Supply chain flows in and across Öresund before and after the Öresund link -facts, risks and a risk analysis model

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A SUNDRISK Project

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- facts, risks and a risk analysis model

by

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The SUNDRISK project

The SUNDRISK project is a multidisciplinary study of maritime risks in the Öresund area financed by Sparbanksstiftelsen Skåne. The object for the SUNDRISK-project is to create knowledge and a base for better risk management and safety work in the Öresund region. Within the settings of the project a number of partial projects are conducted at different departments within Lund University. The SUNDRISK project (including the different partial projects) is in its turn conducted within the settings of LUCRAM.

LUCRAM

LUCRAM stands for Lund University Centre for Risk Analysis and Management and is a centre for risk research within Lund University.

*”Each year more than 40.000 ships pass through the Drogden channel (the passage on the Danish side of Öresund, west of Saltholm) and more than 4.000 through the Flint channel (the passage on the Swedish side of Öresund, south-east of Saltholm on a level with Malmö). In 1996 more than 5 million passengers took the boat between Malmö and Copenhagen (Akselsson et al., 1997), and 13,4 million (1997) between Helsingör and Helsingborg (HH-link). The width of Öresund at the HH-link is only 4 km, and there the intensive traffic flows in the east/west direction (97.000 ships/year) shall interplay with the north/south traffic flows (18.000 ships/year).”**

Ek & Akselsson (2000) *Fartygsolyckor i Öresund – människan, människa-tekniksystemet och organisationen som risk- och säkerhetsfaktorer (Ship accidents in Öresund – man, man-machine-system and organisation as risk- and safety factors*).* Page 7.

*”There was a heavy fog. A northbound container ship hit one of the protective islands of the high-level bridge pillars. Through the collision some containers fell into the sea, one of them containing carbide. The container, which for security reasons had been placed as far as possible away from the crew and the machine room, was damaged when it fell into the sea. Water came in and acetylene gas was formed, which caught fire through the formation of sparks between the hull, which turned to the north, and the container, which scraped against the side of the hull. A rather powerful explosion followed and fire started in the bow. The bridge pillar was enveloped in flames and it was feared that the concrete would become weakened, so the traffic on the bridge was closed down”.**

Risk scenario by Sölve Arvedson presented in a paper with the title *“Sund-Risk projektet” (The Sound-risk project*)* dated Tore del Mar 990821. Page 2.

“Today’s society is a risk society, where the risks have become more and more difficult to discover and interpret. Risk management therefore has increased in importance and extent”.*

Hamilton, Gustaf (1996) *Risk Management 2000*. The backside of the cover.

* = Translation from Swedish by Ulf Paulsson, the author of this report.

Abstract

This research report has two objectives, both focusing on the supply chain flows passing or crossing the Öresund maritime area.

The *first objective* is to identify and describe the flows in Öresund and the risks for disturbances in those flows before and after the opening of the Öresund Link in July 2000.

With the opening of the Öresund Link a new goods and passenger flow was created. As a result two ferry lines, Limhamn-Dragör (car ferry) and Danlink (rail ferry) between Helsingborg-Copenhagen, and also some passenger lines between Denmark and Sweden were closed down. The total volume of passengers, vehicles and rail transported goods crossing the Öresund has increased substantially after the opening of the Öresund Link, the volume of transported goods to/from the ports in the region has decreased, an effect of the finishing and opening of the Öresund link, and the passages through Öresund, measured as the number of ships, have declined somewhat.

The total risk situation in Öresund has probably become better because of fewer crossing flows at sea level, improvements have been made in the Drogden and Flint channels, and there is no big catamaran ferry operating between Limhamn and Dragör any more, and those risk-reducing factors are together more important than the risks connected to the new flow - the crossing of Öresund by the Öresund Link - or the link as a new obstacle in Öresund.

The *second objective* of the study is to develop a multi-purpose flow risk model for risk analysis of disturbances in the supply chain flows passing or crossing Öresund, focusing on the economic consequences following from those disturbances. The model developed can be used to identify, describe and assess risks and to consider, choose and implement actions.

Keywords: Disturbances, Maritime risks, Multi-purpose model, Risk analysis, Risk analysis model, Supply chain, Supply chain flows, Supply chain risks and Öresund.

Summary

Background

The chain of transport and storage activities from first supplier to end customer has changed character over the years and gradually developed from a step-wise chain via a logistical chain into a supply chain that is highly integrated, lean and characterised by just-in-time (JIT) deliveries and almost no buffer stocks. This development has made the chain more vulnerable - the negative consequences of a disturbance somewhere in the chain are easily spread to other links upstream and downstream in the chain. Even a small disturbance can have severe economic consequences for those companies and organisations that in one way or another are "linked" to the supply chain.

Öresund is one of the maritime areas in the world with most ship movements. About 40.000 ships bigger than 50 gross tons are passing through the sound every year in the north-south direction or opposite, and substantial crossing flows between Denmark and Sweden also exist. To this can be added a number of smaller ships like leisure craft and fishing boats. The Öresund region is also a heavily populated area with about 2 million inhabitants living at the sound or quite near it. The consequences of an accident involving a tanker carrying oil or chemicals in bulk, for instance, could therefore be severe. It is in other words, we have a situation with many latent risks.

From the first of July 2000 there is a combined bridge, artificial island and tunnel called the Öresund Link between Malmö and Copenhagen, which has changed the goods, and passenger flows in the region as well as the risk situation.

Objective

The objectives of the study are, focusing on the supply chain flows passing or crossing the Öresund maritime area, as follows:

- to identify and describe the flows in Öresund and the risks for disturbances in those flows before and after the opening of the Öresund Link.
- to develop a multi-purpose flow risk model for risk analysis of disturbances in those supply chain flows, focusing on the economic consequences following from the disturbances.

Method

Theories are taken from the literature about risk management, risk analysis and supply chain management, as well as from research reports, mainly from the SUNDRISK project, dealing with risk issues in Öresund. Those research reports also include a lot of empirical data about incidents and accidents and other related issues. Empirical data about the flows mainly in the form of statistics are gathered from annual reports from ports in the region and from official statistics.

Results

<u>Flows</u>

Three different types of flows were identified: passing through Öresund, crossing Öresund and to/from a port in Öresund. With the opening of the Öresund Link a new flow was created. As a result two ferry lines, Limhamn-Dragör (car ferry) and Danlink (rail ferry) between Helsingborg-Copenhagen, and also some passenger lines between Denmark and Sweden were closed down. The

effects of the opening of the Öresund Link on the flows started already at the end of October 1999 when the ferry line between Limhamn and Dragör was closed down. 1998 has therefore been chosen as the year to represent the flow situation before the link opened. In order to see as clearly as possible the long-term effects of the opening of the Öresund Link a year as up-to-date as possible has been chosen - the year 2002. For those two years (1998 and 2002) the flows and flow data for crossing or passing through Öresund or going to or from a port in the area are compared.

The average number of ships that were passing through Öresund during the period has decreased by 7,6 % (from 40.307 to 37.232 ships), and the total volume of goods to/from ports has declined by 13 % from 25,7 to 20,5 million tons. The crossing flows are of special interest and studied in greater detail. Danlink with 2,6 million tons of rail goods in 1998 had ceased to exist 2002. Over Helsingborg-Helsingör the passenger traffic has dropped by 15 % (from 13,7 to 11,6 millions), and the number of vehicles with about 10 % (from 2,7 to 2,4 millions). In the south part of Öresund, 14 million passengers, and 3,4 million vehicles crossed Öresund by the Öresund Link in 2002. If we compare that with 5 million passengers, 0,3 million cars and 0,05 million trucks and busses in 1998 we can see a substantial increase in the number of both passengers and vehicles. To this can be added 3,2 million tons of rail transported goods in 2002 – a mode of transport that was not in use in this part of Öresund in 1998.

If we look at Öresund as one "entity" we could conclude that the passenger figure has increased from about 19 million in 1998 to about 26 million in 2002. The figure for vehicles has gone up from about 3 million to almost 6 million, and rail goods have gone from 2,6 to 3,2 million tons. Thus the total volume of passengers, vehicles and rail-transported goods crossing the Öresund has increased substantially after the opening of the Öresund Link, the passages through Öresund, measured as the number of ships, have declined somewhat, and the volume of transported goods to/from the ports in the region has decreased as a result of the finishing and opening of the Öresund link.

Flow risks in Öresund

Passing through or crossing a narrow water passage always results in risks of different kinds. Öresund is no exception. Öresund is a quite narrow sound with a difficult navigation situation caused by among other things strong currents. Another source of risks is the substandard ships, ships that do not fulfil international regulations regarding safety at sea and the protection of the environment, passing through Öresund. The risk situation is *complicated* by two things: First the fact that two different countries are involved and that they both have to agree upon and co-ordinate actions if they are to become effective. Secondly "The Öresund treaties", signed back in 1857, which promise "free passage through Öresund for everyone" and today make it very difficult for the Danish and Swedish authorities to take proactive safety increasing actions on foreign ships.

The opening of the Öresund Link has meant that some of the earlier risks have disappeared, some have changed character and some new risks have appeared. Since the flows from Danlink, Limhamn – Dragör and some passenger lines have disappeared, the risks linked to those flows have been eliminated. Especially important to mention here is the risks linked to the car and truck catamaran traffic between Limhamn – Dragör. Big catamarans are often involved in incidents and accidents. The Drogden channel and the Flint channel are still there, but they have been made deeper, straighter and better marked. So it ought to be less risky now to pass through one of those channels. The Öresund

Link itself creates new risks. The traffic over the link causes risks, especially the passage of the tunnel, but far-reaching precautions have been taken to make crossing of Öresund by the link safe. The link itself (the bridge part and Pepparholm) is also a new object that could be hit by ships passing through Öresund. Also here a number of far-reaching precautions have been taken to avoid an accident/delimit the consequences.

The total risk situation in Öresund has probably become better because there are fewer crossing flows at sea level, the Drogden and Flint channels have been improved, and there is no catamaran ferry operating any more. All these risk-reducing factors taken together are more important than the risks connected to the new flow - the crossing of Öresund by the Öresund Link - or the link as a new obstacle in Öresund.

Future flow risks in Öresund

International trade is expanding. So is the EU. From 2004 there will be 10 new member states in the EU of which four are situated on the Baltic Sea. This will lead to more traffic in Öresund. There might also be an increase in the number of oil tankers exporting Russian oil. Those transports are today often carried out by sub-standard ships. There are no indications that there will be, at least not in the nearest future, any change in this regard. The increased number of oil transports therefore clearly also leads to increased risks in Öresund. To this can be added that integration in the Öresund region can be expected to increase and this will lead to more goods and human beings crossing Öresund, and probably also to changed flows because of changes in the division of tasks within the region. On the other hand, in the future new technologies will be available to increase safety in the flows – technologies that are of special interest in narrow and heavily trafficked maritime areas like Öresund. One example is the AIS (Automatic Identification System) based on transponders fixed on the ship continuously sending basic information about the ship, its cargo, position, speed etc. to other ships in the area and to shore.

A multi-purpose model

To be able to do risk analysis, i.e. to identify, describe and assess risks and to consider, choose and implement actions, general models have to be developed – a common "language" is needed. In this study a multi-purpose model for risk analysis of disturbances in the supply chain flows in and across Öresund is developed. The different parts of the model are developed and in Chapter 5 and the full model is presented in an Appendix.

A final remark

In this report, and also in the other Sundrisk reports, new knowledge has been created about how to identify, describe and assess the maritime risks in Öresund. The next step might be to focus on *actions* and increasing the knowledge about *how to handle those risks*, knowledge that would be of value not only to the actors in supply chains in Öresund and the Öresund region but to everyone dependent upon safe and secure transports in a maritime environment.

Preface

This report is part of the SUNDRISK project, which is a multidisciplinary study of maritime risks in the Öresund area funded by Sparbanksstiftelsen Skåne. The work has been carried out at the Department of Industrial Management and Logistics, Division of Engineering Logistics at Lund University.

While awaiting what happened after the Öresund Link, this report has been completed a couple of years later than the rest of the reports in the project. To a certain extent it also rests on some of these reports.

This report, which is written by Ulf Paulsson, Licentiate in Economics, is to be seen as concluding the SUNDRISK project.

A number of people have been of great help during the work, and we want to thank all of them for that. We also hope the report will be of value to people and organisations with connections to the problem area.

Lund, November 2003

Everth Larsson

Head of Department, Project leader

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1 INTRODUCTION

1.1 BACKGROUND

Öresund is one of the maritime areas in the world with most ship movements. More than 40.000 ships bigger than 50 gross tons pass through the sound every year in the north-south direction or opposite. To this can be added a number of smaller ships like leisure craft and fishing boats. Öresund is a quite narrow sound, with an overall width of some 4-5 kilometres at its most narrow passage between Helsingör and Helsingborg, with a difficult navigation situation, caused by strong currents, among other things. The Öresund region is also a heavily populated area with about 2 million people living at the sound or quite near it. The consequences of an accident involving a tanker carrying oil or chemicals in bulk, for instance, could therefore be severe. Since the first of July 2000 there is a combined bridge, artificial island and tunnel called the Öresund Link between Malmö and Copenhagen, which has changed the traffic flows in the region. The Öresund region is obviously an area with many latent risks. To be able to handle those risks we need to identify and describe the flows in Öresund and the risks for disturbances in those flows.

The goods flows in Öresund are part of different supply chains. The chain of transport- and storing activities from first supplier to end consumer during the 20th century has developed from a stepwise chain where the goods were moved forward in the chain one link at a time, via a logistical chain to a supply chain where the different links are strongly integrated and the movement of the goods can be described as a flow[1]. The demands on service and efficiency in the chain have also increased. This development has had many consequences. One is increased vulnerability to disturbances. Since the chain consists of a number of usually independent companies and organisations, the ”risk picture” for the individual company/organisation has also changed. And today everyone, no matter whether a private firm, a municipal or a government authority is dependant upon different supply chains in their daily life, and disturbances in those flows will quickly produce negative consequences.[2] [3] [4]

With increasing outsourcing, i.e. the individual firm is buying more from suppliers and doing less itself, concentrating only on its special field of competence, the chains are becoming longer in the sense that the number of individual links is increasing. With increasing globalisation the chains are also becoming more geographically spread. Other trends are the increasing integration of the different links in the

[1] Cooper M., Lambert, D. & Pagh, J (1997) "Supply Chain Management: More Than a New Name for Logistics".

[2] *Utvecklingen inom transportsektorn - Konsekvenser för sårbarhet och transportberedskap (The development within the transport sector – consequences for vulnerability and transport preparedness)* (2001).

[3] *Sårbarhetsanalys inom transportsektorn sett ur ett användarperspektiv (Vulnerability analysis within the transport sector seen from a user perspective)* (2001).

[4] *Avbrott i den fasta Öresundsförbindelsen (Disruptions in the Öresund Link)* (2000).

chain and the endeavour to keep the chain as lean as possible, that is to use as few resources as possible to keep the chain going.

A disturbance in a supply flow could have negative consequences both *upstream* and *downstream* in the supply chain[5]. So the risks cannot be treated in isolation – they have to be looked upon in a systems perspective[6]. The risks also have to be identified early and actions considered in advance if we are to be able to handle them in an effectively[7]. A *wrong action* could worsen the consequences instead of mitigating them. For instance: The most severe economic consequences of the mad cow disease in Great Britain came from the decision of the authorities to close the infected area for tourism, and not from the slaughtering of the cattle. *Overreaction*, i.e. the action is correct but too strong, is another risk. In other words we need both to consider the risks in the chain and the way we manage those risks. The wrong kind of risk management is in itself a risk.

International *terrorism* and *natural disasters* are not new phenomena but both, especially terrorism[8], have increased in recent years causing many problems including disturbances in supply chain flows.

Traditionally risk research has been concentrated on the *risks for human beings* to get killed or hurt. In the past two decades, *ecological risks* have also been increasingly recognised and investigated. *Economic risks* have also received some attention but often in a rather narrow sense, considering only the primary consequences. Studies of the "total" economic consequences of disturbances are so far rare. So there is a need to supplement present risk research with studies of secondary and total economic consequences of disturbances in the supply chain flow.

Also for the supply chains passing through or crossing Öresund there is a need to look at secondary and total economic consequences of disturbances in those flows in different situations. Many different kinds of actors can be affected by such disturbances, and they tend be affected in different ways. To be able to do risk analysis of those flows a model is needed, and this model must be applicable by many different actors in many different situations. The model must be a "multi-purpose model".

1.2 OBJECTIVE

1.2.1 Objectives of the study

The objectives of the study, focusing on the supply chain flows passing or crossing the Öresund maritime area, are:

- to identify and describe the flows in Öresund and the risks for disturbances in those flows before and after the opening of the Öresund Link.

[5] *Säkra företagets flöden! (Secure the flows of the company!)*. (1999).
[6] *Riskhantering i ett systemperspektiv (Risk-handling in a systems perspective)* (1997).
[7] Rasmussen, J. & Svedung, I. (2000): *Proactive Risk Management in a Dynamic Society*.
[8] Sheffi, Yossi (2001): "Supply Chain Management under the Threat of International Terrorism".

- to develop a multi-purpose flow risk model for risk analysis of disturbances in those supply chain flows, focusing on the economic consequences emanating from the disturbances.

1.2.2 Focus and delimitation

The focus in this study is on *goods* being transported and on the *economic consequences* of disturbances in the supply chain flows whose activities partly or totally take place in the Öresund maritime area.

The air transports crossing the Öresund could be a maritime risk – e.g. an airplane trying to land at Copenhagen airport might get lost in the fog and hit the high-bridge section of the Öresund Link. Two big airports are located in the area, Copenhagen airport and Sturup airport, and there are also a number of international flights crossing Öresund without landing. Helicopter services across Öresund have also existed. But, because of lack of time and the judgement that the risks are limited, *air transports are not included* in this study.

1.2.3 Target groups

Since the objectives are quite general the results of the study are of interest for many. But there are three groups in particular to whom this study might be of interest.

Decision makers in public organisations with responsibility, in one way or another, for the risk situation in a narrow passage like Öresund will get new models that make it easier for them to do risk analysis. They will also get some empirical data about the risk situation in Öresund.

Risk managers in companies will get new models to structure the risk situation in maritime transportation of goods with special focus on the consequences of disturbances in lead times in supply chains, with the help of which they could more easily do risk analysis and find new solutions to their risk problems. For those companies passing or crossing Öresund there will also be some up-to-date information about the flows and the actual risk situation in Öresund.

Scholars will get a new model that will make it easier for them to do risk analysis for the risk situation in a narrow passage like Öresund. They will also get a model that takes into account the "total" economic consequences concerning disturbances in supply chain flows.

1.3 RESEARCH APPROACH AND METHOD

Three of the most common research approaches are analytical approach, systems approach and actors approach. Those approaches are considered here.

The *analytical approach* regards reality as being objective, and the desire is to discover and explain reality as far as possible. The researcher's own subjective view is not to be considered, since it does not affect reality. The knowledge gathered is thus considered to be independent of the researcher/observer. Explanations of reality are in the form of cause and effect relationships. This means that explanation of reality can be done by splitting an objective into parts, studying the parts and then summing up the parts, because the sum of those parts equals the whole. Discoveries, descriptions and explanations of reality can be seen as universal and absolute.

The *systems approach* also views reality as being objective and also has the desire to discover and explain reality as far as possible. It sees reality as being made up of objects that are related to each other. The objects are in many cases interdependent and cannot therefore easily be summed. The whole can be bigger or smaller than the sum of its parts, or it can be equal to the sum of its parts. A description of a specific system reality cannot automatically be seen as universal i.e. to describe all other systems of the same kind. Possibilities to generalise exist but have to be argued for.

The *actors approach* is quite different from the other two, because here you look upon reality as a social construction. Individuals interact with the perceived reality and affect it and are themselves affected by it. The description of reality is a result of how actors experience, interpret and act in that reality. Reality is not viewed as objective but rather as being dependent on the researcher/observer. A description of reality cannot be seen as universal, only as a description of a specific system.

The supply chain consists of physical entities like ferries, trucks and goods, human beings operating the supply chain and information systems that are measuring supply chain activities and processing the data. The *systems approach is chosen* because it offers good possibilities to give a realistic description of the interaction that goes on between the physical entities, the human beings and the information systems that constitute the supply chain.

The most common *data collection methods* are: case study, experiment, observation, interview, literature study, survey and written materiel other than literature (like agendas, PMs and annual reports). The main data collection methods used in this study are literature studies (including research reports), other written material and interviews.

Theories are taken from the literature about risk management, risk analysis and supply chain management, as well as from research reports, mainly from the SUNDRISK project, dealing with risk issues in Öresund. Those research reports also include a lot of empirical data about incidents and accidents and other related issues. Empirical data about the flows mainly in the form of statistics are gathered from official statistics and from annual reports from ports in the region.

In section 5.1 the method for creating a multi-purpose model is described in more detail.

1.4 OUTLINE OF THE REPORT

Interest is concentrated on the supply chains that are passing through or crossing Öresund, the disturbances that could happen in those flows and the consequences they could have. We therefore need to know what characterizes Öresund, where the flows are and their volume and how they have changed. We also need models and theories. Theoretical inspiration is collected from risk analysis, risk management and supply chain management.

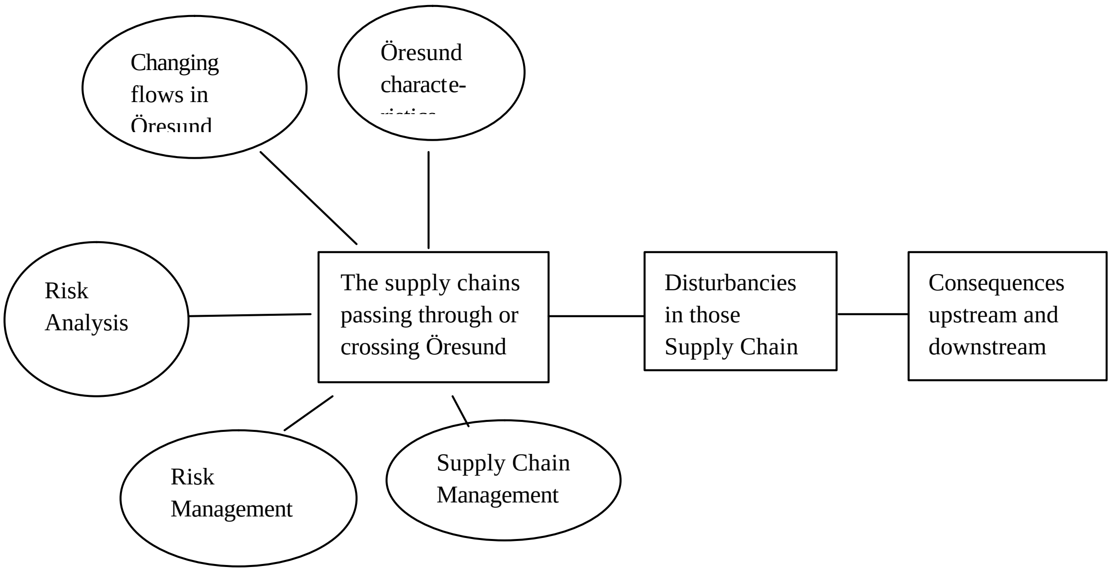

Figure 1.1: The area of the study.

In the first chapter the background, objectives, method and outline of the report are presented. A number of studies of risk issues in Öresund have been conducted over the years and they are presented in Chapter 2. In Chapter 3 statistics about the flows in Öresund before and after the Öresund Link are presented and commented upon. Chapter 4 is a presentation of theories about risk analysis, risk management and supply chain management that could be used as a basis and inspiration for the modelling that is done in Chapter 5, where a multi-purpose model is developed step-by-step. In Chapter 6, finally, the results are summed up and discussed.

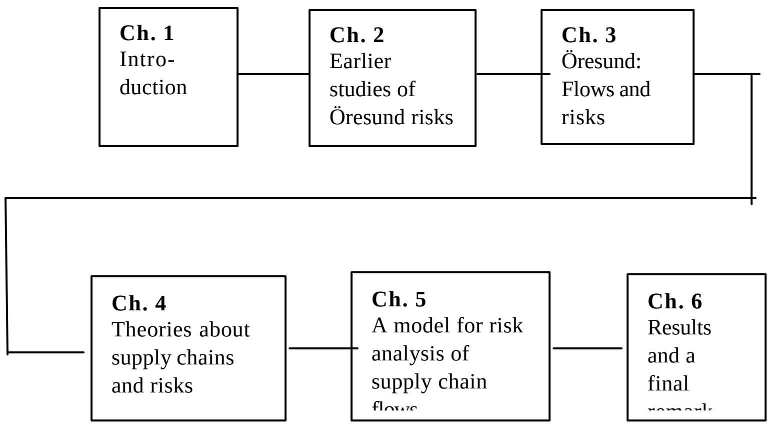

Figure 1.2: Report outline.

2 EARLIER STUDIES OF ÖRESUND RISKS

2.1 THE DIFFERENT SUNDRISK STUDIES OF RISKS IN ÖRESUND[9]

The SUNDRISK project is a multidisciplinary study of maritime risks in the Öresund area financed by Sparbanksstiftelsen Skåne. The objective for the SUNDRISK project is to create knowledge and a basis for better risk management and safety work in the Öresund region. Within the settings of the project a number of partial projects are conducted at different departments within Lund University. The SUNDRISK project (including the different partial projects) is in its turn conducted within the settings of LUCRAM.

Maritime risks of many kinds exist and they could be grouped under different labels. In the SUNDRISK project different researchers have looked at the risk situation in Öresund from their respective points of view.

2.1.1 General maritime risks in Öresund

In *Larsson (1998)*[10] different types of general maritime risks are discussed. Mentioned are among others: grounding (grundstötning), collision with firm obstacle respective moveable obstacle (kollision med fast föremål resp. rörligt föremål), ship wrecking (förlisning), cargo damages (lastskador), passenger injuries (passagerarskador), fire on board (brand ombord), drowning (drunkning) and pollution (utsläpp). The latter is divided into pollution allowed in operation, pollution not allowed in operation and accident-correlated pollution. As risk-influencing internal factors are mentioned engine breakdown on main engine (haveri på huvudmaskin), breakdown on the steering engine (fel på styrmaskin), breakdown of the helm (roderhaveri), breaches in the hull (sprickor i skrovet), fire or explosion on board (brand eller explosion ombord), tiredness or carelessness by the crew (trötthet eller oförsiktighet hos besättningen), navigation mistakes and steering mistakes (felnavigering och felmanövrering). As risk-influencing external factors are mentioned poor visibility (dålig sikt), radar interference from rain and snow (radarstörningar från regn och snö), rough wind (hård vind), high waves (hög sjö), strong currents (kraftiga strömmar), bad ice conditions (svåra isförhållanden), the traffic situation (trafiksituationen) and pirates (pirater). Some examples of dangers particularly for the crew members are also given.

[9] Some of the SUNDRISK reports are written in Swedish. Translation from Swedish to English of relevant parts has been made by Ulf Paulsson, the author of this report.

[10] Larsson, Everth (1998) *SUNDRISK - Maritima risker i Öresundområdet, lägesrapport*" *(SUNDRISK - Maritime risks in the Öresund area, working report).*

Harrami & Kylefors (1999)[11] refer in their introduction to the fact that the Swedish Rescue Services Agency (räddningsverket) makes a division of accidents into "traffic accidents (trafikolyckor), natural disasters (naturolyckor), fire (brand), explosions (explosioner), chemical outflow (kemikalieutflöden), nuclear accidents (kärnenergiolyckor) and combination accidents (kombinationsolyckor)". After having chosen not to study nuclear accidents and concluding that the risk of natural disasters is very low in the Öresund area, the authors delimit themselves to the other risks. First they deal with the transportation of dangerous goods, which is divided into bulk ship transports, transports in ships with packaged dangerous goods and handling of dangerous goods on land. Then different types of accidents are discussed. Mentioned are grounding (grundstötning), collision (kollision), pollution from ships of dangerous substances like oil (utsläpp från fartyg av farliga ämnen som olja), drowning/drowning incidents (drunkning/drunkningstillbud), pollution in the port or from nearby activities (utsläpp i hamn eller från intilliggande verksamhet), fire (brand) and accidents and incidents caused by cargo shifting (olyckor och incidenter p.g.a. lastförskjutning). As risk-influencing factors are mentioned, among others, the condition of the ship (fartygets skick), the crew and the organisation of its daily work (besättningen och dess arbetsorganisation), co-operation with pilot (samarbete med lots) and co-operation with VTS (Vessel Traffic Service). The report also mentions the risk that high-speed ferries (höghastighetsfärjor) could constitute. Possible actions that are mentioned are to make the sailing channels (seglingsrännorna) wider and deeper, separation of the different traffic flows (trafikflödena), access to pilot (tillgång till lots), compulsory pilot (obligatoriskt att använda lots) and a permanent supervision centre of the VTS type that is exchanging information with the ships.

Olsson (1999)[12] discusses in his report different types of existing sea supervision systems, which of them are used in Öresund today and how an increased use of sea supervision systems could lead to a safer situation. Three types of sea supervision systems are identified: a) Vessel Traffic Service (VTS), where a land-based supervision centre gives information and advises the ships, b) Ship Reporting Systems (SRS), where each ship has to report and give certain information when entering or leaving a certain area at sea, and c) Traffic Separation Scheme (TSS), which separates the traffic flows in different directions from each other.

Hägg (2000a)[13] concludes that a considerable number of substandard ships each year pass through Öresund. Those ships are not only in bad condition, but they also have a crew of low quality. Hägg discusses the possibility to start an open ship register for all those shipping companies which have traffic in the Baltic and Öresund areas to strengthen safety at sea and give better protection to the environment in those areas. In exchange for taking into consideration the shipping companies' wishes when it comes to labour, risk capital and taxes, increased demands on the implementation of sea safety standards and general safety at sea can be placed on the shipping companies.

[11] Harrami & Kylefors (1999) *Riskinventering Öresund (Risk inventory Öresund).*
[12] Olsson, Ulf (1999) *Sjötrafikövervakning (Sea Supervision Systems).*
[13] Hägg, Göran (2000a) *Det internationella sjösäkerhetssystemet och dess brister (The international sea safety system and its shortages).*

Ericsson (2000)[14] in his report has put together statistics of accidents in Öresund during a 15-year period according to the variables flag state, type of accidents, type of vessel and the position of the ship when the accident took place.

E*k & Akselsson (2000)*[15] identify and discuss four groups of risk factors, namely geography and natural phenomena, occasional obstacles for navigation, man-machine systems of the ships and the sea supervision, and finally the organisation of the daily work on board and ashore. As examples of geography and natural phenomena, “water depth, stream conditions, waves, poor visibility and ice obstacles” are mentioned. As examples of occasional obstacles for navigation “leisure boats, boat races, accidents at sea and the construction of the Öresund Link” are mentioned.

2.1.2 Oil spills in Öresund

Some of the SUNDRISK reports are concentrating on *oil spills* in Öresund.

Törneman (1999)[16] looks at the risks that exist in Öresund concerning pollution of oil from ships. Pollution can be divided into deliberate pollution and unintentional pollution. The latter, for instance, occurs in connection with groundings or collisions. The consequences on flora, fauna and human beings are dependent upon, among other things, the type of oil (oljetyp), the place of pollution (utsläppsplats), wind and stream conditions (vind- och strömförhållanden) and the height of the waves (våghöjd), and those factors are studied for the Öresund area.

Nilsson (2000)[17] concentrates in his report on accidents causing oils spills and tries to identify different scenarios for that. He considers the following factors as interacting in the scenarios: systems attributes, technical failures and technical hazards, the human factor including organisation and staff, maintenance, environmental factors, societal factors, infrastructure factors, legal and financial factors and finally also market factors.

Nilsson & Törneman (2001)[18] present in their study accident statistics for a 20-year period (1978-1997). The Öresund area is divided into a number of sub-areas that are separated by biological and/or physical characteristics. The vulnerability of each sub-area is assessed. The authors have concluded that although oil-vulnerable areas dominate most of Öresund, the main accidental areas as well as the most ecologically sensitive areas are situated in the southern part of Öresund.

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[14] Ericsson, Per (2000) *Reports on accidents (serious and non-serious) in the Sound 1985-1999 registered by the Swedish maritime administration.*

[15] Ek & Akselsson (2000) *Fartygsolyckor i Öresund – människan, människa-tekniksystemet och organisationen som risk- och säkerhetsfaktorer (Ship accidents in Öresund – man, man-machine-system and organisation as risk- and safety factors).*

[16] Törneman, Niklas (1999) *Miljörisker med transport av olja i Öresund (Environmental risks concerning transportation of oil in Öresund).*

[17] Nilsson, Jerry (2000) *Vulnerability analysis – Öresund.*

[18] Nilsson, Jerry & Törneman, Niklas (2001) *Vulnerability and Hot Spot Assessment of Öresund for Oil Spills - a Mapping Approach.*

Mullai & Paulsson (2002)[19] in their report have studied the hazardous events and causes of oil spills in Öresund for the last 15 years. Grounding, contact, collision, hull failure, machinery and listing/capsizing were the hazardous events which led to oil spill/release. Causes and contributing factors of the above events were human, technical, weather/sea and other related factors (such as vessel traffic). They also, based on data of major oil spills in the world and from statistics about traffic in Öresund, made estimations about the likelihood of accidents causing oil spills in Öresund and their economic consequences when it comes to claims. Average third-party claim cost is estimated to be in the range of $ 140.000 – 180.000 per year. In the worst scenario case claims are estimated to be between $ 120.000.000 – 260.000.000. Finally they also discuss some safety-increasing measures.

2.1.3 Safety issues in general

Three of the SUNDRISK reports do not limit themselves to the Öresund area but deal with safety issues in general:

Hägg (2000b)[20] in his study gives a general overview of how maritime risks from an institutional perspective have been regulated both today and historically. Although Hägg points at many problems, such as convenience flags and sub-standard ships, he thinks that we are slowly moving towards higher and higher safety.

Sampson (2001)[21] in his report makes an overview of the existing needs and practices of maritime risk analysis and maritime risk management, including work both on the national maritime administration level and the international level like IMO (International Maritime Organisation). He stresses the need both to analyse incidents and accidents and to work pro-actively, among other things with the help of different risk scenarios. The proactive decision making must be linked to an ability to quantify the risk or vulnerability levels, and these levels must be used as justification for the adoption of appropriate risk management techniques.

Ericsson & Mejia (2001)[22] in their report have examined the studies of the human factor in maritime transport (shipping) undertaken by IMO in recent years. For that purpose they have reviewed numerous documents related to the human factor, including resolutions, recommendations, proposals, studies, reports and articles. The review also includes one of the most important documents developed by the IMO in the area of the human factor, the International Safety Management (ISM).

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[19] Mullai & Paulsson (2002) *Oil spills in Öresund – hazardous events, causes and claims.*
[20] Hägg (2000b) *Riskhantering och säkerhetsskydd – översikt av regleringen av maritima risker från ett institutionellt perspektiv (Risk handling and safety protection – overview of the regulation of maritime risks from an international perspective).*
[21] Sampson (2001) *Maritime Risk Analysis and Management - Existing Pracitices, Existing Needs.*
[22] Ericsson & Mejia (2001) *IMO's Work on the Human Element in Maritime Safety.*

2.2 OTHER STUDIES OF RISKS IN ÖRESUND

In a study by COWIconsult (1992)[23] the risks and consequences of a ship running into the bridge were analysed. The following are some of the key findings. Oil spills were considered the main hazard of maritime pollution in Öresund. Oil spills are evaluated based on data available for the period 1973-1981 (9 years) and for 1990 and 1991 (2 years). The number of oil spills was dominated by small discharges up to 1 cubic metre. Most of them were illegal. Table 2.1 shows oil spills reported to the Danish EPA (Miljöstyrelsen - Environment Protection Agency) in 1990 and 1991. Oil spills in ports were not included. The table also shows the number of maritime events (collisions and groundings) during the same period. Only one spill was due to maritime events. The rest are not accidental oil spills i.e. not due to maritime events.

Table 2.1: Oil spills, collisions and grounding in Öresund reported in 1990 and 1991. (COWIconsult 1992: Analys av risker för påsegling av bron. Doc. No. 22071-00, 1992)

	1990	**1991**
Oil spills (< 1 cbm)	13	26
Oil spills (> 1 cbm)	0	0
Collisions (one minor oil spill)	1	0
Grounding (no oil spills)	6	3

Table 2.2 shows that during the period 1973-1981 (9 years) 7 large ("major") oil spills occurred in Öresund. Four spills were accidental due to collisions and groundings. The "unknown" category (3 out of 7 spills) covered non-accidental spills most probably resulting from illegal discharges.

Table 2.2: Large oil spills reported in Öresund during 1973-1981 (9 years). (COWIconsult 1992: Analys av risker för påsegling av bron. Doc. No. 22071-00, 1992)

	Numbers	**Spill size (cbm)**
Collisions	2	200, 300
Grounding	2	40, 50
Unknown	3	50,70, 200

The average size per event was estimated at 130 cbm or approx. 120 tonnes. The largest spill sizes were reported in collision events, in particular when tanker ships were involved.

There are two ways to pass through Öresund between Malmö and Copenhagen and that is through the Drogden channel on the Danish side and through the Flint channel on the Swedish side. The

[23] *Analys av risker för påsegling av bron (Analysis of the risks of collisions with the bridge)* (1992). COWIconsult.

allowed depth is 7 meters in the Flint channel and 7.7 meters in the Drogden channel which means that no really big ships can pass through, at least not loaded. They have to use the Belt instead.

The worst cases of oil spills were anticipated: 19,000 tons in Flintrännan and 50,000 tons in Drogden (Table 2.3).

Table 2.3: Contents of oil tankers in Flintrännan and Drogden - the worst-case scenarios. (COWIconsult 1992: Analys av risker för påsegling av bron. Doc. No. 22071-00, 1992).

Ship size - dwt		**Movements 1990 (no.)**	**Oil contents in tons**			
			Total	Centre tank	Wing tank	Bunker tank
Flintrännan	45.000	4	19.000	3.500	1.750	900
Drogden	110.000	4	50.000	9.250	4.500	1.700

In this study the following risks of transports in Öresund were not considered or not reported, and consequently not considered: wastes – nuclear wastes, have not been considered; liquid chemicals – spills of liquid chemicals have not been reported; dangerous goods carried in packaged form have been lost, but no such accidents have been reported; oil spills inside ports have not been considered.

3 *ÖRESUND: FLOWS AND RISKS*

3.1 THE MARITIME AREA ÖRESUND

The Öresund geographical water area – The Sound – in Danish "Øresund", in Swedish "Öresund" - (henceforth Öresund) is the strait between Sjælland (Denmark) and Skåne (Sweden), connecting the Kattegat Strait (northwest) with the Baltic Sea (south).[24] Its maximum length, between Kullen and Falsterbo (Sweden), is 110 km. The most landlocked portion, between Helsingør-Helsingborg in the north (width 4.7 km) and Copenhagen-Malmö in the south (width 14 km), is 52 km long. The strait is shallow and has a surface current of up to 3 to 4 miles per hour toward the Kattegat. Ice in the almost tide less strait may impede navigation during severe winters. Four islands are located in Öresund: Amager, which is partly embraced by Copenhagen, Ven, Saltholm and Pepparholm. The last two divide the waters into the channels of Drogden (west) and Flintrännan (east). Dragör, Copenhagen and Helsingør are the principal ports on the Danish side and Malmö, Landskrona, Helsingborg and Höganäs on the Swedish side.

The Öresund Link (Öresundsbron) connects the cities of Malmö in Sweden and Copenhagen in Denmark. The total length of the Öresund Link is about 16 km. The last three kilometres close to the Danish shore are a tunnel emerging on a man-made island, the Pepparholm Island. The part of the link that crosses the navigation channel is called the High Bridge and is a cable-stayed bridge. The length of the High Bridge is 1,092 m and its span is 490 m. The height of the pylons is 203.5 m with a free height in the navigation channel of 57 m. There is both a motorway and a double-track railway on the link.[25] The link could be seen as an obstacle to navigation in Öresund.

The total population of the Öresund region, which includes the Sjælland (Denmark) and Skåne (Sweden) regions, is approx. 3.5 million inhabitants - approx. 2.4 and 1.1 million people live on the Danish and Swedish sides, respectively.[26] Of those around 2 million live on the Öresund coast or near it.

3.2 FLOWS IN ÖRESUND

[24] Encyclopaedia Britannica 2001. Downloaded from http://corporate.britannica.com/

[25] Nationalencyklopedin. Search-word: *Öresundsförbindelsen*. Downloaded from www.ne.se 2003-07-21.

[26] www.oresundnetwork.com/: *The Öresund region – a selection of statistics, key figures and organisations*. 2001.

The connection to Öresund could be of three different kinds: crossing Öresund, passing through Öresund and entering/leaving a port within the Öresund area. Helicopter transports are excluded – see section 1.2.2 Focus and delimitation.

The Öresund Link was opened on the first of July 2000, and as a result of this two ferry lines have been closed down: Danlink, the railway ferry line between Helsingborg and Copenhagen, and Scandlines Limhamn-Dragör, the ferry service for passengers, cars and trucks between Limhamn outside Malmö and Dragör outside Copenhagen. Danlink kept on going until the Öresund Link was opened, but Limhamn-Dragör closed down already at the end of October 1999. The shipping company did not find it profitable to run the service during the winter season and lose money when they could no longer compensate for the losses during the winter season with a profitable summer season because of the new competition from the Öresund Link beginning in the summer of 2000.

Some specific passenger lines have also closed down. Between Malmö-Copenhagen SAS closed down in summer 2000 and Pilen on the 15th of October 2000. The passenger line between Landskrona and Copenhagen was closed down later as a result of the combined effect of the opening of the Öresund Link and a new extension of the railway "Västkustbanan". The new railway extension was opened in January 2001, putting Landskrona directly on the Västkustbanan and not, as before, being an end station with connection to Västkustbanan. In January 2001 the "Öresund trains", which from the 1st of July 2000 have been running between Malmö and Copenhagen, started to run all the way from Ängelholm/Helsingborg and bypassing Landskrona on their way to Copenhagen, making it very difficult for a passenger line between Landskrona-Copenhagen to compete.

There are two new flows. One is a new catamaran passenger line that started between Helsingborg and Copenhagen – but it was closed down in November 2001. The other is of course the Öresund Link. The Öresund Link could be said to be a "road and railway" having nothing to do with ships. That is true, but since the link has changed the flow patterns in Öresund and since it is a new obstacle in the sound it affects the maritime risk situation and is therefore included in this study. It is also relevant in the sense that a closing down of the Öresund Link, e.g. because of an accident or bad weather, for more than just a few hours will have direct consequences on the ferry lines and passenger lines crossing Öresund, increasing the demand for their services.

3.2.1 Passing through flows in Öresund

An alternative way to enter or leave the Baltic Sea is through Great Belt strait or Little Belt strait. Below are presented data for the numbers of ships passing through Öresund or the Belt during the period 1998 – 2002. What is measured is the number of ships entering or leaving Öresund in the north part of Öresund and the south part of Öresund. Some of those ships have not actually passed through the whole of Öresund but visited a port in Öresund and then returned the same way.

Table 3.1: Number of ships ***passing through*** *Öresund or the Belt* ***1998-2002***. (Statistics from the Danish Maritime Authority, distributed 2003-06-06).

Number of ships in the year*: **Passing through flow:**	1998	1999	2000	2001	2002
Helsingborg- Helsingör-northbound**	19.693	20.303	19.534	18.475	17.704
Helsingborg- Helsingör- southbound**	21.011	21.367	20.213	19.151	19.162
Helsingör-Helsingborg: Northbound + southbound	*40.704*	*41.670*	*39.747*	*37.262*	*36.866*
Malmö-Copenhagen-northbound***	19.687	19.723	19.672	18.459	18.055
Malmö-Copenhagen-southbound***	20.222	20.307	20.402	19.334	19.542
Malmö-Copenhagen; Northbound+southbound	*39.909*	*40.030*	*40.074*	*37.793*	*37.597*
Average between Helsingör-Helsingborg and Malmö-Copenhagen: Northbound+southbound	**40.307**	**40.850**	**39.911**	**37.528**	**37.232**
Stora belt-northbound****	10.005	9.518	9.231	9.232	9.061
Stora belt-sorthbound****	8.878	8.348	7.957	7.797	7.662
Stora belt; Northbound+ southbound	*18.883*	*17.866*	*17.188*	*17.029*	*16.723*
Lilla belt-northbound****	1.847	1.585	1.507	1.270	1.412
Lilla belt-sorthbound****	1.859	1.641	1.644	1.452	1.433
Lilla belt; Northbound+ southbound	*3.706*	*3.226*	*3.151*	*2.722*	*2.845*
Stora belt+Lilla belt: Northbound+ southbound	**22.589**	**21.092**	**20.339**	**19.751**	**19.568**

* =bigger than 50 gross tons (bruttoton)
** =observations from Helsingör by Sövärnets Operative Kommando.
*** =observations from Drogden by Sövärnets Operative Kommando.
**** =observations by Sövärnets Operative Kommando.

Between Helsingör and Helsingborg the Öresund strait is only 4,7 kilometres wide and the ships have to go through certain separate corridors, so there is basically just one way to go. Between Malmö and Copenhagen the ships could choose between going through the Drogden channel or the Flint channel. The data for Malmö-Copenhagen in Table 3.1 above includes both these channels.

3.2.2 Flows to/from ports in Öresund

There are, if smaller ports for leisure boats are excluded, seven port facilities in Öresund: Dragör, Copenhagen and Helsingør on the Danish side and Malmö, Landskrona, Helsingborg and Höganäs on the Swedish side. The flows to and from Landskrona and Höganäs are limited and therefore not included in the table below. Helsingör Port has practically no traffic except for that to and from Sweden/Helsingborg. The same can be said about Dragör with its ferry traffic to/from Limhamn. For the remaining three big ports, you can see in Table 3.2 the figures for the flows/volumes to and from the ports during the period 1998 - 2002. Beginning in 2001 the ports of Copenhagen and Malmö are operating jointly under the name of Copenhagen Malmö Port.

*Table 3.2: Volumes for flows **to/from** the three major ports in Öresund **1998-2002**.*

Year: / **Flows to/from ports in million tons:**	1998	1999	2000	2001	2002
Helsingborg Port*					
- Bulk	1,8	1,8	1,9	1,8	1,7
- Car ferry goods	4,7	5,2	5,2	4,5	4,4
- Rail ferry goods	2,6	2,6	1,7	--	--
- Other goods	1,0	1,0	1,1	1,1	1,0
Total goods	*10,1*	*10,6*	*9,9*	*7,4*	*7,1*
Malmö Port**					
- Bulk	1,2	1,3			
- Oil	1,4	1,5			
- Ferry	3,1	3,2			
- Other goods	0,6	0,5			
Total goods	*6,3*	*6,5*			
Copenhagen Port***					
- Bulk	3,1	2,4			
- Oil	3,3	2,6			
- General Cargo	5,5	4,6			
Total goods	*11,9*	*9,7*			
Copenhagen Malmö Port****					
- Bulk			3,4	2,9	3,1
- Oil			4,2	5,5	5,4
- Ferry			3,7	3,5	3,3
- Other goods			1,9	1,6	1,6
Total goods			*13,2*	*13,5*	*13,4*
All ports together	**28,3**	**26,8**	**23,1**	**20,9**	**20,5**

* The annual reports for Helsingborg Port 1998 – 2002.
** The figures are estimated from a piled diagram in the Annual report for Malmö Port 1999, page 7.
*** Figures received from Copenhagen Malmö Port, Marketing Coordinator Sören Balken. Date 2003-08-06.
**** The annual reports for Copenhagen Malmö Port 2001 – 2002.

3.2.3 Crossing flows in Öresund

Of the goods to and from the ports in the Öresund region, the crossing flows are of special interest and will here be looked at separately. Since the crossing flows are between the Danish and the Swedish side of Öresund and since the figures for each port include both the flows to and from the port, only one side of Öresund has to be studied. The Swedish side has been chosen because of easier access to data.

The different flows will be labelled with five figures like this: “XX-XX-XX”. The first two letters indicate the type of ship, e.g. a high speed catamaran ferry (CF), an ordinary ferry (OF), an ordinary passenger ship (OP) or a high-speed catamaran passenger ship (CP). The two letters in the middle indicate the two towns that are involved, and the two digits the period. For instance: OF-HH-98 means ordinary ferry, Helsingborg- Helsingör, 1998. (When the first two letters are ÖL, it means that the flow is over the Öresund Link.)

3.2.3.1 Crossing flows in Öresund before the Öresund Link

The Öresund Link was opened in 2000, but even during 1999 the effects were seen on the crossing flows because the ferry line Limhamn-Dragör closed down already at the end of October 1999. That is why 1998 and not 1999 has been chosen to illustrate the situation before the opening of the Öresund Link.

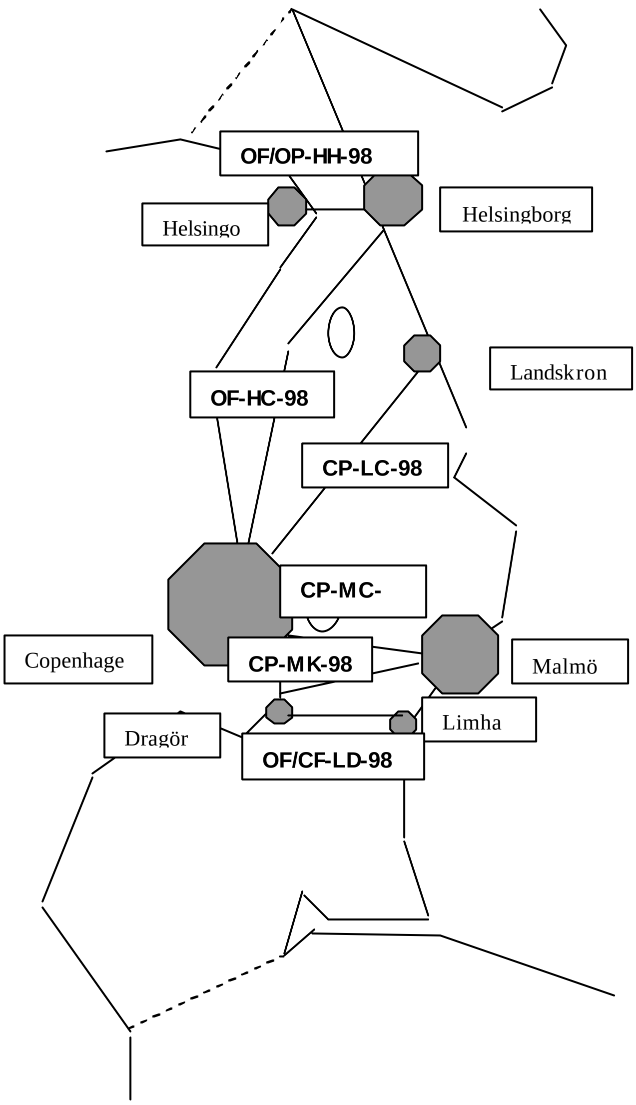

Figure 3.1: ***Crossing*** *flows in Öresund* ***1998*** *(before the Öresund Link).*

Table 3.3: Volumes for ***crossing*** *flows in Öresund in* ***1998.***

Volumes: / **Crossing flows:**	Passengers in numbers	Cars in numbers	Busses in numbers	Goods vehicles in numbers/ tons of goods	Rail wagon goods in tons
Via Helsingborg					
HH links* (OF-HH-98)	11,5 million**	2,1 million ***	0,05 million ***	0,51 million/ 4,7 million***	–
Sundsbussarna **** (OP-HH-98)	2,2 million**	–		–	–
Danlink (OF-HC-98)	–	–		–	2,6 million *****
Via Landskrona					
Flygbåtar (CP-LC-98)	0,16 million ***	–		–	–
Via Malmö					
Flygbåtar + Pilen (CP-MC-98) ******	3,2 million ***	–		–	–
SAS ******* (CP-MK-98)	Included in the 3,2 million above	–		–	–
Limhamn-Dragör: ferry (OF-LD-98) + catamaran (CF-LD-98) ********	1,8 million**	0,3 million **	0,02 million **	0,03 million/ 0,2 million**	–

* There are two different car ferry services operating between Helsingborg and Helsingör: Scandlines and HH ferries. Scandlines is also a rail ferry service for passenger trains.
** Trafikstatistik för Helsingborgs hamn 1998. Helsingborgs hamn AB. 1999-01-25.
*** "Utrikes och inrikes trafik med fartyg 1998 (Swedish shipping 1998)". Statistiska meddelanden T 45 SM 9901. SCB. Table 10A and 10B "Passenger vessels and ferries between Sweden and foreign ports 1998".
**** Sundsbussarna is a passenger ferry service.
***** Annual report Helsingborg Port 1998.
****** There are two passenger catamaran lines between Malmö-Copenhagen; Flygbåtarna and Pilen.
******* The SAS catamaran between Malmö – Kastrup (Copenhagen airport) is open only for SAS passengers to and from the airport at Kastrup.
******** The car ferry service between Limhamn and Dragör is operated both by a catamaran and by regular ferries.

3.2.3.2 Crossing flows in Öresund after the Öresund Link

Here it is important to have as up-to-date statistics as possible, because it probably takes a while after the opening of the Öresund Link before the effects on the flows in the Öresund region have been stabilised. Data from 2002 have therefore been chosen.

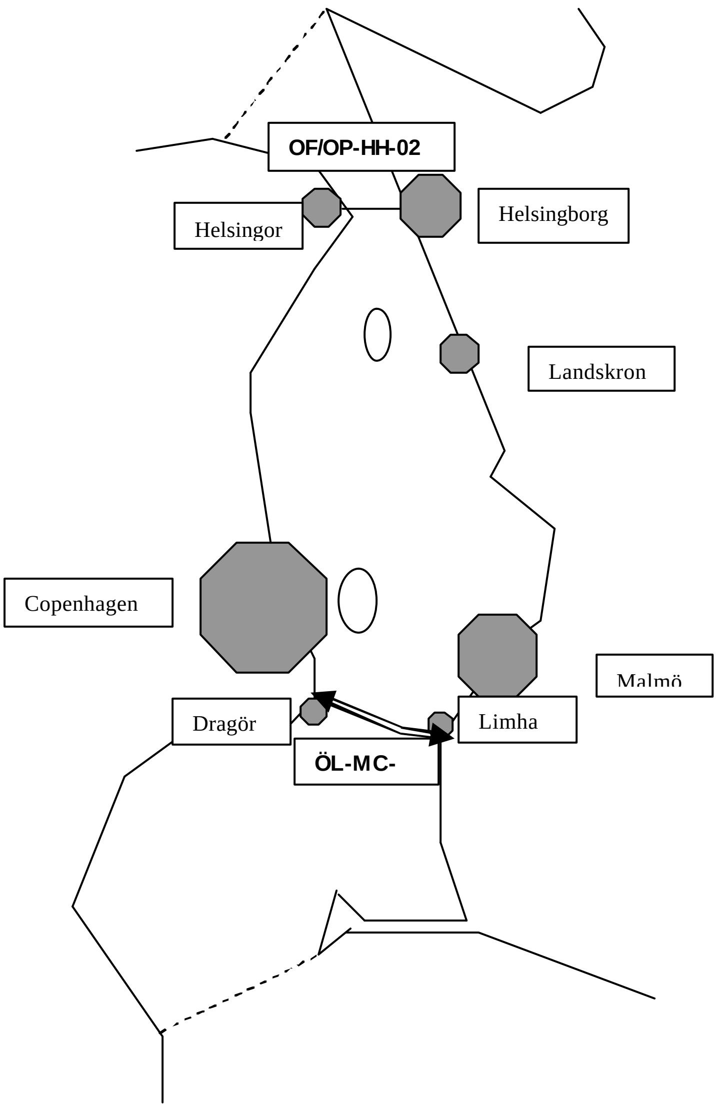

Figure 3.2: ***Crossing*** *flows in Öresund* ***in 2002****.*

Table 3.4: Volumes for ***crossing*** *flows in Öresund during* ***2002.***

Volumes: **Crossing flows:**	Passengers in numbers	Cars in numbers	Busses in numbers	Goods vehicles in numbers/ tons of goods	Rail wagon goods in tons
Via Helsingborg					
HH links* (OF-HH-02)	11,6 million**	1,9 million ***	0,04 million ***	0,45 million/ 4,4 million***	-
Sundsbussarna **** (OP-HH-02)	1,5 million**	-		-	-
Via Malmö					
Öresund Link (ÖL-MC-02)					
- Road	8,7 million *****	3,1 million *****	0,04 million *****	0.26 million *****	-
- Rail	5,3 million ******	-	-	-	3,2 million *******

* There are two different car ferry services operating between Helsingborg and Helsingör: Scandlines and HH ferries.
** Trafikstatistik för Helsingborgs hamn 2002. Helsingborgs hamn AB. 2003-01-15.
*** "Utrikes och inrikes trafik med fartyg 2002 (Shipping goods 2002)". Statistiska meddelanden SSM.021:0304. SIKA. Table 10A and 10B "Passenger vessels and ferries between Sweden and foreign ports 2002".
**** Sundsbussarna is a passenger ferry service.
***** Statistics from Öresundsbro Konsortiet (www. Oresundskonsortiet.com.). Search word: Traffic figures. Date 2003-06-06.
****** Statistics from DSB. Figures for passenger traffic by train over the Öresund Link received by e-mail from Karsten Längerich, strategisk planläggare, Öresundbro Konsortiet. Date: 2003-06-02.
******* Figures for rail wagon goods over the Öresund Link received by e-mail from Banverket, Statistikfunktionen, Lars Sjöberg. Date: 2003-08-20.

3.3 CHANGED FLOWS IN ÖRESUND AND A NEW RISK SITUATION

3.3.1 The changed flows in Öresund

When the Öresund Link was taken into daily service in July 2000 it meant a substantial change in the flows in the Öresund area. With the Öresund Link a new flow was created. As a result two goods ferry lines, Scandinavian Ferry Lines (SFL) between Limhamn and Dragör (i.e. Malmö–Copenhagen) and Danlink between the ports of Helsingborg and Copenhagen, disappeared, as well as some passenger lines between Denmark and Sweden.

But let's start with the ships *passing through Öresund*. In 1998 the average number of ships passing through the sound in the north-south direction or opposite was 40.307 and in 2002 it was 37.232 – a decrease of 7,6 % (see Table 3.1). An alternative way to enter or leave the Baltic Sea is through the Belt. From 1998 to 2002 there was a decrease in the number of passages through the Belt from 22.589 to 19.568 – a decline of 13,4 % (see Table 3.1). The Öresund Link does not seem to have made the passage of Öresund less attractive – the opposite seems rather to be the case since the decline for Öresund during the period studied is less than that for the Belt. We must also take into consideration that the average size of the ships tends to increase.

The total volume of goods *to/from* the three major *ports* in the region has declined from 25,7 million tons in 1998 to 20,5 million tons in 2002 - a difference of 7,8 million tons (See Table 3.2). Of this difference 1,8 million tons can be explained by the fact that 1998 was the last year for Copenhagen Port to have activities connected to the construction of tunnel elements for the Öresund Link[27]. 5,2 million tons (2,6 in Helsingborg and 2,6 in Copenhagen) is the result of the closing down of Danlink and the use of the Öresund Link instead for rail goods. Another 0,2 million tons is explained by the closing down of Limhamn- Dragör. Remaining unexplained is just 0,6 million tons.

The crossing flows over Öresund can be divided into three parts; the north part of Öresund (Helsingborg-Helsingör) the south part (Malmö-Copenhagen) and Danlink between Copenhagen and Helsingborg.

If we compare the situation in 1998 with that in 2002 for the northern part of Öresund, we can se that the flow over Helsingborg-Helsingör has dropped from 13,7 million passengers and 2,7 million vehicles in 1998 to 11,6 million passengers and 2,4 million vehicles in 2002. The passengers have thus dropped by 15 % and the number of vehicles with about 10%.

In the southern part of Öresund the ferries between Limhamn-Dragör have been replaced by the Öresund Link. In 2002 14 million passengers, and 3,4 million vehicles crossed Öresund by the Öresund Link. If we compare that with 5 million passengers, 0,3 million cars and 0,05 million trucks and busses in 1998, we can see a substantial increase in the number of both passengers and vehicles (see Tables 3.3 and 3.4). To this can be added 3,2 million tons of rail transported goods – a mode of transport that wasn't in use in this part of Öresund in 1998.

Danlink which in1998 transported 2,6 million tons of rail goods between Copenhagen and Helsingborg had ceased to exist 2002.

If we look at *the whole of Öresund* we can conclude that the passenger figure has increased from about 19 million in 1998 to about 26 million in 2002. The figure for vehicles has gone up from about

[27] Between 1998 and 1999 there was a decline of 2,2 million tons in total goods volume for Copenhagen Port. 80 % of this could be explained by the fact that the production of tunnel elements for the Öresund Link ceased in 1998 (Annual report: Port of Copenhagen 1999, page 8).

3 million to almost 6 million. And finally, rail goods have gone from 2,6 million tons in 1998 to 3,2 millions in 2002.

The total volume of passengers, vehicles and rail transported goods crossing Öresund has thus increased substantially after the opening of the Öresund Link, while the volume and the passages through Öresund have declined somewhat. Transport of goods to/from the ports in the region has decreased substantially but the decrease can be explained by the consequences of the finishing and opening of the Öresund link.

3.3.2 Changed risks in Öresund

Passing or crossing a narrow water passage always entails exposure to risks of different kinds. Öresund is no exception. During the 90s many incidents have been reported, and several accidents have occurred. Öresund is today one of the areas in the world with most ship movements, and the volumes are increasing due to the high level of economic activity in the Baltic Sea region.

Öresund is a quite narrow sound with a difficult navigation situation caused by among other things strong currents. Risks of different kinds are at hand[28]. One source of risks is the substandard ships, ships that do not fulfil international regulations governing safety at sea and the protection of the environment, passing through Öresund[29]. Another source of risk is failures in communications between man and technology. Improvements in safety systems mean that accidents caused by just one factor are becoming rarer. On the other hand, accidents caused by several factors tend to increase. One reason is that the safety systems are becoming so sophisticated that only a limited number of persons have a total grasp on how they work. Another reason is that it is tempting to change behaviour, for instance increase the speed of the ship, when you get more sophisticated, risk-reducing technology so that in the end the risk level tends to be about the same.[30] [31]

The risk situation is dependent upon many factors, above all, of course, upon which flow, like Malmö-Copenhagen or Helsingborg-Helsingör, is studied and the volumes and types of goods connected to that flow. The total risk situation in Öresund can be estimated by summing up the risks for each individual flow.

A flow is defined by its starting and ending points, the infrastructure used and the transport mode and means utilised. Different flows have different risk patterns. The risk situation of a flow is also

[28] Harrami & Kylefors (1999) *Riskinventering Öresund (Risk inventory Öresund).*
[29] Hägg, Göran (2000a) *Det internationella sjösäkerhetssystmet och dess brister – kan ett öppet fartygsregister stärka miljö- och sjösäkerheten i Öresund och Östersjön? (The international sea safety system and its shortages – can an open ship register strengthen the environmental and sea safety in Öresund and the Baltic?)*
[30] Ek, Åsa (2000) *Fartygsolyckor i Öresund – människan, människa-tekniksystemet och organisationen som risk- och säkerhetsfaktorer (Ship accidents in Öresund – man, man-machine-system and organisation as risk and safety factors).*
[31] Reason, James (1997) *Managing the risks of organizational accidents*, Chapter 1.

dependent upon volumes and what is transported. Normally, increased volumes also mean increased total risks. Passengers and goods are transported. Passengers all look very much the same, but goods can differ a lot in size and characteristics and can be divided into different categories. One very important division is between dangerous goods and non-dangerous goods. Another is between fluid versus non-fluid goods, and a third between bulk versus packaged goods.

In Öresund there are crossing flows of goods and passengers; the north-south and south-north flows cross the east-west and west-east flows. The east-west and west-east flows must, if the Öresund Link is not used, include a change/combination of transport means. Transport technology is under rapid development in terms of both infrastructure and transport mode units. We also have a change in market shares of the different transport means. More goods are transported by truck and fewer by railway. On top of that the goods are changing character; especially important here are changes concerning new types of dangerous goods.

The Öresund area is also a heavily populated area, with many people living on the sound or quite near it. The consequences of an oil tanker accident, for instance, could therefore be severe[32].

The consequences of an accident can also be spread outside the Öresund region. Most of the goods passing through or crossing Öresund are bound for destinations outside the Öresund region or will just be processed/value-added within the region and then transported out of the region again. Seen from the point of view of the goods owner/the shipper having a shipment passing through or crossing Öresund means being exposed to risks of different kinds in the Öresund area.

The opening of the Öresund Link has meant that some of the earlier risks have disappeared, some have changed character and some new risks have appeared. Since the flows from Danlink, Limhamn-Dragör and some passenger lines have disappeared, the risks linked to those flows have been eliminated. Especially important here is to mention the risks linked to that part of the ferry traffic between Limhamn-Dragör that was operated by a big catamaran (Felix) that was able to transport cars, busses and lorries. Big catamarans tend to be more involved in incidents and accidents than ordinary ships. The Drogden channel and the Flint channel are still there, but they have been improved. For instance has the Flint channel been made deeper, straighter and better marked out. So it ought to be less risky now to pass through one of those channels. The Öresund Link itself creates new risks. The traffic over the link causes risks, especially the passage of the tunnel. The link itself (the bridge part and Pepparholm) is also an object that could be hit by ships passing through Öresund. But far-reaching precautions have been taken to avoid/delimit the consequences of hitting the link. Extensive precautions have also been taken to make the crossing of Öresund by the link safe. All together this creates *a changed risk situation* in Öresund and the Öresund region.

The risk situation is complicated by the fact that two different countries are involved, meaning that they both have to agree upon and co-ordinate actions if they are to become effective. There are also some areas in Öresund that are international water and where international agreements are valid – not national laws. This makes it more difficult for Denmark and Sweden to implement risk-reducing

[32] Törneman, Niklas (1999) *Miljörisker med transport av olja i Öresund (Environmental risks when transporting oil in Öresund).*

actions. To this can be added some international agreements called "The Öresund Treaties[33]" (Öresundstraktaten) from 1857 that make it especially difficult to take proactive risk-reducing actions. In 1429 the Danish State started to collect fees and later customs for every ship passing through Öresund or the Belt. This was, over the decades to come, an important source of income for the Danish State and existed until 1857, when a number of treaties were signed according to which Denmark, on the one hand, received a lump sum and on the other hand promised to keep free and uninterrupted passage in Öresund and the Belt for all ships for all the years to come. These nearly 150-year old treaties make it very difficult today for the Danish and Swedish authorities to take action on foreign ships before an accident has happened. Proactive actions like entering the ship and checking the sobriety of the crew members on duty could be looked upon by the ship owner as interference into the right of free and uninterrupted passage.

The total maritime risk situation in Öresund has probably become better because there are fewer crossing flows at sea level, improvements have been made in the Drogden and Flint channels, and there is no big catamaran ferry operating any more between Limhamn and Dragör; those risk-reducing factors combined are more important than the new risks connected to the passage over the Öresund Link or the link as an obstacle in Öresund.

3.3.3 Future flow risks in Öresund

In the future, integration in the Öresund region can be expected to increase, and this will lead to more goods and human beings crossing Öresund, and probably also to changed flows because of changes in the division of tasks. One example is the newly started company Copenhagen Malmö Port that operates the earlier two separate ports of Malmö and Copenhagen as one port, avoiding the duplication of resources and using the labour force more efficiently. Some years ahead it is probable that co-operation based on the same basic idea will exist between the airports of Kastrup and Sturup. Many other application areas are also possible. The production "pattern" around Öresund will change.

International trade is increasing all the time. Both within the EU and outside it. From 2004 there will be 10 new member states in the EU, of which four are situated at the Baltic Sea (Estonia, Latvia, Lithuania and Polen). This will lead to increases in the flows, both those that are passing through Öresund and those that are crossing Öresund, the latter because of the expected new truck traffic from the Baltic countries across Sweden and further down to the continent.

We can also expect a rapid increase in the number of oil tankers exporting Russian oil. Those transports are today in some cases carried out by substandard ships. There are no indications that there will be, at least not in the immediate future, any change in this aspect. The increased number of oil transports clearly leads to increased risks in Öresund if they choose Öresund for their passage to and from the Baltic Sea. But we must remember that because of the limited depth in the Flint and Drogden channels the really big ships have to choose the Belt instead.

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[33] Nationalencyklopedin. Search-word: *Öresundstraktaten*. Downloaded from www.ne.se 2003-03-16.

New technology in different forms will be used in the future to increase safety in the flows. One technology that already exists and is now under full-scale implementation is the Automatic Identification System (AIS) based on transponders fixed on ships. The transponder is loaded with basic information about the ship, its cargo, position, speed etc., and this information is continuously updated and spread via signals in the air – signals which could be received by others who have the same kind of equipment. The AIS is both a Ship – Ship system and a Ship – Shore system. As a Ship to Ship system the AIS aids the watch officer to take appropriate measures to avoid collisions and incidents by giving him up-dated information about all other ships in the neighbourhood also equipped with AIS. As a Ship to Shore system, AIS can send information to shore where it could be used by different authorities, the ship owner and others.[34] IMO has taken the decision to make AIS compulsory for all ships of 300 gross tons on international voyages, 500 gross tons for non-international voyages and all passenger ships. The system is being introduced step-wise from 1 July 2002 and will be fully in use no later than 1 July 2008. The system has the potential for a clear increase in maritime safety in the Öresund region.[35]

[34] Swedish Maritime Administration: *Automatic Identification System (AIS)*. Downloaded from www.sjofartsverket.se 2003-07-16.

[35] Global Positioning & Communication: *IMO maritime AIS world standard*. Downloaded from www.gpc.se 2003-07-17.

4 THEORIES ABOUT SUPPLY CHAINS AND RISKS

4.1 SUPPLY CHAIN MANAGEMENT

A *Supply Chain* can be described as the flow of raw material, components and/or ready-made products that are associated with a certain product[36]. The supply chain ends with the ultimate consumer and starts with the raw material supplier.

Supply Chain Management is an integrating philosophy to manage the total flow of a supply chain from supplier to end customer that 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. By using this holistic approach benefits of different kinds can be achieved. One is shorter lead –times, which often give substantial reductions in capital tie-up, higher flexibility and better customer service.

Supply chain management is a concept that has evolved during the 90's. Chains of suppliers have always existed, and so has the effort to integrate those chains, but the concept of supply chain management was not in common use before the 90s. However, it is no coincidence that the concept evolved at that time. It is the result of a number of new factors in the environment, which makes the ideas/theories behind the concept more relevant today than before

The advantage of looking at the supply chain from a holistic perspective increases when each company in the chain adds less of the total value. One of the strongest trends during the late 90s has been to *focus on core competencies* and core activities[37]. If a company is going to survive in the international arena, it is not enough just 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, none-core activities are farmed out and replaced by components/services bought from the outside. Today, you often find that 80 – 90 % of a company's turnover stems from outside the company, and that the added value of the company itself only amounts to 10 – 20 %. The practice of letting a supplier produce the components/services that the company uses in its own production is called *outsourcing*. 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.

Owing to the *increased rate of change*, it is also 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

[36] Christopher, M. (1998) *Logistics and Supply Chain Management. Strategies for reducing cost and improving service.*
[37] Christopher, M. & Towill, D. (2000): "Supply chain migration from lean and functional to agile and customised".

development efforts on their own core competence area, letting other firms develop the other components[38].

Traditionally, competition has existed between different individual firms. However, since each firm in the chain now tends to add less and less value, competition 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.[39]

Another important factor is *globalisation*. Today, the potential for competition is world-wide. The same applies to co-operation with other firms in the supply chain, since they may be located almost anywhere in the world. Through globalisation, the supply chains tend to become more geographically dispersed, leading to more transportation and increased transport costs.

Each of the Nordic countries has a relatively small population and a high living standard, which is heavily dependent upon exports. Several Nordic companies sell more than 90 % of their production abroad. Consequently, the theories behind supply chain management are specifically important to companies in the Nordic countries.

Similar to most other new management concepts, there is no clear and generally accepted definition of supply chain management. Examples of definitions are:

> *"An integrating philosophy to manage the total flow of a distribution channel from supplier to ultimate customer (Cooper and Ellram)"* [40]
>
> *"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 flows all materials and finished goods, all information, even all transactions. 'It requires looking at your business as one continuous process'…."* [41]

In the above-mentioned continuous process, we can identify activities that are linked to each other. Therefore, we can talk about chains of activities, or activity chains.

The flow in a chain can be initiated in two different ways. One involves a company that decides to place an order based on sale prognoses with its supplier, which in turn places an order with its supplier based on its own prognoses, and so on. Alternatively, the flow in the chain might be initiated by the end consumer who buys a product leading the seller to place an order with its supplier, which in turn orders from its supplier, and so on. In the latter case, it is an actual sale rather than prognoses that initiates the flow.

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[38] Mason-Jones, R., Naylor, B. & Towill, D. (2000): "Engineering the leagile supply chain".
[39] Towill, D., Childerhouse, P. & Disney, S. (2000): "Speeding up the progress curve towards effective supply chain management".
[40] Coyle, Bardi & Langely (1996) *The Management of Business Logistics*, page 9.
[41] Gattorna & Walters (1996) *Managing the Supply Chain - a Strategic Perspective*, page 12.

In one book, the characteristics of supply chain management are summed up thus (translated from Swedish).

> *"…..can the following characteristics of supply chain management be identified:*
> *- 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"* [42]

So far the flow has mainly been discussed as a flow of raw materials, components and ready-made products from the raw material supplier to the end consumer. This could be called the physical flow, but there are also at least two other flows — the information flow and the financial flow.

The *physical flow* consists of raw materials and components as well as of packages, containers, lorries and the like. Logistics early focused on the physical flow and tried to make it more efficient. The *information flow* is the flow of information in the chain, and the task is to manage the physical flow so that this becomes efficient. The *financial flow,* the flow of "money", is also of importance for the efficiency in the supply chain. The suppliers must get their payments quickly, safely and cost-effectively. The physical flow goes mainly forward, while the financial flow goes mainly backwards. The information flow goes in both directions.

There is a close connection between the information flow and the physical flow. An integrated information system for the whole supply chain gives knowledge about the end consumer's actual purchase, and distributes this knowledge on an on-line basis to all the companies in the chain. Other relevant information like inventory levels in the chain is also distributed. This information sharing makes it often possible to reduce safety stocks substantially and to find better solutions for the chain as a whole.

4.2 RISK THEORIES

4.2.1 Risk analysis

The general term used to describe the study of decisions subject to uncertain negative consequences is *risk analysis*[43]. It can be divided into risk estimation and risk evaluation. Another general term is

[42] Paulsson, Nilsson & Tryggestad (eds.), (2000) *Flödesekonomi – supply chain management (Flow Efficiency - Supply Chain Management),* page 32.

risk management. This term is often used when we are focusing on the decision process in a risk situation.[44] *Risk estimation* includes (a) the identification of outcomes, (b) the estimation of the magnitude of the associated consequences of these outcomes, and (c) the estimation of the probabilities of these outcomes. *Risk evaluation* determines the significance or value of the identified hazard and risk to those concerned.[45]

Hazards of different kinds have always been at hand and threatened human beings, their belongings and their environment. Many of the traditional hazards have diminished or even disappeared. Others have grown in importance and new ones have emerged.

> *"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 many times have very severe consequences. Risk Analysis and Risk Management have therefore become more and more important".*[46]

Risks are today in the political spotlight much more than before. In the US about 150 billion dollars are spent each year on risk and environmental regulation, which is twice the cost of all traditional regulation taken together. Liability costs are also rising. In the US compensation for job accidents now equals the cost of unemployment compensation. To this can be added the tort liability for risky products and risky jobs. [47]

Risk analysis is therefore becoming increasingly important for individual companies, for organisations and for society.

4.2.2 Risk management

Risk Management means focusing on the decisions in a risk situation, and can be 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"[48]. It can be described as an area of theories that gives firms and organisations models for evaluating and handling their risk situations in a systematic way.

"Risk management means taking deliberate action to shift the odds in your favour" [49]. The risk situation can be structured in different ways. Hamilton has developed the Risk Circle[50], which he has divided in two parts — "Risks within production" and "Risks outside production". Risks within

[43] *Risk: Analysis, Perception and Management* (1992), page 3.
[44] Ibid, page 5.
[45] Ibid, page 3.
[46] Hamilton, Gustaf (1996): *Risk Management 2000*, back cover.
[47] Viscusi, Kip (1998) *Rational risk policy*, page 1.
[48] *Risk: Analysis, Perception and Management* (1992), page 5.
[49] Borge, Dan (2001): *The Book of Risk*.
[50] Hamilton, Gustaf (1996) *Risk Management 2000*, page 16.

production have to do with operational risks that could cause production disturbances. Risks outside production are divided into political risks, responsibility risks and marketing risks.

Hamilton says that we are living in a "risk society" where the risks have been much more "hidden" and difficult to see and the consequences more difficult to evaluate. Society has become much more complex and integrated, and dependent on the technology functioning. As an example of the new and big risks that companies are taking Hamilton mentions IT. An investigation[51] was conducted in 1991 by the Gartner Group of 400 American companies to see what would happen if there was a computer breakdown. A two-day breakdown would have a direct effect on the results of 45% of the companies, and if the breakdown were to last more than a week quite a few of the companies would go bankrupt.

To be able to lower the total risk costs in a company it is necessary for the company to do risk analysis and take pro-active measures, i.e. to have *a structured* and *professional way to deal with risk matters*.

Actions are the ways in which firms and organisation try to handle the hazards. But before efficient action can be taken, *assessment* has to be done. One way to act is to pro-actively try to eliminate or diminish the causes and contributing factors; another is to try to minimise the negative consequences. One example of the latter is insurance.

Yet the usefulness of insurance is limited. You can only insure yourself against some of the negative effects, not all. Normally it is the immediate, primary consequences like loss of goods that you can insure yourself against. Unfortunately those consequences are in many cases only a small fraction of the total consequences. In his book *Managing the Risks of Organisational Accidents* James Reason refers to an investigation by HSE (Health and Safety Executive) from 1993 saying, "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"[52]. Among those mentioned in the study are "production losses" and "lost sales". For transportation this can mean that the most important negative consequences from an accident resulting in lost goods is not the loss of the goods 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 just look at immediate, primary consequences and to work pro-actively with a number of different risk-handling methods – not just traditional insurance.

If the findings of the HSE study mentioned above are valid for the Öresund area, then this also means that public organisations with safety responsibility in one way or another for the area *increasingly must consider secondary, tertiary etc. consequences* and spend more effort on pro-active work *to become more efficient in saving human lives, the environment and money for firms, organisations and society.*

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[51] Ibid, page 27.
[52] Reason, James (1997) *Managing the Risks of Organizational Accidents*, page 238.

Materials management (inbound logistics) and physical distribution (outbound logistics) are identified by Hamilton as two key areas when it comes to company risks, and he also stresses the importance of working pro-actively in those areas. Disturbances in inbound logistics could easily lead to having to change production plans, and in more severe cases to closing down production temporarily. This leads to increased production costs, lost sales and perhaps even lost market shares. Disturbances in outbound logistics also lead to increased costs, perhaps because a more expensive transport solution has to be chosen, lost sales and lost market shares. Disturbances in one link in the chain also easily spread to other links, causing increased costs and lost sales/market shares in those links. The transport of goods is a main source of risk in many supply chains.

4.3 TIME-BASED SUPPLY CHAINS AND VULNERABILITY

It is today common to focus on time in the supply chain to create a more efficient and effective chain. Time-based management implies a focus on the time aspects of the different operations/activities 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 effective. In most cases, such procedures will reduce the time spent on the necessary activities.[53] A central concept in time-based management is lead time.

Lead time could be defined in different ways. One often-used definition is "the total time that elapses between an order’s placement and its receipt"[54]. More generally, you can define lead time as the time that passes between the ordering of an activity to the fulfilment of that activity. A lead-time component is a lead-time activity linked to a special part of the chain. Each lead-time component can be split into two parts, one administrative lead-time part and one physical lead-time part[55]. In most cases the former dominates totally.

Among the first to realise the importance of time for the overall efficiency in the organisation were Stalk and Hout back in 1990[56]. When they compared different companies with one another they found that those companies focusing upon time had a better record. When you look more closely at the total lead time you often find that a large part, up to 95% of the total time, consists of waiting time[57]. 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 to him. Therefore an important part of the Supply Chain Management concept is the search for reductions in lead times.

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[53] Beesley, A. (1997): “Time compression in the supply chain”.
[54] Coyle; Bardi & Langley, (1996) *The Management of Business Logistics*, page 615.
[55] Persson & Virum (1996) *Logistik för konkurrenskraft*, chapter 10, page 246.
[56] Stalk & Hout (1990) *Competing against time.*
[57] See for instance *Storhagen* (1995), chapter 5.

In Sweden, research has been done about the importance of lead times in production by among others John Wedel[58] and in external distribution by among others Mats Abrahamsson[59] and Andreas Norrman[60].

It is very hard to find a natural starting point and a natural ending point for most supply chains, especially today when re-use of packages and worn-out products becomes more and more usual. Actually you have several different lead times depending on what you include in the supply chain and where you take your starting and ending points.

Another important lead-time factor is the magnitude of change in demand compared to plan. It is for instance one situation when demand is within the forecast and it is just a question for the producer to deliver the products ordered from stock, but quite another situation when demand becomes so high that the producer is running out of stock and needs to start producing to be able to deliver.

The *quality demands* on raw material, components and processes have increased dramatically. Figures like 20 p.p.m., i.e. only 20 parts per million are allowed not to meet the quality demands, are mentioned in the car assembly industry. In the literature about Six Sigma[61] – a statistics-based methodology that provides a structured framework for organizing and implementing strategic process improvement initiatives to attain reductions in process variability – the desired quality level in a single part or stage is set to be at least six sigma i.e. 99,99966 %. Huge improvements in the reliability and in some cases also the flexibility of the machines used in production have also taken place. This has led to reductions in buffer stock levels. When quality and reliability are high you do not need so much safety stock anymore. A couple of decades ago most distribution channels/supply chains still functioned as a number of independent links that were "isolated" from each other with substantial buffer stocks. Each link could be dealt with separately. The buffers made it unlikely that disturbances in one link would spread to other links in the chain. Today the situation is quite different. Integration is higher, the buffer stocks are smaller and sometimes even nonexistent. Especially in the last few years there have been strong trends towards more integrated and leaner supply chains, chains that also tend to have more links (be longer) and be more geographically spread out. This has led to a significant *increase in the vulnerability of the supply chains*, especially as the buffer stocks are growing substantially lower or even nonexistent. Ericsson Mobile Telephones is a recent example of this. A loss of 1.8 billion Swedish crowns for the first 6 months in the year 2000 for consumer products (of which mobile telephones were a part) was fully explained by the CEO Kurt Hellström by the supply problems that had existed for components to the mobile phones during that period caused by a minor fire in a factory of one the component suppliers[62].

[58] Wedel, John (1996) *Lead-time Reduction in Manufacturing - from initiation to realisation.*

[59] Abrahamsson, Mats (1992*) Tidsstyrd direktdistribution (Time-based direct distribution).*

[60] Norrman, Andreas (1997) *Organizing time-based distribution in transnational corporations.*

[61] Abdelhamid, Tario S. (2203) "Six-Sigma in Lean Construction Systems: Opportunities and Challenges".

[62] *Sydsvenskan*, Saturday, 22nd of July 2000, page A10.

4.4 DISTURBANCES IN THE SUPPLY CHAIN FLOWS

Disturbances in the supply chains affecting the lead times (often prolonging them) have always existed, and the disturbances have mainly been handled by having buffer times in many operations, substantial safety stocks in each link and several suppliers of each raw material/component.

Today the situation is very much different. The sensibility for disturbances in the lead times has increased substantially because there tend to be more links in each supply chain, caused by the increased specialisation/outsourcing, less or even no buffer time in many operations, very small or perhaps even no safety stocks in the different links in the chain and a concentration on fewer suppliers, perhaps just one (single sourcing) or two (dual sourcing) for each raw material/ component.

Disturbances in the lead times in supply chains can have many causes and exist within many areas. Transportation is one such area. Goods transported can be destroyed or lost through accidents. This means that new goods have to be sent out, which often means increased lead times. Goods can also be delayed because of other causes like planning mistakes or bad weather conditions. Dangerous goods are especially exposed to disturbances because they have to be transported under special conditions, e.g. on special routes or during special hours of the day, which make this kind of transport less flexible. Dangerous goods can also be delayed because of intense control of papers and/or equipment or lack of proper documentation and/or equipment.

The magnitude of the negative consequences, not least the negative economic consequences, of disturbances in supply chains has now been recognised and "supply chain risk management" has become a new and expanding research area of its own. The first international conference about "Risks in Supply Chains" was held in London in 1999. Another example is the newly started (October 2001) international network for those interested in supply chain risk issues called the ISCRIM network (International Supply Chain Risk Management network[63]). The first dissertations have also been produced. In Sweden Knut Fahlén[64] has studied the consequences of disturbances on manufacturing companies' effectiveness and written a doctoral thesis about the subject, and Göran Svensson[65] has written a thesis about vulnerability in logistic channels.

Transportation tends to constitute a bigger and bigger part of the total activities in the chain because stocks are eliminated or lowered and more and longer transports are needed when the chains become longer and more geographically dispersed. *This makes transport a very "weak link"* in the chain.

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[63] For more information – see: http://www.iscrim.org

[64] Fahlen, Knut (1997) *Störningars konsekvenser för tillverkande företags effektivitet (Consequences of disturbances for the efficiency in manufacturing companies).*

[65] Svensson, Göran (2001) *Sårbarhet i logistikkanaler (Vulnerability in logistics channels).*

5 A MODEL FOR RISK ANALYSIS OF SUPPLY CHAIN FLOWS

5.1 METHOD FOR CREATING A MULTI-PURPOSE MODEL

In the first part of this chapter, section 5.2 and section 5.3, based on the general theories about risks and supply chain management presented earlier in Chapter 4, two overview models for describing and analysing risks in supply chain flows are developed.

In the second part of the chapter a multi-purpose supply chain flow model is developed step-by-step. The structural elements of the multi-purpose model are based on the second overview model developed in the first part of the chapter. For each structural element, based on earlier studies of risks when passing or crossing Öresund, a number of variables are added. Most of those earlier reports have been conducted within the SUNDRISK project.

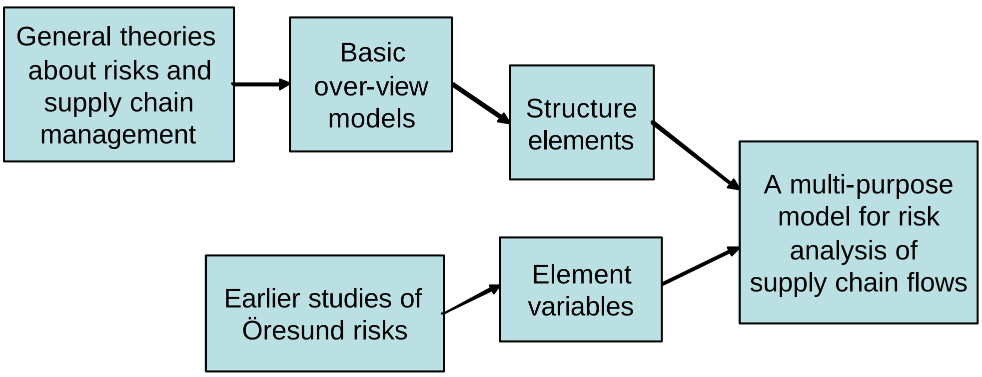

Figure 5.1 Method used for creating a multi-purpose model for risk analysis of supply chain flows.

The earlier studies of Öresund risks have been presented in detail in Chapter 2, sections 2.1.1 – 2.1.3. Each report has been scrutinized in search of variables for the structural elements. The findings are used intensively in section 5.4, especially 5.4.2 – 5.4.7, but they are not explicitly referred to in the different sections.

5.2 DEVIATIONS AND CONSEQUENCES – A BASIC MODEL

The *supply chain flow* under study has to be defined. So has the special *"setting"* or "context" that we are particularly interested in, for instance the passage of a certain geographical area during a certain period of time. A *deviation* in this flow occurs when something happens that makes the flow deviate from what was planned or expected. This deviation could have *consequences* for *actors* in the chain, consequences that could be *both negative and positive* depending on how the individual actor is "linked" to the chain and to deviations in the chain. The actors will thus be *affected*. The deviation is caused by an *event* affecting the supply chain flow in one way or another, and the event is happening against the background of the "setting".

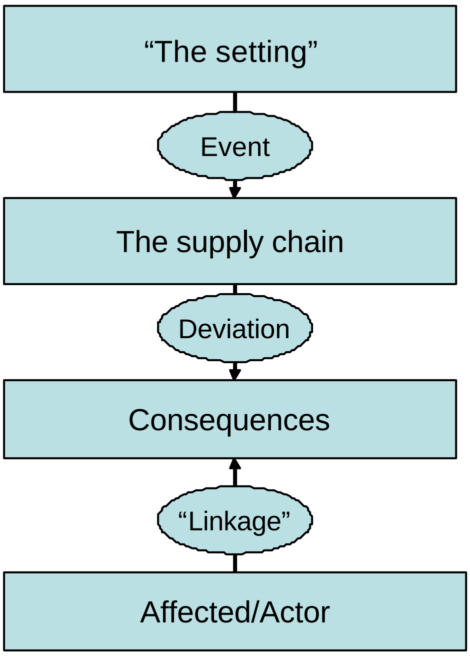

Figure 5.2: Deviations in supply chain flows and their consequences – a basic overview model

5.3 A BASIC RISK ANALYSIS MODEL

The "setting" in this study is the passing or crossing of the geographical *maritime area Öresund* and the focus is on risks, i.e. on deviations in the supply chain flows with mainly negative consequences. Those kinds of deviations are usually called *disturbances*. The event resulting in a disturbance is often called "a hazardous event", but since the focus in this study is on economic consequences and not on the effects on human beings, the word "hazardous" will not be used. Instead I will use the word "triggering" and talk about a *"triggering event"* i.e. the initial event that causes the disturbance. Behind the triggering event are different *causes* and *contributing factors*.[66]

A disturbance in the supply chain flow has *flow consequences*. The *primary* flow consequences are those that are the immediate result of the disturbance; the *secondary* flow consequences result from the primary flow consequences. The secondary flow consequences could spread step-by-step in the

[66] Mullai & Paulsson (2002) *Oil spills in Öresund – hazardous events, causes and claims*. Page 14 – 15.

chain all the way back to the first supplier, and all the way down to the ultimate consumer. The consequences could in other words be spread both *upstream* and *downstream*. [67]

When a flow consequence affects an actor, economic consequences, both positive and negative, will often be the result. We are here looking at situations where the negative consequences dominate, since we are dealing with risk analysis issues.

The affected company/organisation will in many cases not just passively accept the situation but *act*. As an actor it will try to *identify* and *assess* the risks in the chain and then take *decisions* and *implement* them.[68]

These implementations will affect the supply chain flow, the "setting" of the Öresund maritime area, and indirectly also the *causes* and *contributing factors*.

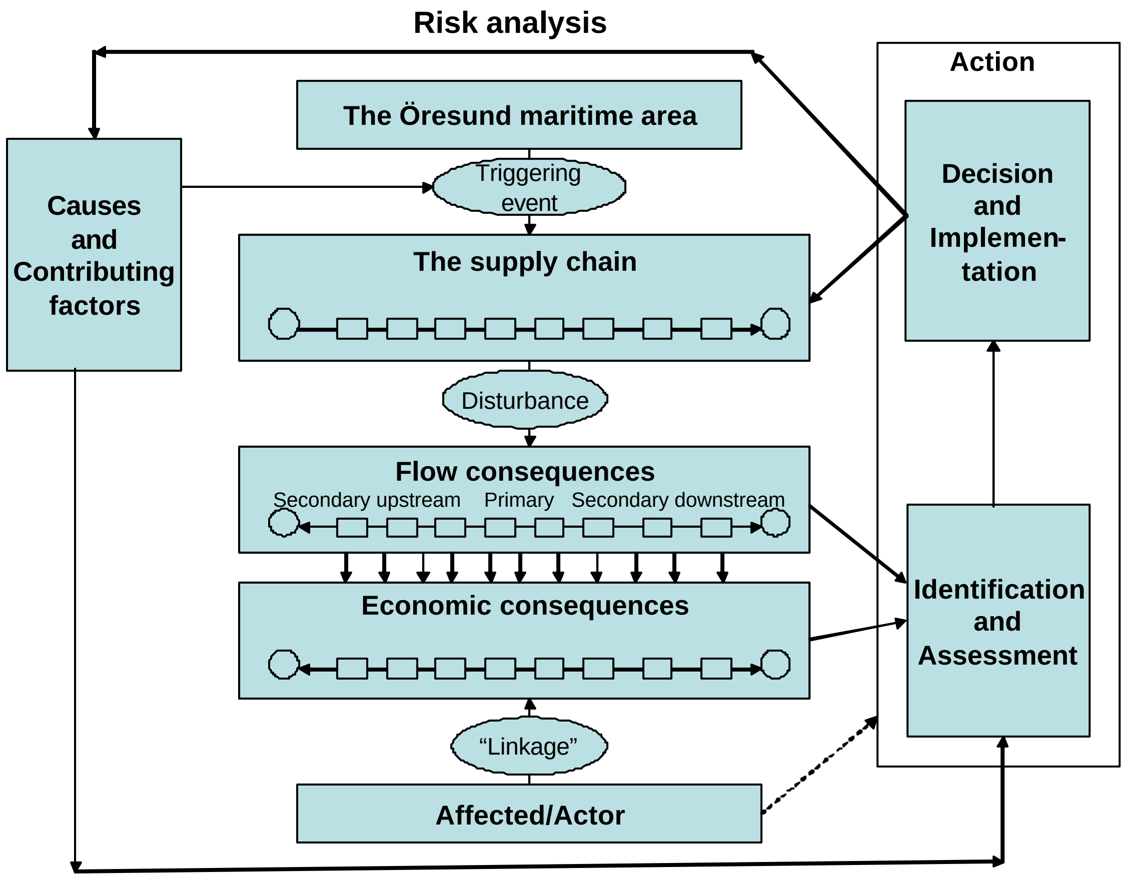

Figure 5.3: Risk analysis of supply chain flows – a basic overview model

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[67] *Supply Chain Vulnerability* (2002).

[68] Deloach, James W. (2000): *Enterprise-wide Risk Management.*

5.4 THE DIFFERENT MODEL PARTS – A CLOSER LOOK

The risk analysis work starts by *defining the system studied*. In this case that means defining and characterizing the Öresund maritime area, which constitutes the general "setting", and the supply chain that is in focus for our interest, a supply chain flow whose activities partly or totally take place in the Öresund maritime area.

Then the event or the possible triggering event is studied. After that we take a look at disturbances caused by those events and their flow consequences both upstream and downstream. Then we try to identify who is affected by those consequences. After we have identified those who are affected we try to estimate the economic consequences of those flow changes. Those affected are also actors, and if they find the economic consequences too severe they will look for new solutions. Therefore they will go back and try to find causes and contributing factors of the triggering event and assess the whole risk situation. This process will lead to decisions and eventually implementation of changes in the supply chain, causes, and contributing factors.

5.4.1 The Öresund maritime area – definition and characterisation

In Chapter 3, section 3.1, the Öresund maritime area was defined as the strait between Sjælland and Skåne, connecting the Kattegat Strait in the northwest with the Baltic Sea in the south. Its maximum length, between Kullen and Falsterbo (Sweden), is 110 km. The most landlocked portion, between Helsingør- Helsingborg in the north (width 4.7 km) and Copenhagen-Malmö in the south (width 14 km), is 52 km long. Four islands are located in Öresund: Amager, Ven, Saltholm and Pepparholm. The last two divide the passage of the water between Malmö and Copenhagen into the channels of Drogden (west) and Flintrännan (east).

The maritime area of Öresund was characterized as a heavily frequented, quite narrow sound with a difficult navigation situation, caused by among other things strong currents. The strait is shallow and has a surface current of up to 3 to 4 miles per hour toward the Kattegat. Ice in the almost tideless strait may impede navigation during severe winters. The Öresund area is also a heavily populated area with many people living on the sound or quite near it.

5.4.2 Supply chain characteristics

Before we can begin to talk about risks and risk analysis we need to ask ourselves the question: "Risk analysis of what?" In other words we need to define the supply chain flow that we want to study.

First we could ask ourselves what the *connection to Öresund* is: Passing through, going to or from a port in Öresund, crossing by sea or crossing by the Öresund Link. We also need to know some basic facts about the *goods* (i.e. their volume and value, what type of goods they are and if they are dangerous or not) and what *period of time* it is. If we are using the Öresund Link we also need to identify the *transport mode*, rail or truck/car, used. When the transport mode is sea transport we need to know what *kind of ship* is used, e.g. whether it is a high-speed ferry or an ordinary ferry, an oil or bulk tanker, a ship for packaged goods or a ship for non-packaged goods.

The discussion is summed up in Table 5.1. The different factors and sub-factors are mentioned in alphabetic order.

Table 5.1: Characteristics of the supply chain studied

Characteristics of the studied supply chain
<u>Connection to Öresund</u>
- crossing by sea
- crossing by the Öresund Link
- going to/from a port
- passing through
<u>Goods</u>
- dangerous/not dangerous
- type of goods
- value
- volume
<u>Period of time</u>
<u>Type of ship</u>
- high-speed ferry or ordinary ferry
- oil or bulk tanker
- ship for packaged or for non- packaged goods
<u>Type of transport mode over the Öresund Link</u>
- rail
- truck/car

5.4.3 Triggering event

There are a great number of possible events that could cause disturbances. Some of the more likely ones that could have severe consequences are *collisions*, both with firm and moveable obstacles. For sea transport other events are *grounding*, *shipwreck* and *water tight failure or breach*. *Fire* and *cargo loss* are two other kinds of events that are relevant for both sea transport and Öresund Link passage, and so is *"queue/reduced speed"*. The latter can, for instance, be caused by the temporary closing down of the Öresund Link because of a car accident or high winds.

Table 5.2: Triggering event behind disturbances in the supply chain flow

Triggering event
Cargo loss/dropped
Collision with firm obstacle
Collision with moveable obstacle
Fire
Grounding
Queue/reduced speed
Shipwreck
Water tight failure/breach

5.4.4 Disturbance and flow consequences

A disturbance hits the supply chain flow at a certain point in the supply chain and has, at that point, direct flow consequences for the flow, like a *deviation in time, direction/place, quantity, quality and/or information*. Those direct consequences are called *primary* consequences. If for instance one link in a certain supply chain is the passage of Öresund by the ferry from Helsingör to Helsingborg and there is a fire in the machine room, this could mean a delay in the transport or, in the worst case, that all the goods are destroyed.

Table 5.3: Primary flow consequences of disturbances in the supply chain flow

Primary flow consequences
Supply chain flow deviance
- in direction/place
- in information
- in quality
- in quantity
- in time

The consequences are sometimes only primary, i.e. local and of short-term nature. But spreading effects often exist. They could make the consequences spread step-wise upstream and downstream in the supply chain. This means that the consequences are spread geographically as well as over time, since there normally is a time delay in each step. In the worst case the consequences could spread to the whole supply chain from first supplier to end consumer, and be global and of long-term nature. Those consequences are called *secondary* consequences.

Table 5.4: Secondary flow consequences of disturbances in the supply chain flow

Secondary flow consequences
Supply chain flow deviances upstream and downstream
- in direction/place
- in information
- in quality
- in quantity
- in time

5.4.5 Linkage and the affected/actor

The flow consequences of a disturbance in the supply chain flow only have a meaning *in relation to someone who is affected* by those consequences and *each* affected party *will be affected differently*.

The *goods owner* (the *shipper*), the *infrastructure provider*, the *logistics service provider*, the *transport operator* as well as all other *supply chain participants* can be affected by a disturbance in the supply flows passing or crossing Öresund

Depending on the nature of the event, there could also be negative consequences for *authorities* at local, regional, national and international levels and, ultimately, society as a whole (*the public*).

Table 5.5: Affected/Actor in the supply chain flow

Affected/Actor
Authorities
- international
- local
- national
- regional
Infrastructure provider
Logistics service provider
Shipper/Goods owner
Supply chain participants
The public
Transport operator

5.4.6 Economic consequences

How well a company is doing economically is usually measured through *profitability,* which can be defined as: *(Revenues – Costs)/Capital bound.* Authorities do not usually consider their activities in terms of profitability, but they have nevertheless to consider the three factors revenues, costs and capital bound, although they may be called something else. All those three factors can be affected by a disturbance, and consequently the risk of disturbances must be considered and actions taken to "handle" those risks.

The short-term economic consequences of the primary flow consequences of a disturbance are often obvious and reasonably easy to calculate. But since the flow consequences tend to spread step-wise upstream and downstream in the supply chain, so do also the economic consequences. To gain a reasonable view of the total economic consequences it might be necessary to look at the whole supply chain. There is also reason to believe that the increasing integration and leanness of the supply chain is increasing the vulnerability to disturbances, and that the total economic consequences of a disturbance tend to become higher than earlier.

Profitability can be measured in the short run and in the long run. *Long-term profitability* is measured in the same way as *short-term profitability*, i.e. by revenues, costs and capital bound, but is very difficult to estimate. Instead you can choose to estimate factors that normally are very important for long-term profitability. One such factor is *market shares*. Lost market shares because of lost sales in the short term will probably mean lost future market –shares, since some of the earlier customers will probably be lost forever. Lost future revenues can also be caused by lost *goodwill*. The customers no longer regard the company as a reliable supplier, and are therefore not prepared to pay as high a price for the products as before. There could also be *other* long-term economic consequences.

The negative consequences of disturbances can be counterbalanced by insurance payouts and by other *compensations* e.g. a payout from the transport firm that was responsible for the goods that were destroyed. But normally only increased costs in the short run, like the costs of buying new components if the original ones are destroyed during the transport, are compensated for, while there is no payout for a loss in sale or for an increase in capital bound. Nor is there normally compensation for the long-term consequences.

Table 5.6: Economic consequences of disturbances in the supply chain flow

Economic consequences
<u>Short-term</u>
- compensation received

- on capital bound
- on costs
- on revenues
Long-term
- on goodwill
- on market share
- others

5.4.7 Identification and Assessment

The party affected by a disturbance is also the party that has reason to try to change the risk situation into a more favourable one. The affected party then becomes an actor. In the basic overview model, Figure 5.3, the actions were divided into two parts: "Identification and Assessment" and "Decision and Implementation".

The detailed discussion of different model parts presented earlier in sections 5.4.1 – 5.4.6 will give a "rich" input to the process of identification and assessment, but the process itself is not dealt with here.

If the affected parties find the economic consequences to be too high they will try to find the causes and contributing factors of the triggering event.

5.4.8 Causes

For sea transport *engine problems* and *engine breakdown* (main engine and steering engine) are two important possible causes. Others are *navigation faults and failures*, *bad weather* and *cargo shifting*. Still others are *oil spills* that could either be *accidental* or *deliberate but not allowed*. When it comes to the Öresund Link — it could be *closed down*.

Table 5.7: Causes to disturbances in the supply chain flow

Causes
Bad weather
Cargo shifting
Closedown of the Öresund Link
Oil spill
Engine problems
- main engine
- steering engine
Navigation failures/faults

5.4.9 Contributing factors

The contributing factors differ a lot depending on whether a *sea* transport or a crossing of the Öresund by the *Öresund Link* that is involved In the latter case *train operators*, *truck operators* and the *Öresund Link consortium* play important roles when it comes to questions both about the staff and how it is trained and about the existing technological safety systems. Another factor is *goods attribute*, such as general cargo, unit loads and dangerous goods. The latter could be sub-divided into oil, chemicals in bulk and packaged dangerous goods. *Weather conditions* (wind, snow, ice and poor visibility) are also an important factor. Finally the efficiency of the *Rescue Services Agencies* in Denmark and Sweden also plays a role.

Table 5.8: Contributing factors to disturbances in the supply chain flows over the Öresund Link

Contributing factors – Öresund Link
Goods attribute
- dangerous goods
- - *oil*
- - *chemicals in bulk*
- - *packaged dangerous goods*
- general cargo
- unit loads
Rescue Services Agencies
Train operators
- staff
- technological safety systems
- training of the staff
Truck operators
- staff
- training of the staff
Weather conditions
- poor visibility
- snow
- ice
- wind
Öresund Link consortium
- staff
- technological safety systems
- training of the staff

Goods attributes and *weather conditions* (currents, high waves/rough winds, ice, poor visibility, rain/snow, and water depth/reef) are also of importance when it comes to sea transport. Added to those are: The *ship* (age, condition, flag state and classification company), its *crew* (education, experience and number), *organisation of the daily work on board* (crew planning and working hours), and *organisation of* the safety *work* on board (safety systems and the training in how to handle them). Factors of importance outside the ship are *crossing permanent flows*, *occasional obstacles* (accidents, boat races and fishing/leisure boats), *pilots* (access/compulsory), and the existence and quality of *sea supervision systems* (AIS, SRS, TSS and VTS). The official language used at sea is English, but sometimes the knowledge of the English language is so bad that *language problems* can arise. The efficiency among the *Rescue Services Agencies* in Denmark and Sweden also plays a role, especially when it comes to limiting the consequences of an accident.

Table 5.9: Contributing factors to disturbances in the supply chain flows at sea

Contributing factors – sea
Crew
- education
- experience
- number
Crossing permanent flows
Goods attributes
- dangerous goods
- *- oil*
- *- chemicals in bulk*
- *- packaged dangerous goods*
- general cargo
- unit loads
Language problems
Occasional obstacles
- accidents at sea
- boat races
- fishing and leisure boats
Organisation of the daily work on board
- crew planning
- working hours
Organisation of the safety work on board
- technological safety systems
- the training of the crew in how to handle those systems
Pilot
- access to pilot
- compulsory pilot
Rescue Services Agencies
Sea Supervision Systems
- Automatic Identification System (AIS)
- Ship Reporting System (SRS)
- Traffic Separation Scheme (TSS)
- Vessel Traffic Service (VTS)
Ships
- age
- classification company
- condition
- flag state
Weather conditions
- currents
- high waves/rough wind
- ice obstacles

- poor visibility
- rain and snow (interfering radar)
- water depth/reef

5.4.10 Decision and Implementation

Based on the information received through the identification and assessment process and the different risk-handling alternatives at hand, decisions are made and implementation is carried out. Those actions affect the supply chain itself, the setting of the supply chain, which here is the Öresund maritime area, or both, and indirectly also the causes and the contributing factors. Those actions are of two different kinds. One is actions taken to decrease the probability that the event will happen. The other is actions taken that decrease the negative consequences of the event.

5.5 A MULTI-PURPOSE FLOW RISK MODEL FOR ÖRESUND

Each of the different parts of the basic overview model presented in Figure 5.3 have now been presented more or less in detail, and together they form a multi-purpose supply chain flow risk model for Öresund. The full model is presented in the a*ppendix*. The model can be used by different actors like carriers, shippers and authorities that in one way or another are linked to the supply chain flows passing or crossing Öresund. The model can be used for very narrow and short-term analysis as well as for broad long-term studies. Depending on the purpose of the risk analysis, certain parts of the model can be excluded and other parts expanded. The model can, in other words, be used in many different situations. The model can therefore be said to be *a multi-purpose supply chain flow risk model for Öresund*

6 RESULTS AND A FINAL REMARK

6.1 THE RESULTS OF THE STUDY

6.1.1 Flows and flow data for Öresund before and after the Öresund Link

Three different types of flows were identified: Passing through Öresund, crossing Öresund and to/from a port in Öresund. What we are considering here are huge volumes of both passengers and goods. The goods are of all different kinds, including a lot of dangerous goods, especially crude oil. The flows are also to some extent crossing each other at the same level, e.g. the ferries between Helsingborg and Helsingör are crossing the flow of ships passing through the northern part of Öresund. In other words, we are considering a situation with many latent risks.

In July 2000 the Öresund Link, the combined bridge, artificial island and tunnel between Sweden/Malmö and Denmark/Copenhagen, was taken into daily service, and this meant a substantial change in the flows in the Öresund area. With the Öresund Link a new flow was created. Two ferry lines, Limhamn-Dragör and Danlink between Helsingborg-Copenhagen have been closed down, and so have some passenger –lines: SAS, Pilen and Flygbåtarna between Malmö-Copenhagen and Flygbåtarna between Landskrona-Copenhagen. Two new flows were initiated, but only one remains: the Öresund Link. The other was a new passenger line between Helsingborg-Copenhagen run by Flygbåtarna, but it was closed down in November 2001.

The effects of the opening of the Öresund Link on the flows started already at the end of October 1999 when the ferry line between Limhamn and Dragör was closed down. 1998 has therefore been chosen as the year to represent the flow situation *before* the link opened. To able to see as clearly as possible the long-term effects of the opening of the Öresund Link a year as up-to-date as possible has been chosen: 2002. For those two years (1998 and 2002), the flows and flow data for crossing or passing through Öresund or going to or from a port in the area are compared.

Let us start with the ships *passing through Öresund*. The average number of ships that passed through the sound in the north-south direction or opposite has decreased during the period by 7,6 % (from 40.307 to 37.232 ships). An alternative way to enter or leave the Baltic Sea is through the Belt. From 1998 to 2002 there was a decrease in the number of passages through the Belt by 13,4 % (from 22.589 to 19.568 ships). The Öresund Link does not seem to have made the passage of Öresund less attractive – the opposite seems rather to be the case, since the decline for Öresund during the period studied is less than that for the Belt. We must also take into consideration that the average size of the ships tends to increase.

The total volume of goods *to/from the ports* has declined during the period from 25,7 to 20,5 million tons. Of this difference of 7,8 million tons, 5,2 million tons can be explained by the closing down of Danlink and the use of the Öresund Link instead, and 1,8 million tons by the construction of tunnel elements for the Öresund Link in Copenhagen Port in 1998. Another 0,2 million tons resulted from the closing down of Limhamn- Dragör. The declaine can thus be explained by the finishing and opening of the Öresund link.

In the northern part of Öresund we can see that the *crossing flow* over Helsingborg-Helsingör has dropped from 13,7 million passengers, and 2,7 million vehicles in 1998 to 11,6 million passengers, and 2,4 million vehicles in 2002. In other words, the rail goods have ceased, passengers have dropped by 15 %, and the number of vehicles with about 10%.

In the southern part of Öresund the ferries between Limhamn-Dragör have been replaced by the Öresund Link. In 2002 14 million passengers, and 3,4 million vehicles crossed Öresund by the Öresund Link. If we compare that with 5 million passengers, 0,3 million cars and 0,05 million trucks and busses in 1998, we can see a substantial increase in both the number of passengers and vehicles (see Tables 3.3 and 3.4). To this can be added 3,2 million tons of rail transported goods – a mode of transport that wasn't in use in this part of Öresund in 1998.

Danlink which in 1998 transported 2,6 million tons of rail goods between Copenhagen and Helsingborg had ceased to exist 2002.

If we looked at *Öresund as one "entity"* we might conclude that the passenger figure has increased from about 19 million in 1998 to about 26 million in 2002. The figure for vehicles has gone up from about 3 million to almost 6 million, and rail goods have gone from 2,6 to 3,2 million tons.

Thus the total volume of passengers, vehicles and rail transported goods *crossing* the Öresund has increased substantially after the opening of the Öresund Link, the volume of transported goods *to/from the ports* in the region has decreased, an effect of the finishing and opening of the Öresund link, and the *passages through Öresund*, measured as the number of ships, have declined somewhat.

The substantial increase in the crossing flows indicates that integration in the Öresund region has increased.

6.1.2 Flow risks in Öresund

The risk situation is dependent upon many factors. Above all, of course, upon which flow, like Malmö-Copenhagen or Helsingborg-Helsingör, is studied and the volumes and types of goods connected to that flow. The total risk situation in Öresund can be estimated by summing up the risks for each individual flow in Öresund.

Passing or crossing a narrow water passage always results in risks of different kinds. Öresund is no exception. During the 90s many incidents have been reported and several accidents have happened. Öresund is today one of the areas in the world with most ship movements, and the volumes are increasing.

Öresund is a quite narrow sound with a difficult navigation situation caused by among other things strong currents. Risks of different kinds are at hand. One source of risks is the substandard ships, ships that do not fulfil international regulations applying to safety at sea and the protection of the environment, that pass through Öresund.

In Öresund there are crossing flows of goods and passengers, the north-south and south-north flows cross with the east-west and west-east flows. The flows in east-west direction and opposite must, if the Öresund Link is excluded, include a change/combination of transport means. Transport technology is under rapid development regarding both infrastructure and transport mode units. We have also a change in market shares for the different means of transport. More goods are being transported by truck and fewer by railway. On top of that, the goods are changing character; especially important here are changes concerning new types of dangerous goods.

The Öresund area is a heavily populated area, with many people living on the sound or quite near it. The consequences of — for example — an oil tanker accident could therefore be severe. The consequences of an accident can also be spread outside the Öresund region. Most of the goods passing through or crossing Öresund are bound for destinations outside the Öresund region, or will just be processed/value-added within the region and then transported out of the region again. Seen from the point of view of the goods owner/the shipper having a shipment passing through or crossing Öresund, this means being exposed to risks of different kinds in the Öresund area.

The opening of the Öresund Link has meant that some of the earlier risks have disappeared, some have changed character and some new risks have appeared. Since the flows from Danlink, Limhamn – Dragör and some passenger lines have disappeared, the risks linked to those flows have been eliminated. Especially important to mention here is the risks linked to the catamaran traffic between Limhamn – Dragör. Catamarans are often involved in incidents and accidents. The Drogden channel and the Flint channel are still there, but they have been made deeper, straighter and better marked out. So it ought to be less risky now to pass through one of those channels. The Öresund Link itself creates new risks. The flow over the link causes risks, especially the passage of the tunnel. The link itself, the bridge part and Pepparholm, is also an object that could be hit by ships passing through Öresund. But far-reaching precautions have been taken to avoid/delimit the consequences of hitting the link. The same can be said of crossing Öresund by the link. Altogether this creates *a changed risk situation* in Öresund and the Öresund region.

The risk situation is complicated by the fact that two different countries are involved and that they both have to agree upon and co-ordinate actions if they are to become effective. There are also some areas in Öresund which are international water and where international agreements are valid – not national laws. This makes it more difficult for Denmark and Sweden to implement risk-reducing actions.

In 1857 a number of treaties - the Öresund Treaties – were signed according to which Denmark on the one hand received a lump sum and on the other hand promised to keep free and uninterrupted passage for all ships for all the years to come. These nearly 150 year old treaties make it very difficult today for the Danish and Swedish authorities to take proactive safety–enhancing actions like entering the ship and checking the soberness of the crew members, on foreign ships.

The total risk situation in Öresund has probably improved because there are fewer crossing flows at the sea level, improvements have been made in the Drogden and Flint channels, and no big catamaran ferry is operating any more between Limhamn and Dragör; those risk-reducing factors together are more important than the risks connected to the new flow, the crossing of Öresund by the Öresund Link, or the link as a new obstacle in Öresund.

6.1.3 Future flow risks in Öresund

In the future, the integration in the Öresund region can be expected to increase and this will lead to more goods and human beings crossing Öresund, but probably also to changed flows because of changes in the division of tasks. One example is the newly launched company Copenhagen Malmö Port, which operates the earlier two separate ports of Malmö and Copenhagen as one port, thus avoiding the duplication of resources and using the labour force more efficiently. Some years ahead it is probable that co-operation based on the same basic idea will exist between the airports of Kastrup and Sturup. Many other application areas are also possible. The production “pattern” around Öresund will change.

International trade is increasing, both within the EU and outside it. Beginning in 2004 there will be 10 new member states in the EU, of which four are located on the Baltic Sea (Estonia, Latvia, Lithuania and Poland). This will lead to increases in the flows, both those that are passing through Öresund and those that are crossing Öresund, the latter because of the expected new truck traffic from the Baltic countries across Sweden and further down to the continent.

We can also expect a rapid increase in the number of oil tankers exporting Russian oil. Those transports are now often carried out by substandard ships. There are no indications that there will be any change in this regard, at least not in the foreseeable future. The increased number of oil transports therefore clearly leads to increased risks in Öresund if they choose Öresund for their passage to and from the Baltic Sea. But we must remember that because of the limited depth in the Flint and Drogden channels the really big ships have to choose the Belt instead.

New technologies in the future will be available to increase safety in the flows. One example is the AIS (Automatic Identification System) based on transponders fixed on the ship. The transponder is loaded with basic information about the ship, its cargo, position speed etc., and this information is continuously updated and spread via signals in the air which could be received by others, both at sea and on shore, that have the same kind of equipment. This and other new technology-based systems have the potential for a future substantial increase in maritime safety in the Öresund region.

6.1.4 Focusing on the whole supply chain

The chain of transport and storage activities from first supplier to end customer has changed character over time, and gradually developed from a step-wise chain via a logistical chain into a supply chain that is highly integrated, lean and characterised by just-in-time (JIT) deliveries and almost no buffer stocks. This development has made the chain highly vulnerable - the negative consequences of a disturbance somewhere in the chain are easily spread to other links upstream and downstream in the chain. Those secondary disturbances can have negative consequences of a magnitude many times greater than the primary consequences, and sometimes even a small disturbance can have severe economic consequences for those companies and organisations that in one way or another are "linked" to the supply chain. That is why the focus needs to be on the whole supply chain, and not only on the link where the initial disturbance happens.

6.1.5 A multi-purpose model

To be able to do risk analysis, i.e. to identify, describe and assess risks and to consider, choose and implement actions, and to communicate the results to others, general models have to be developed – a common "language" is needed. The multi-purpose model developed here can be regarded as a contribution to such a common language. The model, taking the supply chain flows passing or crossing Öresund as its starting points, presents a general model for risk analysis. In Chapter 5, the different parts of the model are presented; the total model can be found in the appendix.

6.2 A FINAL REMARK

In this report, and also in the other SUNDRISK reports, new knowledge has been created about how to identify, describe and assess the maritime risks in Öresund. The next step might be to focus on *actions* and increase the knowledge about *how to handle those risks*, knowledge that would be of value not only to the actors of supply chains in Öresund and the Öresund region but to all who are dependent upon safe and secure transports in a maritime environment. To not act at all could be a mistake, but so could overreaction or taking the wrong kind of action. What to do to handle the short-term primary flow consequences of a disturbance is in many situations quite obvious, because the flow consequences are in themselves so obvious. Actions for dealing with secondary economic consequences upstream and downstream the chain are not so obvious, but knowledge about this is crucial since — in many cases — the most severe economic consequences are those that occur upstream and downstream. Here much more knowledge is needed.

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APPENDIX

The multi-purpose model for risk analysis of disturbances in the supply chain flows passing or crossing Öresund is below presented in the form of a *checklist*.

Studied flow: **Structure elements with variables:**	**Supply chain flow 1**	**Supply chain flow 2 etc.**
Definition and characterisation of the Öresund maritime area (the "setting")		
Characteristics of the studied supply chain Connection to Öresund - crossing by sea - crossing by the Öresund Link - going to/from a port - passing through Goods - dangerous/not dangerous - type of goods - value - volume Period of time Type of ship - high-speed ferry or ordinary ferry - oil or bulk tanker - ship for packaged or for non- packaged goods Type of transport mode over the Öresund Link - rail - truck/car		
Triggering event Cargo loss/dropped Collision with firm obstacle Collision with moveable obstacle Fire Grounding Queue/reduced speed Ship wrecking Water tight failure/breach		

Primary flow consequences Supply chain flow deviance - in direction/place - in information - in quality - in quantity - in time		
Secondary flow consequences Supply chain flow deviances upstream and downstream - in direction/place - in information - in quality - in quantity - in time		
Affected/Actor Authorities - international - local - national - regional Infrastructure provider Logistic service provider Shipper/Goods owner Supply chain participants The public Transport operator		
Economic consequences Short-term - compensation received - on capital bound - on costs - on revenues Long-term - on goodwill - on market-share - others		
Identification and Assessment		
Decision and Implementation		

Causes <u>Bad weather</u> <u>Cargo shifting</u> <u>Close down of the Öresund Link</u> <u>Oil spill</u> <u>Engine problems</u> - main engine - steering engine <u>Navigation failures/faults</u>		
Contributing factors – Öresund Link <u>Goods attribute</u> - dangerous goods - *- oil* - *- chemicals in bulk* - *- packaged dangerous goods* - general cargo - unit loads <u>Rescue Services Agencies</u> <u>Train operators</u> - staff - technological safety systems - training of the staff <u>Truck operators</u> - staff - training of the staff <u>Weather conditions</u> - poor visibility - snow - wind <u>Öresund Link consortium</u> - staff - technological safety systems training of the staff		
Contributing factors – sea <u>Crew</u> - education - experience - number <u>Crossing permanent flows</u> <u>Goods attributes</u> - dangerous goods - *- oil* - *- chemicals in bulk* - *- packaged dangerous goods*		

- general cargo - unit loads Language problems Occasional obstacles - accidents at sea - boat races - fishing and leisure boats Organisation of the daily work on board - crew planning - working hours Organisation of the safety work on board - technological safety systems - the training of the crew in how to handle those systems Pilot - access to pilot - compulsory pilot Rescue Services Agencies Sea Supervision Systems - Automatic Identification System (AIS) - Ship Reporting System (SRS) - Traffic Separation Scheme (TSS) - Vessel Traffic Service (VTS) Ships - age - classification company - condition - flag state Weather conditions - currents - high waves/rough wind - ice obstacles - poor visibility - rain and snow (interfering radar) water depth/reef		

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