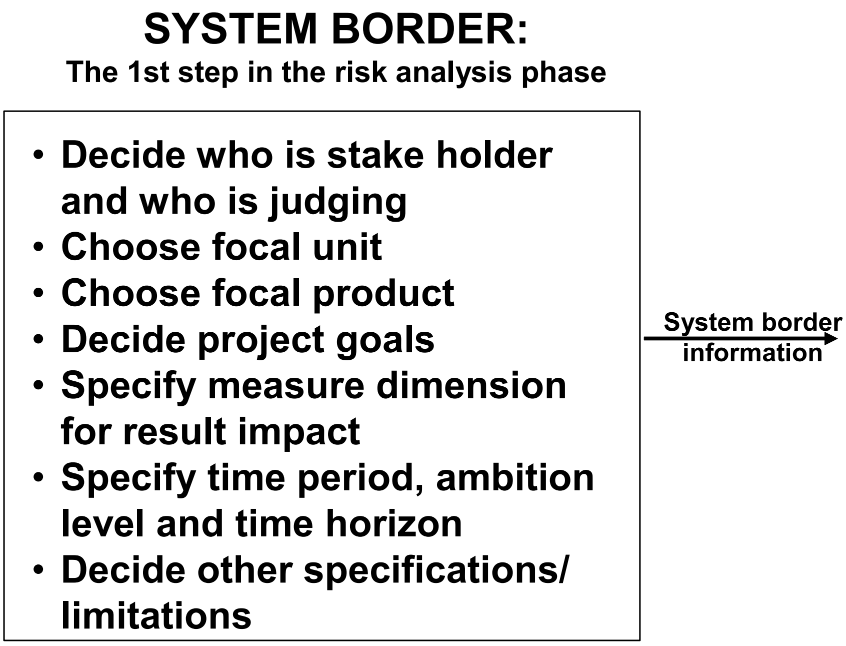

Figure G: System border model – Level 4

Hazard identification model

Input to the model is the system border information. Output from the model is information about potential vulnerability sources and about present risk management activities. The hazards are mapped within a supply chain network links and supply chain risk essentials structure.

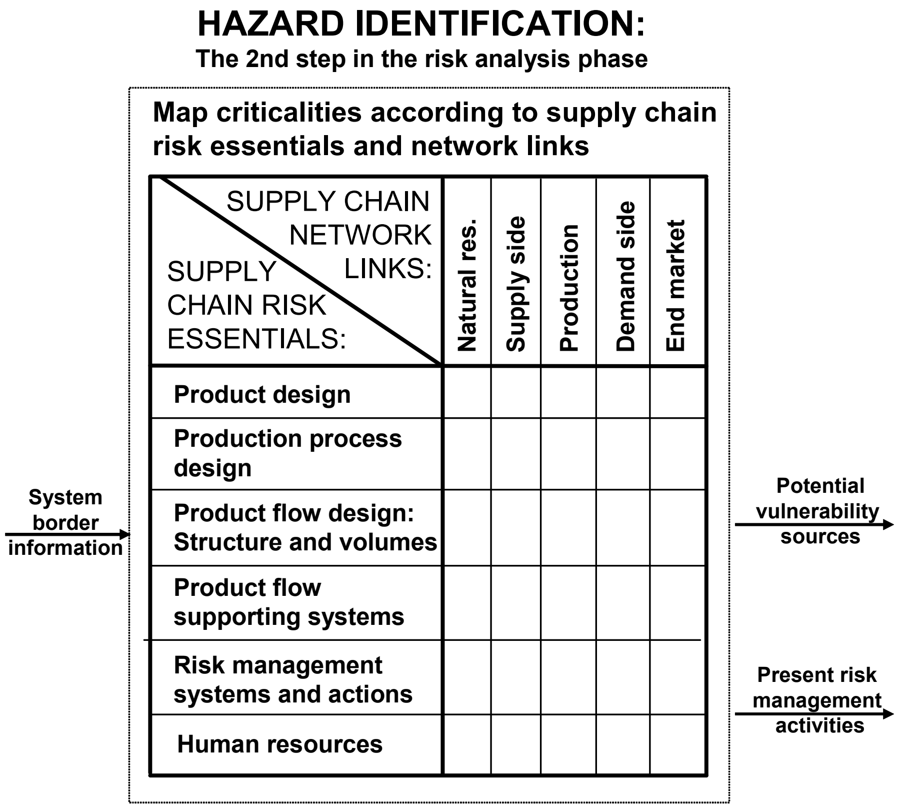

Figure H: Hazard identification model – Level 4

Risk exposure estimation model
The risk exposure estimation model consists of; *risk exposure box structure*, and *estimation of result impact*. Output from the model is information about estimated risk exposure.

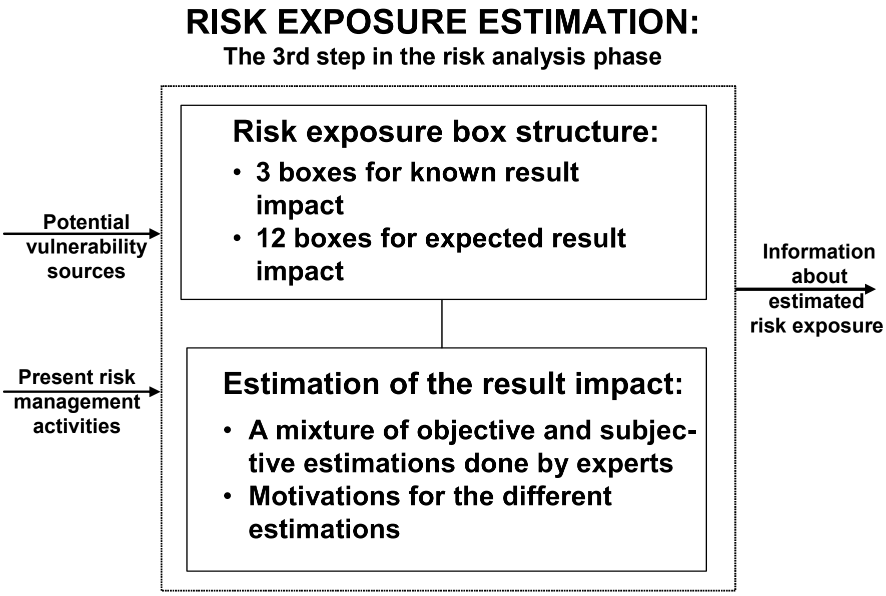

Figure I: Risk exposure estimation model – Level 4

Risk evaluation

The risk evaluation phase (Level 3) consists of the two steps *acceptable risk* and *analysis of alternatives.*

Acceptable risk model
If a specification of the level of acceptable risk already has been set in the system border step that specification is to be applied. If not, it is time to do the specification now. Output from the model is a list over non-acceptable risks and the information about estimated risk exposure from the previous step.

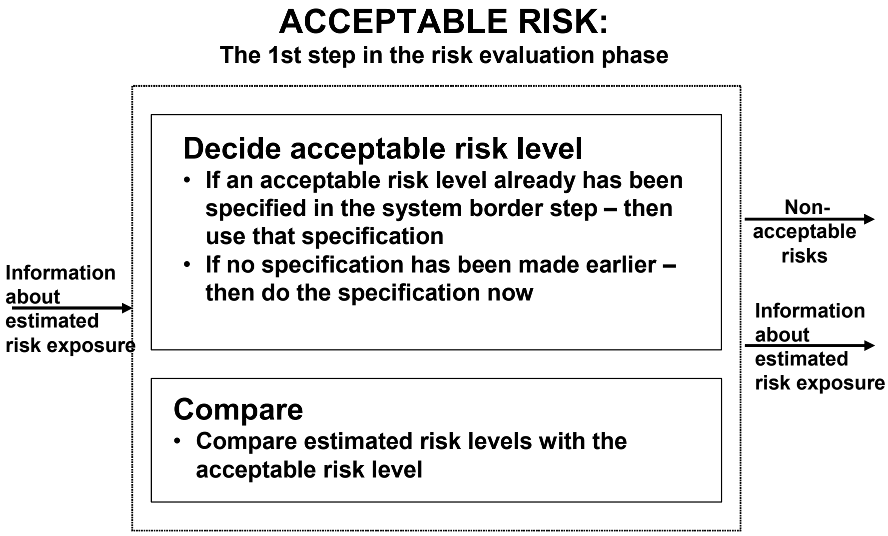

Figure J: Acceptable risk model – Level 4

Analysis of alternatives model

Input to the analysis of alternatives model is information about estimated risk exposure and information about which risks that, compared to the acceptable risk level set, are considered non-acceptable. After having identified what is critical for the non-acceptable risks we now try to find new acceptable alternatives by choosing one or several risk handling methods and apply them on one or more supply chain risk essentials.

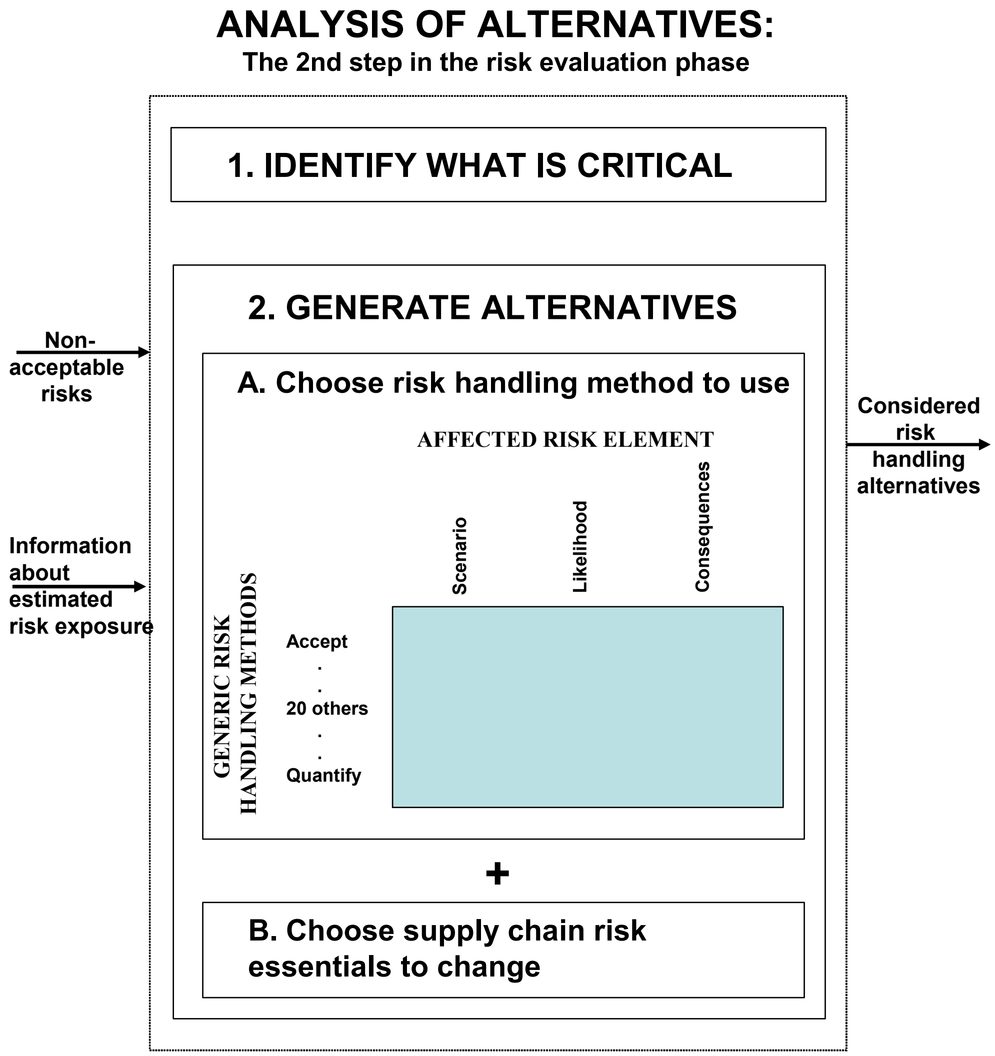

Figure K: Analysis of alternatives model – Level 4

To facilitate the generation of new alternatives 22 different generic risk handling alternatives have been identified

Risk reduction and risk control

The risk reduction and risk control phase (Level 3) consists of the three steps; *decision making*, *implementation*, and *monitoring*. The last two steps are just mentioned, and stressed to be important, but not penetrated further.

Decision making model
Input to the decision making model is the risk handling alternatives considered in the previous step. They are now *catalogued* and the ones that are considered to have the best potential are selected. For each of those *the marginal change* in present result impacts is *estimated* and *also other aspects* that need to be regarded are considered. Finally the alternative that fulfils the project goals the most is *chosen*.

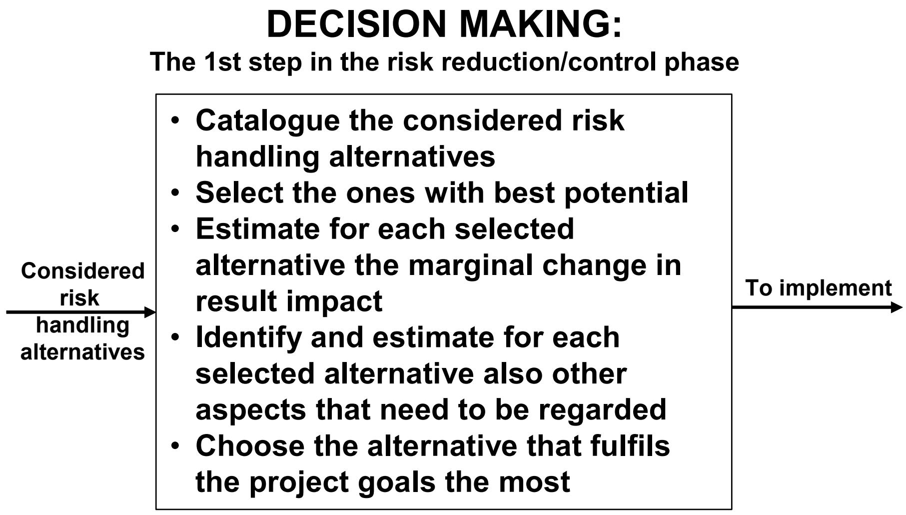

Figure L: Decision making model – Level 4

APPENDIX 6: CASE BRÄMHULTS: IDENTIFIED HAZARDS IN LISTING

Identified hazards are:

Natural resources

- Changing weather conditions like heat, cold or an unusually dry period
- Natural disasters like flooding and hurricanes

Supply side

- Necessary "components" for the production of the fresh juice are mainly citrus fruits, packages of plastic, electricity and water.
- Electricity and water are single sourced and bought locally.
- Packages are also single sourced and bought from a nearby company.
- The design of the bottle is unique and has a trademark protection. For the production of the bottles, certain unique forms are needed.
- Citrus fruits are always available on the supply market, but price and quality could change according to e.g. weather conditions.
- Wrong deliveries and late arrivals could cause inbound delivery problems.
- Bad fruit quality could cause delays because the shipment is not useable for production. A new one has to be ordered.
- If a shipment with bad fruit is not detected, then it might enter production and cause problems.
- The company buys their citrus fruit from many different producers spread over many regions and countries and even continents.
- The company buys fruit from certified producers if possible.

Production

- Some buffer stock of packages
- Almost no buffer stock of citrus fruits
- No buffer stock at all of the finished products/juices

- Just one production unit
- Just one production line
- No unique production equipment
- Production mainly during night-time
- The products/juices are not pasteurized, which means that their shelf life is quite short – if kept at the right temperature – 10 days.
- Un-pasteurized juice also means that there are some contamination risks.
- Production personnel have a low level of formal education in how to treat foodstuffs.
- The risks in production are linked in the figure below to the five different production steps that have been identified.

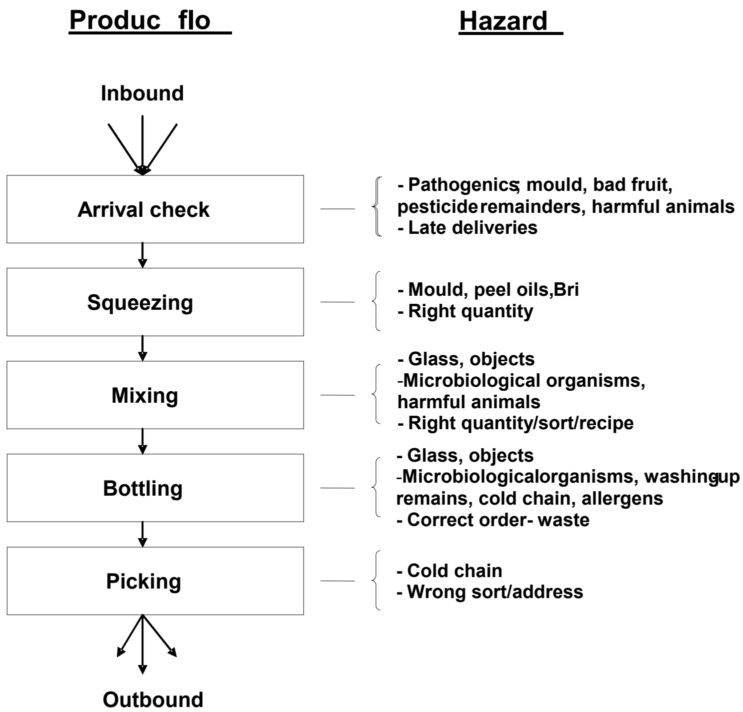

Figure: Product flow and hazards (Based on a PowerPoint-presentation by Ulf Tylestrand, dated 2005-02-04)

- At arrival of the fruit: Always taking the temperature in the delivering lorry, and if temperature is over the set limit the consignment is sent back.
- At arrival of the fruit: Visual control of the fresh fruit and sorting away those fruits that do not measure up to the required quality level.
- At arrival of the fruit: Now and then taking a sample of the fruit and sending it to a test laboratory for analysis.
- Specific routines for the washing-up of the machines, but no central washing-up-function
- Routines for handling of customer complaints that might give indications of quality problems in production.

<u>Demand side</u>

- At the shops; some stock of juice covering a couple of days' demand.
- Limited shelf life – only 10 days.
- The bottle with juice might be spoiled especially if the cold chain is not maintained.
- The cold chain might not be maintained throughout the whole distribution.
- The shops might not immediately pick up the delivered juice and place it in refrigerated display cabinets.
- The temperature in the refrigerated display cabinets at the shops might be too high.
- Customers might regret picking the product while they are still in the shop and just put it on an ordinary shelf or leave it at the check-out counter. The shop might occasionally delay returning the juice back into the refrigerated cabinet.
- Direct distribution from factory to the individual shop with Brämhults own trucks driven by their own chauffeurs who know the products well and are aware of the importance of keeping the cool chain.
- Routines for chauffeurs checking the quality of the products on the shop shelves.
- Routines for handling customer complaints.

- Routines for picking up bad products belonging to batches that do not maintain the quality standard and should therefore be taken back.

<u>End market</u>

- If Brämhults juice is not on the shelf, there is a risk that the customer will take a competitor's product instead and like it.
- Spoiled products might be on the shelves and be bought by a customer.
- The end customer (consumer) might not keep the temperature low enough during the transport of the juice from the shop to the refrigerator back home.
- The end customer's refrigerator might hold a too high temperature or the customer exposes the juice to heat, e.g. at the kitchen table, too long.

APPENDIX 7: SURVEY; QUESTIONNAIRE

Name:
…………………………………………………………………………....

Position:
…………………………………………………………………………

Company/Organisation:
………………………………………………………..

The answers will be treated anonymously!

QUESTIONS ON THE DRISC MODEL

1. When you perform a risk analysis, which models or guidelines do you use? (Please give references here or enclose them separately).

2. What is good and what is less good or missing with these models/guidelines?

3. What do you think research and development of supply chain risks should focus on?

4. Is there anything in the DRISC model that is obvious and could be deleted?

5. Is there anything in the DRISC model that is unclear and should be clarified?

6. Do you feel the lack of anything in the DRISC model that should be added?

7. Is the terminology used in the DRISC model comparable to the terminology that you yourself use? If not, please point out the deviations.

8. What other similar models or frameworks are you familiar with? Please make references.

9. How would you like to position the DRISC model in relation to other models within the area? Similarities and differences?

10. How can the DRISC model be useful for you and your company/organisation?

11. How can the DRISC model be useful for your colleagues within the risk management profession?

12. What other persons do you suggest we should send these questions (including the presentation of the DRISC model) to?

APPENDIX 8: SURVEY; DRISC MODEL PRESENTATION

The DRISC model. A short presentation.

DRISC stands for "Disruption Risks In Supply Chains".

EXECUTIVE SUMMARY

Brämhults juice
Fresh juice is tasty but could easily get spoiled. To delimit that risk, Brämhults introduced a pasteurizer in their production process in May 2005. A pasteurizer kills almost all of the potential bacteria that could spoil the juice. The investment in the pasteurizer, which was about 2 million SEK, paid for itself already during the first year through the substantial drop in returns of spoiled juice. We can illustrate this drop with the help of the DRISC model. The model can also help us to see that there were a number of other effects – mainly positive – as well, and where they occurred.

Need for generic risk models
A number of trends – e.g. globalisation, outsourcing, single sourcing, leanness and a higher degree of integration between the supply chain links – have led to a more vulnerable supply chain flow and, as a consequence, to new and higher risks. In a rapidly changing world, the "risk picture" also changes constantly. There is therefore an increasing need for generic models that can assist risk managers, and other people in the organization who are responsible for flow-related risks, in dealing with those issues. The DRISC model, which will be presented below, is one such model that recently has been developed.

The aims of the DRISC model are:

1. To be a useful tool in identifying, analysing and evaluating *product flow disruption risks* in the supply chain seen from the point of view of an individual company or organisation in the chain (*focal company*) and concerning a specific product or product group (*focal product*).
2. To assist in finding new ways to handle those disruption risks.
3. To be a tool of special relevance to highly integrated supply chains, where a disruption in one link can easily spread to other links in the chain with consequences that are sometimes devastating.
4. To consider market reactions after the ending of the disruption as well.
5. To facilitate a dialogue about disruption risk issues between different professions/departments within the company/organisation and between the company/organisation and other links in the chain.

THE DRISC MODEL ON THE TOP LEVEL

The object of our interest is the *potential disruptions in the supply chain product flow*. These are the result of the supply chain itself and how its risks are managed. Those two – the *supply chain* and the *risk management process* – are in constant interaction. The supply chain with its product flow creates risks. Some of those risks are handled in the risk management process by finding and implementing certain risk handling actions. Those actions change the supply chain in one way or another. A changed supply chain creates a new risk situation to which risk management might then react with new risk handling actions, and so on.

These three basic elements – the supply chain, the risk management process and the potential disruptions in the supply chain product flow – and their interaction can be identified, described and analysed in a number of ways. It is, however, advisable to have certain fixed structures that govern how these three basic elements and their interaction are identified, described and analysed. Those fixed structures will be called the *framework for description and analysis*, which is the fourth basic element of the DRISC model. Changes in the supply chain (and, as a consequence, also changes in risks) can be internally generated within the supply chain but can also come from outside the supply chain – from its *environment*. Therefore the environment of the supply chain is included in the model as a fifth basic element. There is also a question of whether the risk situation is "good enough" or not. If the answer is "no", a new risk management process "round" is initiated.

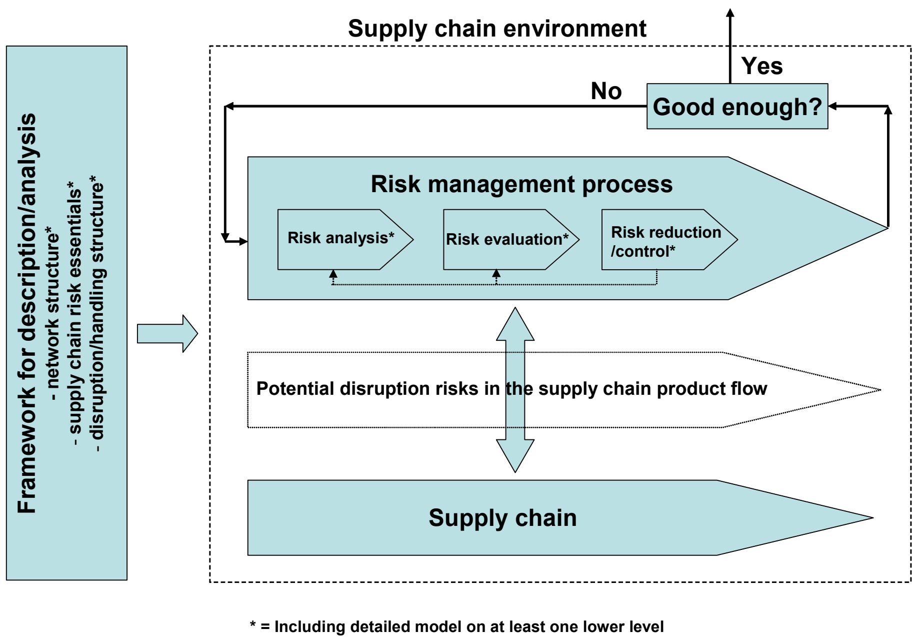

Figure A: The DRISC model – top level (Level 1)

A CLOSER LOOK AT TWO OF THE BASIC MODEL ELEMENTS

Two of the basic elements, the framework and the risk management process, are developed on one or more lower levels, which are described below.

Framework for description and analysis

The framework for description and analysis consists of: *network structure, supply chain risk essentials*, and *disruption and handling structure*.

Framework for description and analysis

- **Supply chain network structure**
- **Supply chain risk essentials**
- **Supply chain disruption and handling structure**

Figure B: Framework for description and analysis model – Level 2

Supply chain network structure

Seen from the perspective of the focal company, three different relevant supply chain parts – *supply side*, *production* and *demand side* – can be identified in a supply chain product flow going from *natural resources* to *end market*.

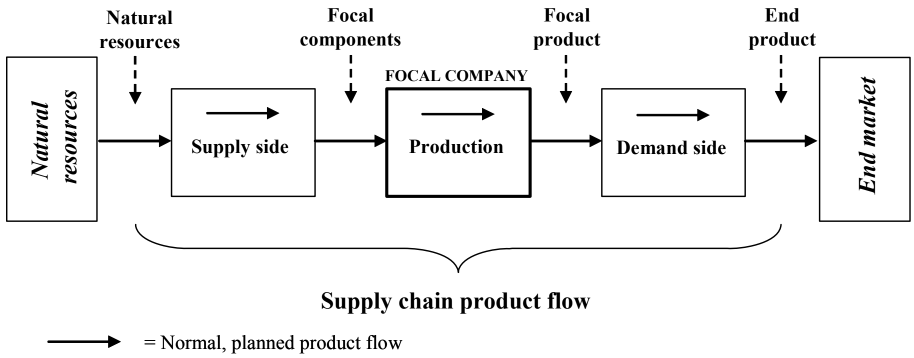

Figure C: Supply chain network structure model – Level 3

Supply chain risk essentials

The supply chain risk essentials model identifies that in the supply chain which is of special significance from a disruption risk point of view. The model consists of six different supply chain risk essentials: *product design*, *production process design*, *product flow design*, *product flow supporting systems*, *risk management systems and actions*, and *human resources*.

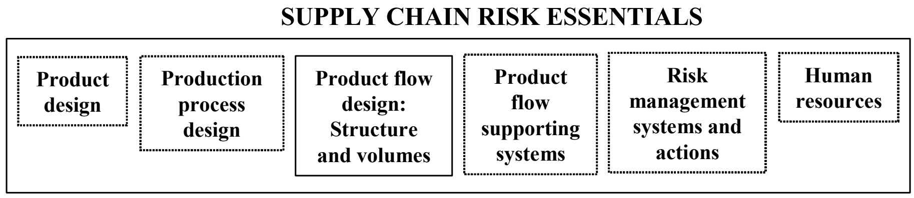

Figure D: Supply chain risk essentials model – Level 3

Supply chain disruption and handling structure

Three different *disruption sources* are identified: disruptions from supply side, disruptions from within production, and disruptions from demand side. Three identified *ways of handling disruptions* can be added: taking preventive measures, internal handling, and exporting.

There are thus nine possible combinations of disruption sources and handling ways, which gives us a certain disruption and handling structure.

Table A: Supply chain disruption and handling structure table – Level 3

	WAYS OF HANDLING:		
DISRUPTION SOURCES:	**Preventive measures**	**Internally handled**	**Exported**
Disruptions from supply side (no components, raw material or similar)	S1	S2	S3
Disruptions from within production (production break-down)	P1	P2	P3
Disruptions from demand side (no orders)	D1	D2	D3

The risk management process

A risk management process consisting of three "phases" – *risk analysis*, *risk evaluation*, and *risk reduction/control* – including eight "steps" altogether is identified on the basis of IEC (1997).

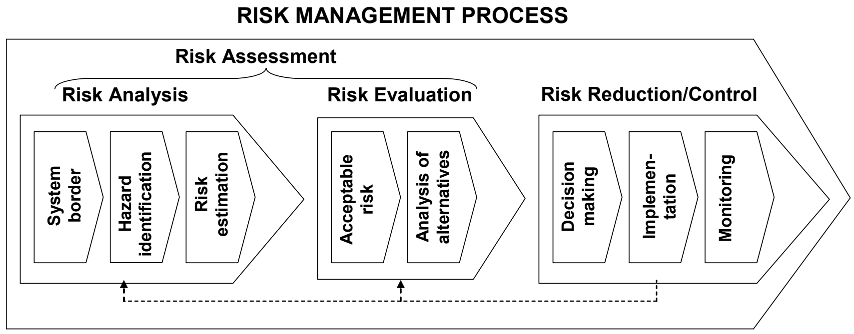

Figure E: Risk management process model (based on IEC, 1997) – Level 2

Each of the eight steps in the risk management process, except the last two ("implementation" and "monitoring") is gone into detail on at least one lower level.

Risk analysis

The risk analysis phase (Level 3) consists of the following three steps: *system border*, *hazard identification* and *risk estimation*.

System border

The first step when using the DRISC model is to decide on the setting, which means: *decide who is judging*, *choose focal company and focal product*, *decide projects goals*, *specify time period, ambition level and time horizon*, and *decide other specifications/limitations.*

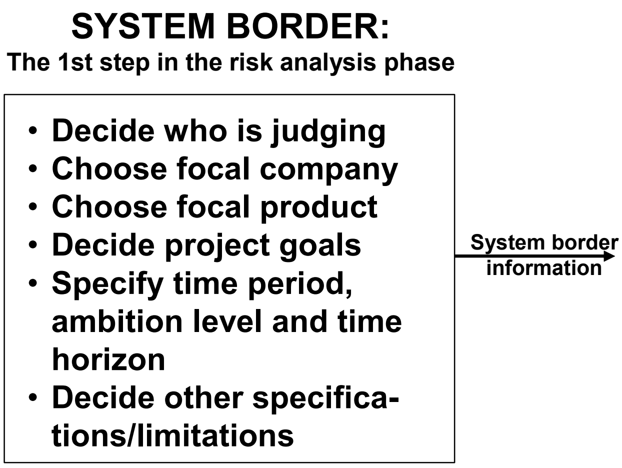

Figure F: System border model – Level 4

Hazard identification

The hazards are mapped within a structure that is a combination of two earlier presented models; the supply chain network model and the supply chain risk essentials model. The output from the model is information about potential risk sources and about risk management activities.

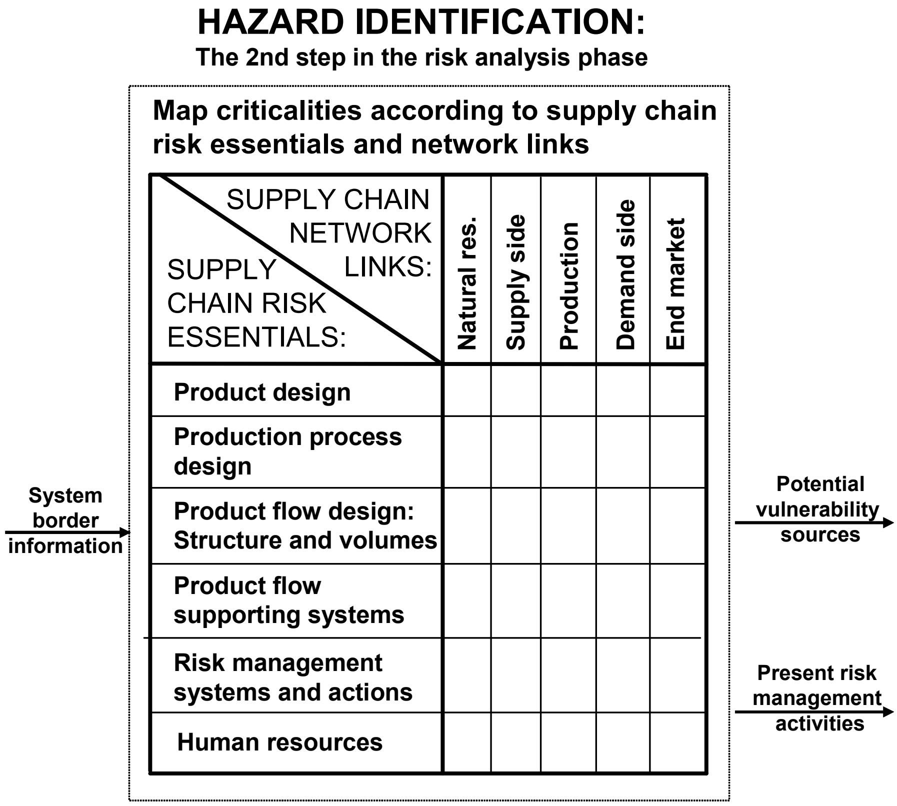

Figure G: Hazard identification model – Level 4

<u>Risk estimation</u>

The risk estimation model consists of *risk cost structure* and *estimation of the risk costs*. The concept "risk cost" is here used as a shorter way of expressing "negative business profit impact". The output from the model is information about estimated risk costs.

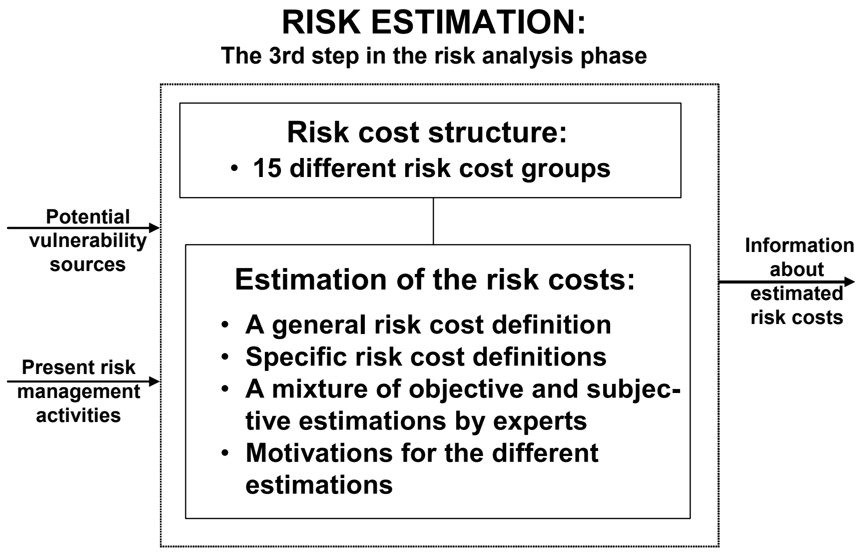

Figure H: Risk estimation model – Level 4

The risk cost group structure is based on the disruption and handling structure presented earlier (see Table A), but here the handling way "export" is split up into three sub-groups: *until disruption ends*, *short run*, and *long run*, which results in a total of 15 different combinations. Short run is also called *market patience* and long run *market confidence*. The disruption itself does not cause any costs, but the risk handling does. Acting in advance by taking preventive measures causes costs, which will be called "known risk costs" since we know that those costs will be incurred. Acting after the disruption has occurred also causes costs, which we will call "expected risk costs", since we do not know if the disruption is going to occur.

Table B: The risk cost group structure model – Level 5

	RISK COSTS, ways of handling **and time dimension:**				
DISRUPTION SOURCES:	**KNOWN RISK COSTS for *preventive measures***	**EXPECTED RISK COSTS for *internally handled* disruptions**	**EXPECTED RISK COSTS for *exported* disruptions upstream/downstream with consideration of market reaction**		
			until the disruption ends	**in the short run (market patience)**	**in the long run (market confidence)**
Disruptions from supply side (no components, raw material or similar)	S1	S2	S3	S4	S5
Disruptions from within production (production break-down)	P1	P2	P3	P4	P5
Disruptions from demand side (no orders)	D1	D2	D3	D4	D5

In theory all the different risks and their risk costs for each of the 15 risk cost groups can be estimated. They can then be summed up into a total risk cost. *In practice* this is seldom done because it is practically impossible, or because such exact information is, from an action perspective, not necessary. Perhaps it would even suffice for each risk cost group to have just two risk cost estimation alternatives: above a certain risk cost level, as e.g. one million, and below it. Below this *risk level* then means acceptable and above unacceptable (something needs to be done). This is a rough evaluation but a time-saving method, and if the aim is to gain a quick overview of the risk situation in a supply chain, using risk levels is probably a practicable method. Another possibility is to use *a set of risk levels*. For instance five levels can be chosen, e.g. very low, low, medium, high and very high. If one wants to be able to sum up the total risk costs, then we can e.g. let each level represent a certain risk cost size like very low = up to 1 million, low = 1-10 million, medium = 10-20 million etc., and then use the middle value for each group, that is ½, 5, 15 etc., when we sum up. We will then acquire a rough estimate of the *total risk costs*.

Risk evaluation

The risk evaluation phase (Level 3) consists of the following two steps: *acceptable risk* and *analysis of alternatives.*

Acceptable risk

If a specification of the level of acceptable risk has already been set in the system border step, that specification is to be applied. If not, it is time to draw up the specification now. The output from the model is a list of the non-acceptable risks and the information about estimated risk costs from the previous step.

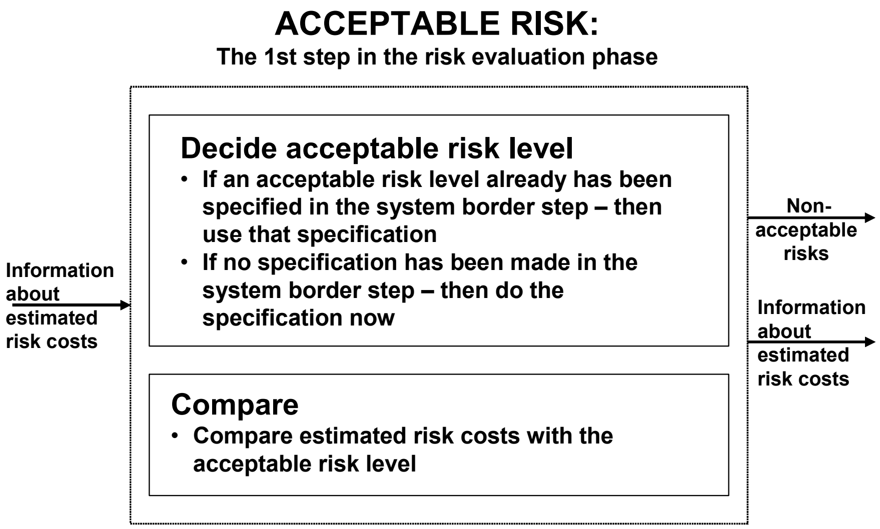

Figure I: Acceptable risk – Level 4

Analysis of alternatives

After having identified what specifies the non-acceptable risks, we now try to find new acceptable alternatives by choosing one or several risk handling methods and applying them on one or more supply chain risk essentials.

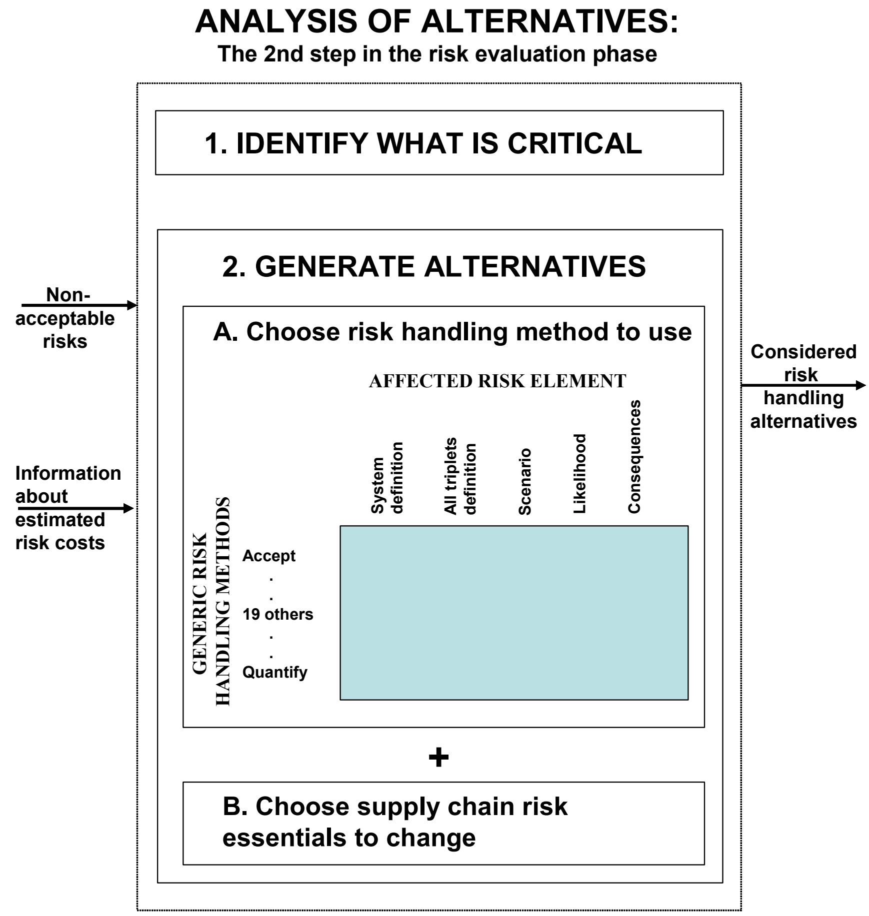

Figure J: Analysis of alternatives model – Level 4

In order to facilitate the generation of new alternatives, 21 different generic risk handling alternatives have been identified, and each of them has been linked to the following three basic questions concerning a risk formulated by Kaplan (1997): "What can happen?" (scenario), "How likely is it?", and "What are the consequences?" If we add "system specification" and "all triplets", we get the five risk elements mentioned by Kaplan. System specification is added because, without a proper specification of the system, the concept "risk" will have no meaning – it could refer to everything and nothing. "All triplets" means that we are usually not interested in just one triplet, but in all triplets of a certain kind. Each one of the generic methods identified is listed below and linked to one or more of the risk elements. The links proposed should be seen as suggestions for, or examples of, possible links.

Table C: The generic risk handling methods linked to affected risk element(s) – principal structure with exemplifications – Level 5

Generic riskhandling methods	Affected risk elements		
	System specification	All triplets definition	Triplet elements
1. Accept		X	
2. Avoid	X		Scenario
3. Back-up plans			Consequences
4. Buffers			Likelihood
5. Concentrate			Scenario and Likelihood
6. Create/increase			Scenario
7. Diversify			Consequences
8. Flexibility			Consequences
9. General reserves			Consequences
10. Good relations			Consequences
11. Identify			Consequences
12. Insure			Consequences
13. Organize			All three
14. Overcapacity			Consequences
15. Protect			Scenario
16. Re-place			Consequences
17. Secure supply chain partners			Likelihood
18. Transfer through contract changes			Consequences
19. Quality assurance			Scenario
20. Quality checking			Scenario
21. Quantify			Consequences

A short description of risk handling methods 1–4 in Table C by way of illustration

- *Accept* means changing the "all triplets definition" so that it will include fewer triplets than before.
- *Avoid* could mean that the "system specification" is changed in such a way that the number of triplets is reduced or totally eliminated.
- *Back-up plans* could mean that the consequences of a potential disruption become less severe.
- *Buffers* could mean that fewer disruptions than before will lead to negative consequences.

Risk reduction and risk control

The risk reduction and risk control phase (Level 3) consists of the following three steps: *decision making*, *implementation*, and *monitoring*. The last two steps will not be further dealt with.

Decision making

The risk handling alternatives that have been considered are *catalogued*, and the ones that are regarded as having the best potential are selected. For each of those, *the marginal impact* on present risk costs is *estimated* and *other aspects* that need to be regarded are also considered. Finally, the alternative that best fulfils the project goals is *chosen*.

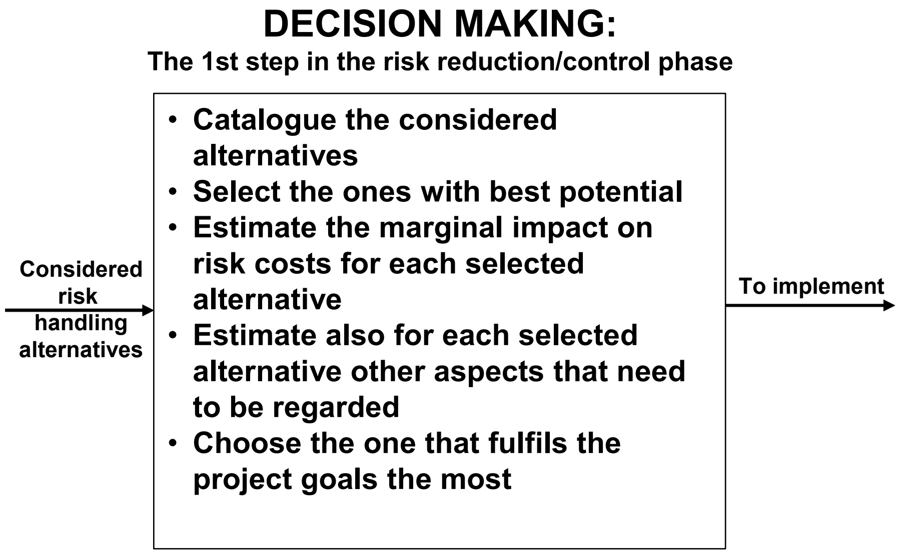

Figure K: Decision making model – Level 4

SUMMING UP THE MODEL AND THE LEVEL STRUCTURES

The DRISC model at the overview level; Figure A (Level 1)

Framework for description and analysis; Figure B (Level 2)

- Network structure; Figure C (Level 3)
- Supply chain risk essentials; Figure D (Level 3)
- Disruption/handling structure; Table A (Level 3)

Risk management process; Figure E (Level 2)

- Risk analysis (Level 3)
  - System border; Figure F (Level 4)
  - Hazard identification; Figure G (Level 4)
  - Risk estimation; Figure H (Level 4)
    - Risk cost group structure; Table B (Level 5)
- Risk evaluation (Level 3)
  - Acceptable risks; Figure I (Level 4)
  - Analysis of alternatives; Figure J (Level 4)
    - Risk handling methods linked to affected risk element(s); Table C (Level 5)
- Risk reduction/control (Level 3)
  - Decision making; Figure K (Level 4)
  - Implementation (not dealt with)
  - Monitoring (not dealt with)

APPLICATION EXAMPLE; BRÄMHULTS JUICE – SUMMARY VERSION

The company and its products

Brämhults started at the end of the 1940s as a small company producing freshly squeezed carrot juice for the local market. From the mid-90s, the company now also produces other juices than carrot juice in the only squeezing machine for citrus fruits in Sweden. But no matter what kind of juice, the philosophy is "as fresh and as natural as possible".

The function of a pasteurizer

A pasteurizer is a machine in which, in this case, the juice is heated to 70–72 degrees Celsius in about 30 seconds, thereby eliminating many of the microorganisms that might spoil the product. Such a machine was taken into use in Brämhults in May 2005.

A short survey of changes

- The pasteurizer installed by Brämhults eliminates almost all possible bacteria, both those in the incoming fruit and those that might have been added through contamination during the production process.
- This has reduced the number of returns and withdrawals by about 90 %.
- It has also prolonged durability from 10 to 18 days.
- The prolonged durability has made it possible to change from distribution by the company's own drivers and lorries to all the different shops over to transporting to a limited number of DCs (distribution centres) belonging to different food chains, which then distribute to the individual shops themselves.

Changes linked to supply chain risk essentials

A supply chain risk essentials model including six different risk essentials was presented in Figure D. This model will here be used to describe the consequences of the installation of the pasteurizer.

First of all, the *product design* has changed from fresh, un-pasteurized juice to pasteurized juice with a number of new qualities. The taste is different, durability is longer and sensibility to contamination is considerably lower. The *process design* has also been changed, since a pasteurization step has been added to the production process. The prolonged durability has made it possible to gradually change distribution from direct distribution to the shops over to distribution to a limited number of distribution centres. Another consequence is fewer returns and withdrawals. The *product flow design* has thus been changed. Instead of a large number of small customers, Brämhults now mainly has a few big ones, which has consequences for invoicing, for example. Thus the *product flow supporting* systems have been affected. Since the juice is now pasteurized, the number of products that are spoiled has decreased considerably, and the potential returns are carried out by the big food chains themselves. On the other hand, routines for the handling and maintenance of the pasteurizer have been introduced and added. The pasteurizer has to be cleaned in the correct way. The right temperature, flow and detergent concentration in the cleaning system are necessary when tanks, pipes and pump station, bottle machines and pasteurizer are cleaned. Consequently, the *risk management systems and actions* are also affected. It is of great importance that the personnel who handle the pasteurizer have the right competence for that task. On the other hand, the company has almost no need for drivers any longer. The effects on the *human resources* are considerable.

It is thus worth noticing that, at a closer look, a change that may initially have been regarded as a change in product and process design turns out to have *affected all the six different supply chain risk essentials.*

Changes in estimations; summary and comments

The estimated risk cost levels after the installation are given in Table D below. The estimations before the pasteurizer are within brackets.

Table D: Risk cost levels for Brämhults AFTER and BEFORE the pasteurizer (BEFORE within brackets)

	***RISK COSTS, ways of handling* and time dimension:**				
	KNOWN RISK COSTS for *preventive measures*	**EXPECTED RISK COSTS for *internally handled* disruptions**	**EXPECTED RISK COSTS for *exported* disruptions upstream/downstream with consideration of market reaction**		
DISRUPTION SOURCES:			**until the disruption ends**	**in the short run (market patience)**	**in the long run (market confidence)**
Disruptions from supply side (no components, raw material or similar)	S1: **Medium** (Low)	S2: **Very low**	S3: **Low** (Medium)	S4: **Medium** (High)	S5: **Medium** (Very high)
Disruptions from within production (production break-down)	P1: **Medium** (Very low)	P2: **Very low**	P3: **Low**	P4: **Low** (Medium)	P5: **Medium** (High)
Disruptions from demand side (no orders)	D1: **Very low** (Low)	D2: **Very low**	D3: **Low** (Medium)	D4: **Medium** (High)	D5: **Medium** (Very high)

Risk cost levels; **Very low, Low, Medium, High, Very high and Not estimated.**

The investment in a pasteurizer is partly to be seen as a risk handling action, and consequently some of the costs linked to this investment are risk costs. The known risk costs are therefore now medium for two of the three disruption types. The risk costs for internally handled disruptions are still very low. Almost all the risk costs that are linked to exported disruptions have decreased and are now low for "until disruption ends" and about medium for the rest.

Risk "picture" before and after the pasteurizer

- Changes in both known risk costs and expected risk costs.
- Changes in all three disruption sources: Imported from supply side, from within production and imported from demand side.
- An increase in two risk cost levels and a decrease in nine.
- Before the installation of the pasteurizer, the risk levels related to market confidence were high or very high, whereas after the installation they are all medium.
- There has been a change towards comparatively more known risk costs and less expected risk costs, since all the increased cost levels concerned known risk costs and all the decreased cost levels concerned expected risk costs.
- However, since there is no "weighting" of the different risk cost groups and their different levels, we cannot say whether the total risk costs in the supply chain have increased or decreased.

There are still two major individual risk sources – an old one and a new one

- The first risk source is the unique package – *the bottle* – where nothing has changed.
- Since the juice is now pasteurized, the risk of spoiled juice causing a drop in market confidence has been more or less eliminated under the condition that the pasteurizer is properly operated and maintained. If this is not the case, the consequences could be even more severe than before, since e.g. the best-before date has been prolonged by eight days and distribution is no

longer carried out by their own drivers and lorries. Hence *pasteurizer maintenance and operation* has become a new major risk source.

Positive risk effects

- The investment in the pasteurizer, which was about 2 million SEK, paid for itself already during the first year through the substantial drop in returns of spoiled juice. This is reflected in Table D in the change of risk cost levels from medium to low in boxes S3 and D3 (*until disruption ends*).
- The risk levels for *short run* and for *long run* have also been lowered, but it is not equally easy to assess those positive effects in money.

PS If you are interested in receiving the full version, 13 pages, of the Brämhults case please send an e-mail to; ulf.paulsson@fek.lu.se.