A Sundrisk Project

Oil Spills in Öresund

– Marine oil spill events, Causes and Claims

by

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The SUNDRISK project

The SUNDRISK project is a multidisciplinary study of marine risks in the Öresund area financed by Sparbanksstiftelsen Skåne. The objective of 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 turn conducted within the settings of LUCRAM.

LUCRAM

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

Summary

Background
Öresund is one of the areas in the world with most ship movements. More than 40,000 ships pass through the sound in the direction north-south or the opposite every year. Other ships/ferries frequently cross the sound in the direction east-west or west-east. The ships carry goods and/or passengers in huge volumes. Since Öresund is a quite narrow sound with a difficult navigation situation, many risks of different kinds are at hand. The Öresund area is also a heavily populated area with many people living at the sound or quite near it. The consequences of an oil spill could therefore be severe to people, the environment and property.

Objective
The objectives of the study are to identify and analyse marine oil spill events in Öresund, to analyse the causes of those events, to estimate potential third-party claims for oil spill events in Öresund and to suggest some safety-increasing actions concerning oil spills in Öresund.

Delimitation
The study is confined to the risks of oil and oil products, including bunker oil, of marine transport and related activities in the Öresund area. Furthermore, when considering the claims, the cost of damage to/loss of ship and goods is not studied. Only third-party claims are considered.

Methods
Following a brief discussion of risk analysis and oil spills, a number of studies of risks in Öresund are presented. Then a description and characterization of the Öresund maritime situation is conducted. After that statistics on accidents and incidents in Öresund are collected and structured, and marine events and the causes of oil spills are analysed. Since statistics from Öresund are limited, world statistics on major oil spills and their claims are gathered and applied to the Öresund situation as well as oil spill statistics from the Baltic Sea. A recent oil spill accident, Baltic Carrier/Tern, which occurred on 29 March 2001 off the southern coast of Denmark, is used as illustration. Finally, different safety-increasing actions are discussed and suggested.

Results
The following categories of *initial events* were directly liable for oil spills in Öresund: grounding, collision, contact, hull/watertightness failure and listing/capsizing. In the latter cases ships have foundered intact, assuming that a foundered ship might have caused an oil spill. There are many worldwide experiences where oil still leaks daily from ships sunk many years ago.

Oil spills may also result from operating activities in ports/terminals, such as loading, discharging, bunkering and other operations. Deliberate or intentional oil discharges are also a concern.

The frequencies of events that have occurred in Öresund (1985-1999), causes, contributing factors and consequences thereof, share similarities and differences with oil spills events that have occurred around the world. Categories of events which led to oil spill were generally similar, but with different frequencies of contribution. Thus, the grounding events contributed

to 60% of oil spills in Öresund compared to 32% of world major oil spills. Compared to worldwide events, “hull/watertight failure” and “foundering” events have occurred at a lower frequency in Öresund.

Most of the marine events were the result of a combination of actions and circumstances, all of which contribute in varying degrees to the outcome. *Causes and contributing factors* of the above marine events were: human, technical, weather/sea and other related factors (such as vessel traffic) where the human related factor was dominant.

The third-party *claim cost* of the worst scenario of an oil spill in Öresund is estimated at $ 300 millions. The average risk cost of "large" oil spills each year in Öresund is estimated at US$ 223,500. However, this figure does not include "operational" oil spills resulting during loading, discharging, and other oil-related activities. Because of prices and “social” inflation, claims have increased over time. Higher claims are expected in the future.

More than 20 suggestions for *safety-increasing actions* are presented and discussed in Chapter 8.

Final remarks

In the 1991 assessment study *oil spill was regarded as the biggest risk* to Öresund waters, and we think that this is still the case. Ships with thousands of tonnes of oil regularly pass through the sound.

A number of *minor oil spills* occur every year and there are fixed routines for handling them. The oil is normally taken care of by the Coast Guard, and the environmental consequences are limited and local.

Some *larger oil spills* have happened over the years but fortunately no really big oil spill has occurred so far. But the possibility of a major oil spill with catastrophic impacts to people, the environment and property is constantly there. This was underlined by the Baltic Carrier/Tern event. The oil slicks very seriously affected the Danish marine environment. It also posed threats to the Öresund area, but thanks to luck with winds and currents the oil never reached it.

Oil spills receive much media attention today. With an increasing number of ship movements in Öresund and a growing public interest in safety matters and environmental issues, *focus on oil spills, oil spill consequences and oil spill prevention will become even bigger in the future.*

Oil spills in Öresund have occurred in the past and probably will occur in the future. Complete prevention i.e. zero oil spill, may be prohibitively costly and practicably impossible. But through risk analysis and risk assessment we could acquire more and better information about risks and their negative consequences as well as of safety-increasing actions and their costs, information that can be used within risk management *to create a safer Öresund at reasonable costs.*

Foreword

This report is part of the SUNDRISK-project, which is a multidisciplinary study of maritime risks in the Öresund area financed by Sparbanksstiftelsen Skåne. The work has been carried out at the Department of Industrial Management and Logistics, Division of Engineering Logistics at Lund University. The authors of the report have complemented each other well in the analysis and evaluation work. One – Arben Mullai – is a Master Mariner with more than 10 years of practical experience who also holds a MSc degree in Shipping Management, Commercial Stream; the other – Ulf Paulsson – is an economist holding a Licentiate degree in Economics. Major parts of the work are based on statistical material collected and worked up by Arben Mullai.

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, 25 February 2002

Everth Larsson

Head of department, project leader

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1 INTRODUCTION

1.1 BACKGROUND

The purpose of this section is to provide a brief background to the Öresund area and to describe the previous study concerning risks in the area and some of its limitations. The need for a re-examination of risks of oil/oil product spills is discussed. The objectives and the delimitation of the study are presented.

1.1.1 Oil Spills and Öresund: A complex and serious risk situation

Öresund is one of the areas in the world with most ship movements. More than 40,000 ships pass through the sound in the direction north-south or the opposite every year. Other ships/ferries frequently cross the sound in the direction east-west or west-east. The ships carry goods, passengers and sometimes both, and in huge volumes.

Since the first of July 2000 there is a combined bridge and tunnel named the Öresund link (the Öresund bridge) between Malmö and Copenhagen, which is changing the traffic flows and the risk situation in the region.

Since Öresund is a quite narrow sound with a difficult navigation situation, caused by among other things strong streams, many risks of different kinds are at hand. The Öresund area is also a heavily populated area with many people living at the sound or quite near it. The consequences, of, for instance, an *oil tanker ship accident* could therefore be severe. In the Baltic Sea oil tankers up to 150,000 dwt each carry approx. 100 million tons of oil per annum. A large amount of this oil passes through Öresund, thus exposing the region to risks from oil spills. Also the *bunker oil* that most ships carry is a threat.

1.1.2 Incompleteness in the 1991 Risk Assessment study

In 1991 a risk assessment[1] was conducted in response to the increasing concern about the marine transport of dangerous goods (oil, oil products, chemicals, gases and packaged dangerous goods) through Öresund waters, and the project for building a new bridge between Sweden and Denmark. The study *showed the risk of oil spills to be the main concern* of dangerous goods in the Öresund area. The study only dealt with the risk of oil spills outside harbours and the negative consequences to the marine environment and damages to the bridge structures. The assessment was based on local data. The frequency of ship collisions with the bridge structure in Flintrännan was estimated. The frequency of oil spills per year due to collisions and severe damages to the bridge structures was also estimated.

According to the 1991 risk study, the total number of oil spills in Öresund was dominated by small discharges up to 1 cubic meter. Accidental spills were rare but larger. The size of accident spills from ships was up to 400 cubic metres or 300 tonnes. Large ("major")

[1] COWIconsult 1992. *Analys av risker för påsegling av bron* (1992). VVB VIAK Underlagsrapport Nr 32. Doc No. 22071-001.

accidental oil spills were mostly reported from ships involved in collisions and groundings. In Flintrännan (the Swedish side of the waterway) the spill size of the worst case scenario was anticipated up to 19,000 tons for the largest tankers, which is a spill of the entire oil content. In Drogden (Danish side), the worst-case scenario was anticipated to be much larger - 50,000 tons.

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

Table 1.1: Contents of oil tankers in Flintrännan and Drogden - the worst-case scenarios.[2]

Some incompleteness exist in the 1991 risk assessment study. The risk was expressed only in terms of amounts of oil spilled into the sea. The risk to people, the environment and properties has not been taken into account. The worst-case scenarios of oil spills were anticipated for marine events involving a single ship. Events that may involve more than one ship were not taken into account. A collision between two of the largest tanker ships (Drogden: 110,000/110,000 dwt = 100,000 tonnes oil and Flintrännan: 45,000/45,000 dwt = 38,000 tonnes oil), which is the worst scenario, has not been predicted. Since there are numbers of large tanker ships passing the Sound (Table 1.1) such a scenario might happen although it may be very unlikely.

1.1.3 Changes since 1991

Since the 1991 study a number of changes have occurred in the Öresund area. The following are some of the changes observed:

- Building of the new Öresund link.
- Increase in water depths in Flintrännan and Drogden, allowing bigger ships than before to pass through the channels.
- Doubling of the number of ships during the period 1990–1999 from 21,000 to about 40,000.[3]
- A corresponding increase in the marine traffic of dangerous goods including oil, oil products, chemicals, gases and packaged dangerous goods (paragraph 3.5).
- Changes in ship construction and maintenance over the 10-year period.

[2] COWIconsult 1992.Analys av risker för påsegling av bron. Doc. No. 22071-00, 1992, page 65
[3] Danish Maritime Administration 2000-05-03.

1.1.4 The claim aspect

No really big oil spills have occurred in Öresund so far. Accordingly no big claims have been paid. But if we look at oil spills and claims from a world perspective, we have a lot of cases of big oil spills and claims connected to them. We have probably all heard about oil catastrophes like the Torrey Canyon back in 1967 (UK) with an oil spill of about 120,000 tons and the Exxon Valdez in 1989 (Alaska) with an oil spill of about 37,000 tons with very severe ecological effects. The economic effects were also substantial. Fishing was, for instance, destroyed for a number of years. Besides the costs of damage or loss of ship and goods, third-party claims have been paid to compensate for the negative economic effects. In the Exxon Valdez case, it was a matter of thousands of millions of US dollars. If an oil catastrophe were to take place in Öresund, substantial third-party claims would have to be paid for environmental damage, cleanup, compensations for deaths/injuries, third party property damage, loss of business and so on. Those would be of general interest to estimate.

The costs of damage to/loss of ship and goods are relatively well known and easy to calculate, while third-party claims are not. Those costs can also be expected to increase more rapidly in the future than the costs for loss of goods and ship. Therefore only claim costs will be dealt with in this study.

1.2 OBJECTIVES

Given the complex and serious risk situation in Öresund, the limitations of the 1991 study and the changes that have occurred in the Öresund waters since 1991, it seems interesting to re-examine the risks of oil spills in Öresund. It also seems reasonable to include claims into such a study, since they could amount to a considerable sum of money and have not been considered in earlier studies. Finally, some suggestions for safety-increasing actions will also be considered.

The interrelated objectives of the study are:

- to identify and analyse marine oil spill events in Öresund
- to analyse the causes of those events
- to estimate potential third-party claims for oil spill events in Öresund and
- to suggest some safety-increasing actions concerning oil spills in Öresund.

More up-to-date knowledge about risks, consequences and claims may contribute to a better management of the risks concerning oil spills in Öresund. Much of this knowledge may also be used to improve risk management of chemical substances other than oil. Some information about dangerous goods in general and some statistics on the volumes of dangerous goods transported in Öresund will therefore also be presented.

1.3 DELIMITATION AND GENERALISATION

This study is confined to the risks of:
- oil and oil products, including bunker oil
- marine transport and related activities
- Öresund area, as being defined.

1.4 TARGET GROUPS

One target group is authorities on both sides of the Sound with responsibility for the "safety" in Öresund. Another group is national and international organisations dealing with sea transport issues including safety matters. A third one is companies engaged in one way or another in the transport of goods and passengers in the Öresund area. And finally a fourth target group is researchers specialising in marine safety and/or environmental issues.

1.5 CHAPTER STRUCTURE

In Chapter 1 the background to the project is given and the objectives and delimitation are established. In Chapter 2, following a short discussion about risk analysis and oil spills, a number of studies of risks in Öresund are presented. Then in Chapter 3 a description and characterization of the Öresund maritime situation is conducted. After that, in Chapter 4, statistics on accidents and incidents in Öresund are collected and structured, and marine events and causes of oil spills are analysed. Since statistics from Öresund are limited, world statistics on major oil spills are gathered and analysed in Chapters 4 and 5. Their claims are then applied to the Öresund situation in Chapter 6. In Chapter 7 a recent oil spill accident, Baltic Carrier/Tern, which occurred off the southern coast of Denmark, is used as an illustration. In Chapter 8 different safety-increasing actions are discussed and suggested. Finally, in Chapter 9 the results are summed up and some final remarks are given.

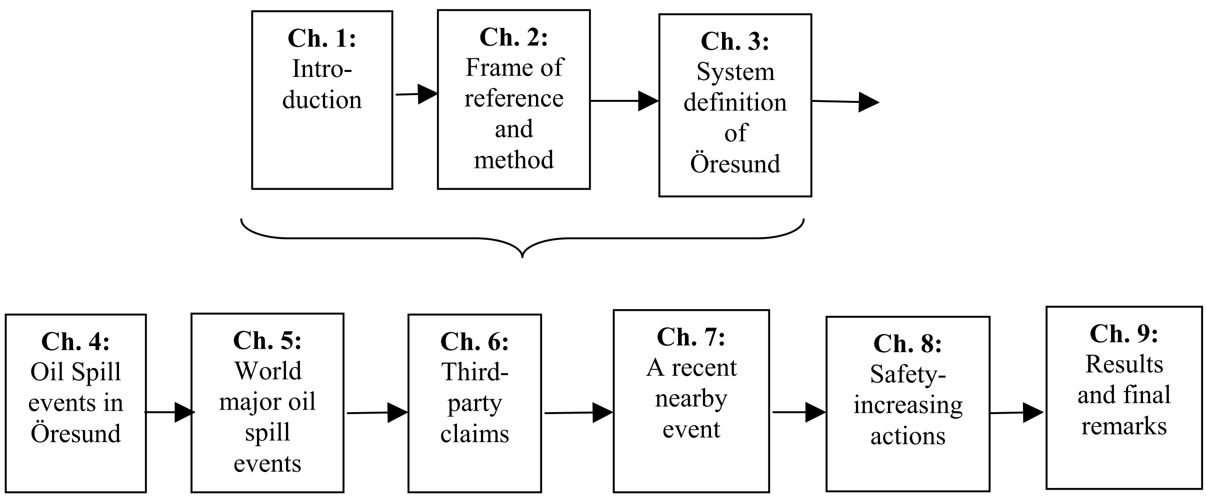

Figure 1.1: Chapter structure of the study.

2 FRAME OF REFERENCE - DEFINITIONS, REGULATIONS, DATA AND METHODS

2.1 DEFINITIONS AND REGULATIONS

2.1.1 Dangerous substances and materials – oil and oil products

Dangerous substances and materials, or hazardous materials as they are commonly known in the US[4], are substances and materials that are listed in the schedules of the following codes for the carriage of cargoes in bulk:

- International Bulk Chemical (IBC) Code, with amendments.
- International Gas Carrier (IGC) Code, with amendments.
- Code of Safe Practice for Solid Bulk Cargoes (BC Code), with amendments.

The International Maritime Dangerous Goods (IMDG) Code deals with packaged dangerous goods. The IMDG Code has been subjected to many changes over the years, both in format and content, in order to keep up with changes in the shipping industry. Various sections of the Code have been revised. Revisions are included in Amendment 30-00. The new edition (2000 edition) incorporates amendment 30-00. It was adopted by IMO's Maritime Safety Committee (MSC) in May 2000, and agreed to enter into force on 1 January 2001, with a 12-month implementation period until 31 December 2001. The Code is in a new format: two A4 (297 mm × 210 mm) paperback volumes.

Dangerous substances and materials are divided into 9 classes. Oil and oil products fall into class 3 (Class 3 – Flammable Liquids). They present a number of hazards. They present safety, health and environmental hazards. The hazard properties of the dangerous goods are of a chemical, physical, biological and radioactive nature. Dangerous goods hazards are: explosion, fire, corrosion, radiation, infection, poison (toxic), and suffocation. Many dangerous goods have more than one property and present "subsidiary risks." Oil and oil products are flammable, but they may also present the following hazards: explosion, poison, and suffocation. Exposure to hazards may be by contact, inhalation, and ingestion.

Oils present environmental hazards as well. Oils are toxic to aquatic life when ingested or absorbed through skin or gills and can interfere with respiratory systems. They can also foul fur and feathers, taint seafood, contaminate water supplies and smother aquatic communities, habitats and bathing beaches. The most sensitive areas are calm shorelines, marshes, sea-grasses and mangroves, which can provide quiet zones for oils and hydrocarbons to accumulate. Recovery time of oiled coastal areas can be as much as 10 years or more.[5] Oils and hydrocarbons are a complex mixture of pollutants, and their toxic effects on marine life vary with both the composition of the oil and the species affected. Generally, younger organisms are more sensitive.[6]

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[4] Castle, Martin (1995) *Transport of Dangerous Goods*. Pira. UK, 1995.
[5] http://www1.imo.org/oilweb/oils_faq.htm#Q1 2000.
[6] ibid.

The International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Pollution from Ships (MARPOL), as amended, deal with the carriage of dangerous goods, including liquid bulk dangerous cargoes. For the Baltic Sea area, however, the 1992 Convention, which entered into force in January 2000, concerns marine environment protection. Article 2 of the Convention defines some important terms, such as: pollution and pollution incident, harmful substances, ship, and oil. For more details see the document "Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992."

Article 2
Definitions

For the purposes of this Convention:

"*Pollution*" means introduction by man, directly or indirectly, of substances or energy into the sea, including estuaries, which are liable to create hazards to human health, to harm living resources and marine ecosystems, to cause hindrance to legitimate uses of the sea including fishing, to impair the quality for use of sea water, and to lead to a reduction of amenities;

"*Ship*" means a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms;

"*Oil*" means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products;

"*Harmful substance*" means any substance, which, if introduced into the sea, is liable to cause pollution;

"*Hazardous substance*" means any harmful substance which, due to its intrinsic properties, is persistent, toxic or liable to bio-accumulate;

"*Pollution incident*" means an occurrence or series of occurrences having the same origin, which results or may result in a discharge of oil or other harmful substances and which poses or may pose a threat to the marine environment of the Baltic Sea or to the coastline or related interests of one or more Contracting Parties, and which requires emergency actions or other immediate response;

Article 5
Harmful substances

The Contracting Parties undertake to prevent and eliminate pollution of the marine environment of the Baltic Sea Area caused by harmful substances from all sources, according to the provisions of this Convention and, to this end, to implement the procedures and measures of Annex I.

2.1.2 Definitions - oil spills and marine events

The following section provides some essential definitions concerning oil spills and marine events in general. Oil spills into the sea are divided into: operational and accidental. Operational discharges are regulated and unregulated. The Intertanko provides the following definitions.[7]

Operational

Regulated discharge is: disposal, pumping or emitting of oil into the sea from ships during day-to-day operations (as limited by MARPOL, e.g. discharge into Special Areas).

7 International Association of Independent Tanker Owners 2000. http://www.intertanko.com/

Un-regulated discharge is: escape, spilling, emptying or leaking of oil into the sea from ships during day-to-day operation.

Accidental

Accidental spill/discharge of oil into the sea as a result of a ship accident, for example collision, grounding, structural failures, fires & explosions etc.

The following are the internationally agreed definitions of types of marine events. They are adopted by the International Maritime Organization (IMO) and the Lloyd's Register of Shipping:

1. *Collision*: striking or being struck by another ship (regardless of whether under way, anchored or moored).
2. *Stranding or grounding*: being aground, or hitting/touching shore or sea bottom or underwater objects (wrecks, etc.).
3. *Contact*: striking any fixed or floating object other than those included in no. 1 or 2.
4. *Fire or explosion* (fire/explosion): casualties where fire or explosion is the initial event.
5. Hull failure or failure of watertight doors, ports etc. (hull/watertightness): not caused by nos. 1 to 4.
6. *Machinery* damage (machinery): not caused by nos. 1 to 5.
7. *Listing or capsizing* (listing/capsizing): not caused by nos. 1 to 6.
8. *Foundering*: not caused by nos. 1 to 7.
9. *Missing*: assumed lost.
10. *Other*: all events that are not covered by nos. 1 to 9.

2.1.3 Conventions and rules for compensation for oil spill damage

Compensation for damage caused by spills of persistent oil from tankers is governed by four IMO conventions, namely: the 1969 and 1992 International Conventions on Civil Liability for Oil Pollution Damage (1969 CLC and the 1992 CLC) and the 1971 and 1992 International Conventions on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1971 and 1992 Fund Conventions).

The 1969 CLC lays down the principle of strict liability for tanker owners and creates a system of compulsory liability insurance. Strict liability is liability even in the absence of fault. The 1971 Fund Convention provides supplementary compensation to those who cannot obtain full compensation for oil pollution damage under the 1969 CLC. The International Oil Pollution Compensation Fund (1971 IOPC Fund) was set up for the purpose of administering the regime of compensation created by the Fund Convention. Countries that are Parties to the 1971 Fund Convention are also Members of the 1971 IOPC Fund. The 1971 IOPC Fund is financed by contributions of companies in Fund Convention countries that receive oil after sea transport.

In 1992, the 1969 CLC and 1971 Fund Conventions were amended and became the 1992 CLC and 1992 Fund Conventions. They entered into force on 30 May 1996.

Table 2.1 presents the maximum amount of compensation available, i.e. the limit of liability, for oil spill damage under each convention. Both 1992 Conventions provide higher limits of compensation and a wider scope of application than the original Conventions. Under 92 CLC and 92 Fund Conventions limits of liability are respectively – US dollars (US$) 80.6 million and US$ 182 million (Table 2.1.). The amounts are based on specified units of account known as Special Drawing Right (SDR). The value of a SDR in terms of a national currency varies. In Table 2.1, the value is expressed in US dollars (US$), where 1 SDR =US$ 1.35.

Tanker's gross tonnage	1969 CLC	1971 FUND	1992 CLC	1992 FUND
5,000	0.8	81.0	4.0	182.0
25,000	4.0	81.0	15.3	182.0
50,000	8.1	81.0	29.5	182.0
100,000	16.2	81.0	57.8	182.0
140,000	18.9	81.0	80.6	182.0

Table 2.1: Maximum amounts of compensation available under the conventions (US $ million)

2.2 DATA AND METHODS

The objective of the study of oil spills in Öresund is to identify and analyse hazardous events, to analyse the causes of those events, to estimate potential third-party claims and to suggest some safety-increasing actions. The initial method used is a description and characterization of the Öresund maritime situation. This constitutes a general basis for all the objectives, and so does some basic theory about risks and risk assessment.

Risks are defined as statistically verifiable and non-verifiable.[8] Statistically verifiable risks are those that could be determined from direct observations. Risks posed by dangerous substances and materials are generally statistically verifiable. Oil spill risks in Öresund are empirically verifiable. The main part of this study is based on empirical data collected from Swedish and Danish maritime databases for the Öresund waters and the Baltic Sea Oil Spills database.

In many studies the analysis of the risks of marine events, in particular those involving dangerous substances and materials, is based on: a) statistical data available for the phenomena in question, i.e. in our case oil spill events in Öresund, and b) statistical data and previous studies from other places, adjusted to the conditions of the local environment, i.e. Öresund.

Both approaches are used in this study. Hazardous events, causes and factors contributing to oil spills in Öresund are mainly identified and analysed by the first approach. The second approach is used when calculating the claims linked to oil spills.

[8] Hammonds, J. S. et al. (1992) *Risk Information to Assist in Risk Management Decision Making* ES/ER/TM-40, Martin Marietta Energy Systems, Inc., Oak Ridge, TN.

2.2.1 Approach for analysis of oil spill events

Figure 2.2. shows various data sources and the way they are used for analysis of oil spills, their causes and contributing factors. Statistics on accidents and incidents in Öresund are collected from maritime authorities on the Swedish and Danish sides of Öresund. From this base hazardous events and causes of oil spills are analysed. The results are then compared with the statistics on world major oil spills.

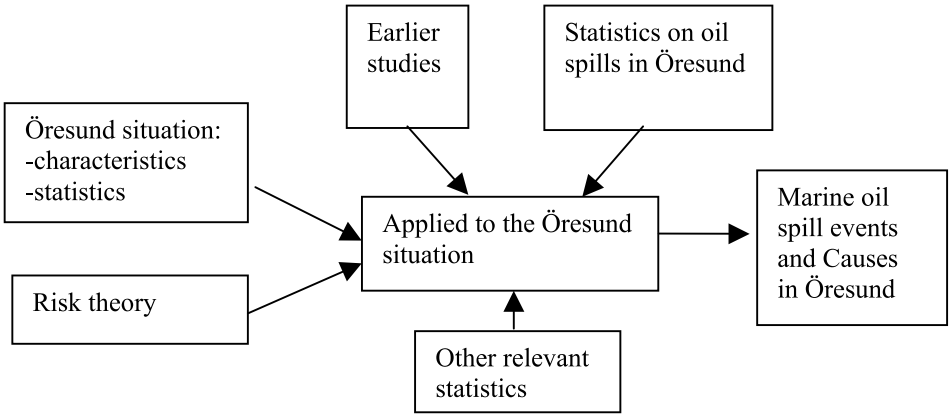

Figure 2.1: Approach for analysing marine oil spill events and causes

2.2.2 Approach for calculating claims

Figure 2.3 shows the approach to estimating oil spill claims for the Öresund area. When it comes to the analysis of potential third-party claims, world statistics on major oil spills and their claims are gathered and applied to the Öresund situation. The reason is that statistics from Öresund are too limited to give a solid base for calculations.

This report uses statistics on major oil spills in the world. Based on this database average, recent (= the last three years in the period) maximum and minimum figures for third-party claims in US$ per ton are calculated. From the Öresund statistics average oil spill/year in tons is calculated. Based on those figures and the figures from world statistics, the potential third-party claims for oil spills in Öresund are calculated.

Finally, the worst scenario for Flintrännan and Drogden respectively is chosen and third-party claims calculated.

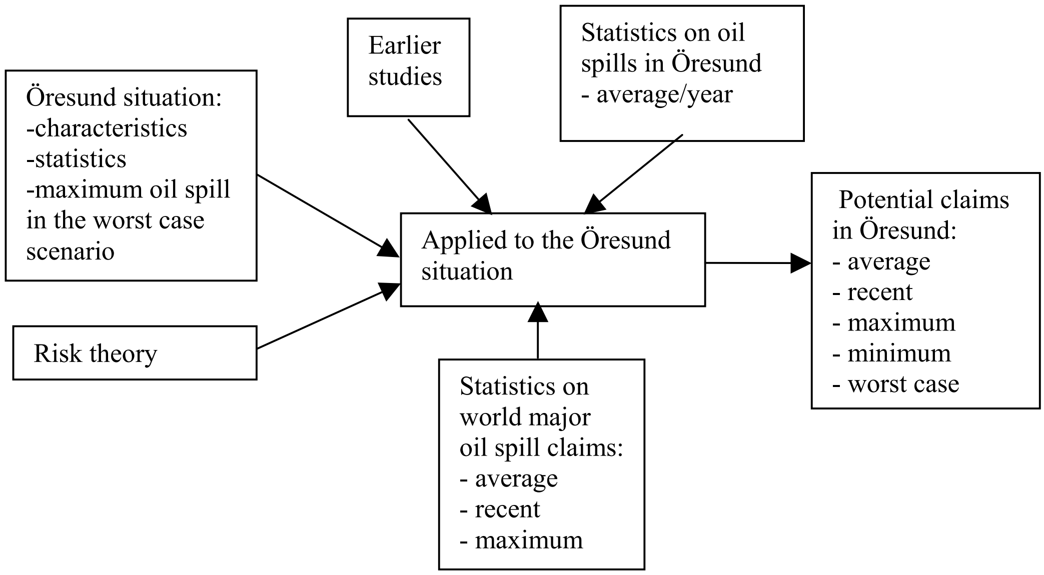

Figure 2.2: Approach for calculating claims

2.2.3 The overall approach

Figure 2.4. depicts the overall approach employed in this study. Based on the overall results and some interviews with persons working with marine safety issues, suggestions for safety-increasing actions are presented. A recent nearby severe oil spill event is used to illustrate the possible causes and consequences of an oil spill and to give inspiration for suggesting safety-increasing actions. This gives us the following overall approach of the study:

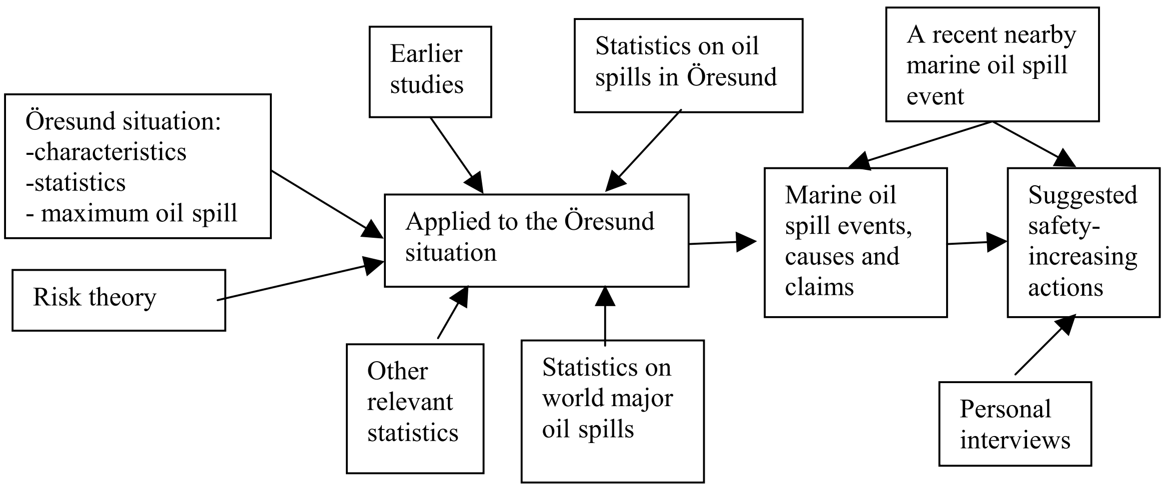

Figure 2.3: The overall approach of the study

2.2.4 Databases and data

A number of different databases have been used. In some cases the database already exists, while in other cases the data have been put together by one of the authors. In Appendix 1 you will find a detailed presentation of all the databases used in this report.

A large part of this research is based on *two sets of data*. The following section describes the nature of those sets of data and the sources from which they were acquired.

The two sets of data were provided by: a) Drogden VTS (Danish) – 264 records and b) Swedish Maritime Administration (SMA) – 562 records. The total number is 826 records. Records are kept on the "ship involved" basis, i.e. one record for each ship involved. Many marine events have involved more than one ship, for example, collisions. Therefore, a case history may consist of more than one record.

In terms of types and the degree of details of information provided, the two sets of data showed similarities and differences. The following section describes each set of data.

Database I
Source: Drogden VTS (Peter Jakobsen) – 15 January, 1999
Sample (1)

Size: 264 records consisting of 33 accidents and 231 incidents or near missings.
Scope:
- Location: Marine events that occurred during navigation in Öresund (Danish Side – Drogden)
- Time period: Covers more than one year, incidents from 1 September, 1997 to 31August, 1998, accidents from 1 September,1997 to 31 December, 1998.
- Types of ships: All types of ships
- Flag (nationality): Any flag
- Types of events: All categories of marine events, including accidents and incidents or near missings.

Database II
Source: Swedish Maritime Administration (SMA), database SOS (SjöOlycksSystemet) – Sjöfartsverket (Gunnel Persson) – February 2000. SMA database SOS contains marine events reported in Öresund waters. This data set consists of two samples.
Sample (1):

Size: 409 records, of which 252 were accidents and 157 incidents or near missings .
Scope:
- Location: Swedish territorial waters only.
- Time period: 1985-1999
- Types of ships: All types – merchant ships, fishing boats and others.
- Flag (nationality): Any flag.
- Types of events: All categories of events: grounding, collision, contact, fire/explosion, machinery, hull/ watertightness, listing/ capsizing and others.

Sample (2):

Size: 153 records, of which 149 were accidents and 4 incidents or near missing .

Scope:
- Location: Danish side (territorial waters).
- Time period: 1985-1999
- Types of ships: All types (see sample 1).
- Flag (nationality): Swedish flag.
- Types of events: All categories (see sample 1).

2.2.5 Further scoping

Compilation of data reduced the number of records that had to been included in the analysis. Some events had no relationship whatsoever to events involving dangerous cargoes, and have therefore been excluded. Events such as "passenger died" and "man overboard" have also been excluded.

As mentioned earlier, events are recorded on the ship basis, i.e. one event may appear more than one time in database records. For example, a collision event between two ships is recorded twice. The number of records depends on the number of ships involved. Data are compiled and analysed on both event and ship basis.

For the purpose of analysis, collision events involving two or more ships are entered (counted) only once and for one ship only, and the ship is considered the "primary" ship. The other ship involved is considered a "secondary" ship. In one case, three ships were involved in a collision event. The criteria for selecting the "primary" ship are:
- oil spill
- sustained damage
- tankers
- larger ships
- cargo ships
- sufficient information

In 1991, for example, near the coast of Råå/Ålabodarna two Bahamas cargo ships – cool carrier and ro-ro cargo ship - collided in poor visibility. Both ships reported sustaining extensive damage to the hull. Both ships spilt oil: the cool carrier spilt a "large" amount of oil, while the ro-ro ship spilt a "minor" amount. Since the cool carrier had spilt a larger amount of oil, she was selected as the "primary" ship. This event was counted as one single "large" oil spill.

Although the SMA database records marine events occurring in Öresund, numbers of events have happened beyond the Öresund limits as being defined in this report. The Öresund area is defined as the area limited– in the north by Kullen (N 56 15, E 13 03) and in the –south by Falsterborev (N 55 18, E 12). Marine events that have occurred outside Öresund waters are excluded. However, for certain purposes of analysis, they have been included, for example for the purposes of hazard identification, such as: weather and navigational hazards, causes and contributing factors related to technical, human and other factors.

2.2.6 Some assumptions and modifications

Most of the categories of marine events were taken as they were reported. However, some categories were modified based on the description of the event. In order to enhance the consistency, they were modified according to international definitions. For example, an initial event labelled as "grounding" was modified to a "machinery" category whenever there were indications that a machinery failure preceded grounding. Some other modifications were:

- "Collision with object (e.g. buoys)" was modified to "Contact". Contact is striking of any fixed or floating object other than those included in "collision" or "stranding or grounding."
- "Collision with a ship" was modified to simply "collision."

All relevant "near missing" events from the Danish data set are included. Any "near missings" events could have led to a serious or very serious accident. Either by chance or due to immediate intervention these events were avoided or did not happen. In a number of cases it was not very certain whether a "near missing" event could have turned into an accident/incident as indicated. Probably, a "near missing" collision could have, for example, turned into a grounding accident.

On their way through Öresund some ships violated a restricted area and later nearly grounded or collided with another ship or a buoy. In such cases, either grounding or collision events are taken into consideration.

Because of inconsistency and incompleteness, data sets are analysed separately and in combination, depending on the level and the purpose of analysis.

2.3 RISK ANALYSIS

In this part the risk analysis model, methods and procedures have been discussed.

2.3.1 Risk analysis methods and procedures

The research process requires a multitude of activities: selecting, collecting, handling, and analysing data. These activities are very much related to the criteria (i.e. criteria for selecting events involving oil spills) chosen and the scope of the study. Although they may vary widely within and among industries and sectors[9], risk analysis methods and procedures share similar principles at the generic level. For the purpose of this study a risk analysis approach has been adopted for marine transport of oil and oil products. The analysis is a structured process consisting of a number of stages (steps), including: a) system definition, b) hazard identification, c) frequency and consequence analysis and estimation and d) risks presentation. Detailed discussions about these steps are provided in a number of works[10],[11],[12],[13],[14]. In this

[9] A centre of excellence and postgraduate school in Major Accident Risk Assessment - MARA. Lund Institute of Technology. 1995.

[10] Purdy G. (1993) "Risk Assessment". *Hazardous Cargo Bulletin*. Dec. 1993. DNV Technica.

[11] The Institute of Marine Engineers. UK. 1997.

report, the results and analyses are provided in accordance with the methods employed by the HSC UK (1991)[15] in the risk assessment of major hazard marine accidents involving dangerous substances and materials.

2.3.2 A basic risk analysis model

Figure (2) presents a basic risk analysis model that is employed for analysis of risks of oil spills in Öresund. Two very useful modelling techniques designed to assess potential risks to a system, are: Fault Tree Analysis (FTA) and Event Tree Analysis (ETA).[16] They are both employed in this study to analyse risks of marine transport of oil spills in Öresund.

The fault tree analysis (FTA) is a graphic logical diagram that shows how a system, i.e. the marine transport system, can fail. The analysis starts with top events that, in this case, are oil spill events. Beginning with the top event, the necessary and sufficient hazardous events, their causes and contributing factors are identified together with their logical relationships. This has been accomplished by using a "backward logic" and asking questions like: "How can oil spills happen?" or "What are the causes and contributing factors of oil spills?" The frequency of some causes and contributing factors is estimated.

The event tree analysis (ETA) is also a graphic logical diagram that identifies and quantifies possible outcomes following initiating events, e.g. oil spills. It provides a systematic coverage of the event propagation through a range of possible consequences. It attempts to answer the questions: "What has happened after oil spills?" "What are the consequences of oil spills" and "How often have they happened?"

The level of analysis resolution in both diagrams (i.e. FTA and ETA) is limited to the extent for which data and information were available.

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[12] Royal Society 1992 *Risk: Analysis, Perception and Management.* Report of a Royal Society Group Study Group 1992..
[13] HSC 1991. *Major Hazard Aspects of Transport of Dangerous Substances.* Advisory Committee on Dangerous Substances, Health and Safety Commission, HMSO. 1991
[14] Nicolet-Monnier, Michel and Gheorghe, Adrian V. (1996) *Quantitative Risk Assessment of Hazardous Materials Transport System.* Kluwer Academic Publishers.
[15] HSC 1991. *Major Hazard Aspects of Transport of Dangerous Substances* . Advisory Committee on Dangerous Substances, Health and Safety Commission, HMSO. 1991
[16] CCPS, 1989. *Chemical Process Quantitative Risk Analysis.* Centre for Chemical Process Safety of the American Institute of Chemical Engineers.

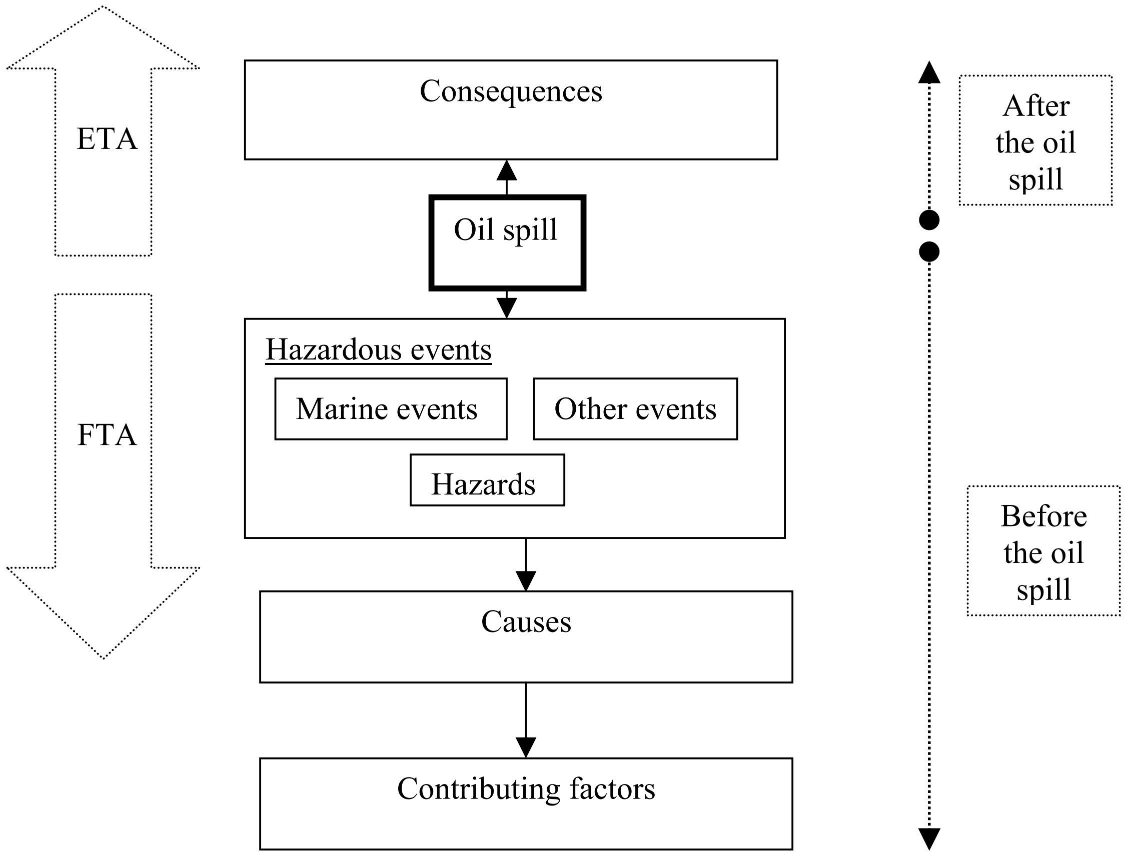


Figure 2. 4: A basic risk analysis model

2.3.3 Methods of analysis

The purpose of this section is to discuss the methods employed in the analysis of empirical data. Methods are mainly constrained by the nature and amount of data available and risk analysis procedures and goals. Risk analysis accommodates both qualitative and quantitative approaches. The following issues will be discussed: design of variables, quantitative and qualitative analysis and the analysis model employed in this study.

2.3.3.1 Variables

The risk analysis process requires collection of a considerable amount of empirical data. A large amount, but not "exhaustive", of empirical data have been collected from a number of sources. The amount and nature of data dictated the necessity to deal with data in a quantitative as well as a qualitative manner.

In order to make a quantitative analysis of empirical data possible, a series of variables have been designed based on: structural and functional properties of the components of the marine transport, marine events, navigational and weather hazards. The type and the number of variables have also been determined by the information provided in the case histories. Variables are metric and non-metric, most of them non-metric or categorical.

The number of variables designed was very large. The main categories of observed variables (constructs) and their sub-categories are given below:

- *Ship:* type, size (dwt, length), flag/nationality, age, number of crew, other structural properties, such as hull material, double bottom/side etc.
- *Ship's activity*: en-route, loading/discharging, other.
- *Weather/navigation hazards*: light/darkness, visibility, current (direction, strength), wind (direction, strength), state of the sea.
- *Marine events:* categories of events, e.g. grounding, collision, contact etc.
- *Time*: date, day, month, year.
- *Location*: locations of marine events oil spills in Öresund.
- *Categories of vessel traffic*: a) east/west bound, b) north/south bound - through traffic and c) Öresund port north or south bound.
- *Consequences:* damage sustained by the ship, for example, in length, width, above or below water line, injuries/fatalities including the number and categories of injuries and fatalities, marine environment consequences expressed in terms of the number and amounts of oil spilt (e.g. "large" and "minor" spills).

2.3.3.2 Quantitative and qualitative analysis

Statistics

Statistical procedures and tools are used to facilitate the risk analysis process. Procedures and tools employed in this study are described below.

Based on the number of variables analysed simultaneously, statistical analyses are divided into: univariate, bivariate and multivariate analysis. Multivariate analysis is when more than two variables are included in the analysis. Given a) the nature of variables (most of them are non-metric) and data-related problems and b) the risk analysis process, univariate and bivariate analysis are used in this study.

Summarisation. Summarisation is one of the statistical procedures. Data are summarised based on the variables designed. Summarisation included the following procedures: frequency, descriptive, explore, cross-tables/ classification. These procedures were performed by means of a statistical software system - SPSS. The SPSS provided a wide range of other statistical procedures and tools that facilitated the data analysis and presentation. Procedures and tools provided by SPSS are:

> *Statistics:* 1) summary (frequency, description, explore, cross-tables/classification). 2) compare means; 3) general liner model; 4) correlations; 5) regression; 6) classification; 7) data reduction; 8) non-parametric tests; 9) time series.
>
> *Graphs and tables* – visual presentation such as: tables, charts (bars, lines, areas, pies, high-low, Pareto, control), plots (box, bars, scatter), and histograms.

Many of the results are presented in tabular or graphic summaries.

Frequency (probability) calculation was an important procedure, because, among other things, the risk analysis process requires frequency calculations for causes, contributing factors and consequences. The risk is estimation based on the formula R = *f* [FXC], where F is the frequency.

Cross-table or classification analysis is one of the statistical procedures employed in the analysis process. The purpose of this procedure is to explore whether any relation exists between two variables i.e. row and column variables. The difference between the "expected" and "actual" number indicates such existence. The "expected number" is the number of cases that would be expected in the cell if the row and column variables are statistically independent or unrelated to one another. The "actual number" is the number of cases present in the cell.

Analysis based on non-statistical inferences (algorithm). The application of algorithms was essential in the risk analysis. It enabled the exploration of complex relations. Models are built based on algorithms. Although aided by the computer, such as Word, Excel, Power Point and SPSS software programs, graphic logical diagrams are designed based on logical analytic procedures such as, for example, the “backward logic” used in risk analysis procedures.

Qualitative analysis
Why qualitative approaches? Some of the reasons are:

- Quantification of all data provided in the case histories was not possible. Some data could not be conveniently represented as quantitative variables.

- In order to explore an “exhaustive” list of all possible hazards (causes and contributing factors) that may lead to oil spills in Öresund, three data sets were pooled together. They are local and regional data sets i.e. data acquired from Swedish, Danish and Baltic Sea databases. To a large extent, the data sets were not comparable and pooling data for the purpose of quantification was not possible. This was due to a number of factors, including: a) unharmonised definitions and b) the type, details and scope of information provided. For the purpose of exploration qualitative analysis has been employed. Such analysis was, for example, employed in the hazard identification process i.e. identification and analysis of causes and contributing factors of accidental/incidental and operational oil spills. By pooling together all data sets, categories of causes and contributing factors of oil spills are identified, enumerated and analysed, but they are not quantified.

- Narrative descriptions. Two oil spill case histories - the "Exxon Valdez" and "Baltic Carrier and Tern" cases - are described and analysed.

- Accommodate missing data. A number of variables and cases had missing data. They have not been eliminated, but are summarised and dealt with in a qualitative manner.

2.3.3.3 Analysis plan

Multivariate techniques allow analysis of all variables simultaneously, determining empirically the most influential variables i.e. those variables that have a significant impact on risks. Analysis may provide answers to the question: What are the most influential variables in fatalities and injuries due to hazards of oil? Because of the nature of variables (most of them are non-metric variables with a large number of categories) and data-related issues, the employment of the multivariate techniques that handle all variables simultaneously was in practice impossible.

Figure (2.5) shows the analysis model and the plan of analysis. The model presents the main categories of variables (constructs) selected and the plan for analysis of the Swedish and Danish data sets. Because of the large number of variables and their possible combinations, the analysis process is concentrated around two variables: a) marine events, which are the immediate causes of accidental oil spills in Öresund and b) consequences i.e. oil spills. This line of approach is determined by the steps of risk analysis. It attempts to answer the question: How have different variables affected marine events and their consequences (oil spills) in Öresund?

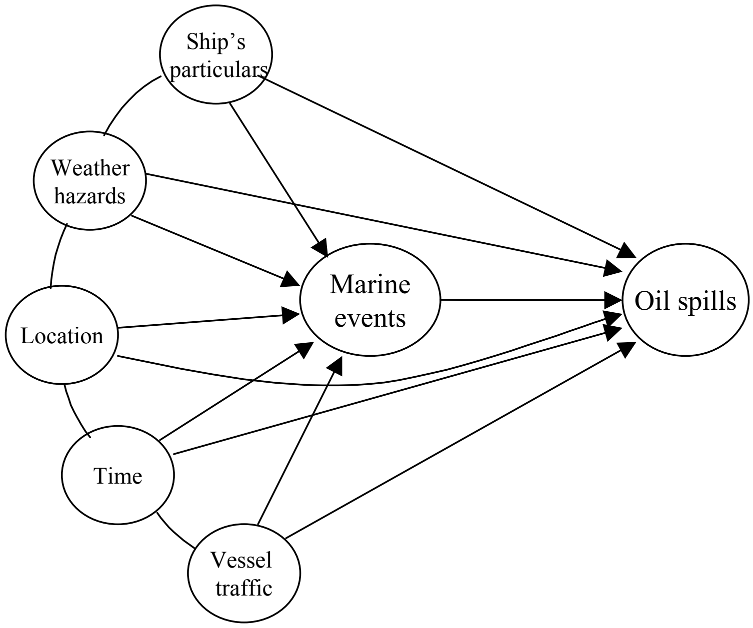


Figure 2.5: The analysis model for empirical data

2.4 OTHER STUDIES OF RISKS IN ÖRESUND

Maritime risks of many kinds exist and 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.

In Larsson (1998) "*SUNDRISK - Maritima risker i Öresundsområdet, lägesrapport*" (SUNDRISK Maritime risks in the Öresund area, working report) different types of maritime risks are discussed. Mentioned are, among others: grounding collision with firm obstacle and moveable obstacle , ship wrecking cargo damages passenger injuries fire on board drowning and pollution The latter is divided into in-operation-permitted pollution, in-operation disallowed pollution and accident-correlated pollution. As risk-influencing internal factors are mentioned: engine breakdown on main engine, breakdown on the steering engine breakdown of the helm cracks in the hull, fire or explosion on board, tiredness or carelessness of the crew, navigation mistakes and steering mistakes. As risk-influencing external factors are mentioned: poor visibility radar interference from rain and snow, heavy wind high seas, strong currents bad ice conditions, the traffic situation and pirates Some examples of dangers particularly for the crew members are also given.

Hägg (2000a) concludes in ”*Det internationella sjösäkerhetssystemet och dess brister*” (The international sea safety system and its shortages) that a considerable number of substandard ships pass through Öresund every year. Those ships are not only in bad shape, but they also have a crew of low quality. Hägg discusses the possibility of starting an open ship register for all those shipping companies that 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 wishes of shipping companies 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 imposed on the shipping companies.

Ericsson (2000) in his “*Reports on accidents (serious and non-serious) in the Sound 1985-1999 registered by the Swedish maritime administration*” has put together statistics on 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.

Harrami & Kylefors (1999) in “*Riskinventering Öresund*” (Risk Inventory Öresund) in their introduction refer to the fact that the Swedish Rescue Services Agency classifies accidents into the following categories: traffic accidents, environmental disasters, fire, explosions, chemical discharge, nuclear accidents and combination accidents. 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 ofdangerous goods on land. Then different types of accidents are discussed, and they mention grounding, collisions, pollution from ships of dangerous substances like oil, drowning/drowning incidents, pollution in the harbour or from nearby activities, fire and accidents and incidents caused by cargo shifting. As risk-influencing factors they mention, among others, the condition of the ship the crew and its organisation of the daily work, co-operation with the pilot and co-operation with VTS (Vessel Traffic Service). The report also mentions the risk that high-speed ferries could constitute. Possible actions that are mentioned are: making the sailing channels wider and deeper, separating the different traffic flows accessing a pilot, compulsory piloting and a permanent supervision centre of the VTS type that can exchange information with the ships.

Olsson (1999) in his report ”*Sjötrafikövervakning*” (Sea Supervision Systems) discusses different types of existing sea supervision systems, which ones 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, namely: a) Vessel Traffic Service (VTS), where a land-based supervision centre gives information and advice to the ships, b) Ship Reporting Systems (SRS), where each ship has to report and give certain information when entering or leaving a special area at sea, and c) Traffic Separation Scheme (TSS), which separates the traffic flows in different directions from each other.

In “*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) Ek & Akselsson (2000) discuss four groups of risk factors, namely: geography and nature phenomena, occasional obstacles for navigation, man-machine system of the ships and the sea supervision and finally the organisation of the daily work on board and on land. 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.

Some of the Sundrisk reports focus on oil spills in Öresund.

In "*Miljörisker med transport av olja i Öresund*" (Environmental risks concerning transportation of oil in Öresund) Törneman (1999) looks at the risks that exist in Öresund concerning pollution of oil from ships. Pollution can be divided into deliberate and non-deliberate pollution. The latter, for instance, are those in connection to groundings or collisions. The effects on flora, fauna and human beings are dependent upon, among other things, the type of oil, the place of pollution, wind- and stream conditions and the height of the waves. These factors are studied for the Öresund area.

Nilsson (2000) in his report "*Vulnerability analysis – Öresund*" focuses on accidents causing oil 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): *"Vulnerability and Hot Spot Assessment of Öresund for Oil Spills - a Mapping Approach.* Institutionen för brandteknik, LTH, Lunds universitet, Lund. LUCRAM. Sundrisk-report number 2001. The study is based on the accident statistics over 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.

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

In his report *Maritime Risk Analysis and Management - Existing Practices, Existing Needs* Sampson (2001) gives 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, e.g. 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 pro-active 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.

In his study *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) Hägg (2000b) gives a general overview of how maritime risks from an institutional perspective have been regulated both today and historically. Although Hägg points out many problems, such as convenience flags and sub-standard boats, he claims that we are slowly moving in the direction of increased safety.

Ericsson & Mejia (2001): *IMO's Work on the Human Element in Maritime Safety.* In their study the authors have examined the work on the human factor in marine 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, reports and articles. The review also includes one of the most important documents developed by the IMO in the area of the human factor, i.e. the International Safety Management (ISM).

3 SYSTEM DEFINITION AND DESCRIPTION - ÖRESUND

In this section the system whose risks are to be analysed is defined and described, i.e. the Öresund area and the marine transport of oil and oil products, including bunker oil and related activities. The discussion will cover the following issues:

- Physical environment system: the Öresund geographical water area
  - Population
  - Property
  - Marine ecosystem - flora and fauna
  - Coastal lines and waters
  - Weather conditions
  - Navigation system

- Marine transport system and related activities:
  - Vessel traffic: categories of traffic , oil and oil products: types, amounts, ships - types, sizes, flags;
  - Related activities - loading, unloading, bunkering and others

The purpose of this section is to: a) define the area b) identify and describe risk receptors - human, environmental and property exposed to oil spills c) identify and describe hazard situations and risk producers.

3.1 GEOGRAPHICAL WATER AREA

Definition of the area

The Öresund geographical water area is described in terms of: population, properties/assets, marine ecosystem, coast lines and water surface/volume. What does the Öresund geographical water area (Öresund) refer to? For the purpose of this study it is defined as follows: 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).[17] Öresund refers to the waters between the lines Gilbjerg Hoved-Kullen in the north and Stevens-Falsterbo in the south.[18] 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 tideless strait may impede navigation during severe winters. Four islands are located in Öresund: Amager, which is partly embraced by Copenhagen, Ven, Saltholm and Pepperholm. The last two divide the waters into the channels of Drogden (west) and Flintrännan (east). Copenhagen and Helsingør are the principal ports on the Danish side and Malmö, Helsingborg and Landskrona on the Swedish side.

The Öresund Bridge (Öresundsbron) (photo 3.2) connects the cities of Malmö in Sweden and Copenhagen in Denmark. The total length of the Öresund Bridge is 7,845 m. The last three

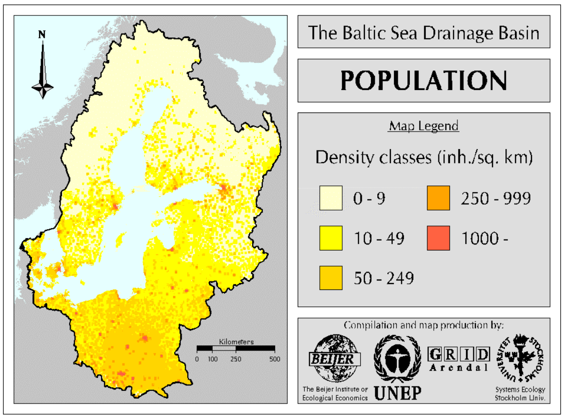
[17] Encyclopaedia Britannica 2001, Britannica.com. http://corporate.britannica.com/
[18] VBB VIAK 1992; *Olyckor och haverier i anslutning till förbindelsen,*: Underlagsrapport nr. 30, pg. 31, June 1992.

kilometres close to the Danish shore are a tunnel emerging on a man-made island, the Pepparholm Island. The part of the bridge 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 also a railway line operating on the bridge. The bridge could be seen as an obstacle to navigation in Öresund.

Photo 3.1: The bridge across Öresund[19]

Population

How many people are exposed to the risks of oil spills? 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 inhabitants live on the Danish and Swedish side, respectively.[20]



Öresund has one of the largest populations (including population concentration as well) in the Baltic area. A number of relatively large cities and towns are located in the area, such as: Copenhagen, Malmö, Helsingborg, Landskrona and Helsingör.

Figure 3.1: Population density map[21]

The Öresund region has a population density ranging from 250-999 to 1000 or more inhabitants per square kilometre (Figure 3.1). A large area including Copenhagen (about 1.2 million inhabitants) and Malmö (about 260,000 inhabitants) has the highest density, which may exceed 10,000 inhabitants per square kilometre[22].

[19] http://www.skanerunt.nu/, 2001
[20] http://www.oresundnetwork.com/: "The Øresund Region - a selection of statistics, key figures and organisations". "The Øresund Region in figures.", 2001
[21] http://www.grida.no/baltic/htmls/maps.htm, 2001
[22] http://www.grida.no/baltic/htmls/maps.htm, 2001

Properties

How much property is exposed? Figure 3.2 shows the largest cities and towns in the Öresund area. There is a large number of valuable public and private properties/assets in the area, including:

- 3.5 million people with their property, e.g. houses, cars etc.
- 170,000 companies with valuable assets operating in the region.[23]
- Infrastructure, including: airports, roads, and the bridge. The Öresund bridge is Sweden's largest construction and Europe's longest cable-stayed bridge for rail and road traffic. It cost approximately US$ 1.5 billion to build.[24]

Figure 3.2: The largest cities and towns in the Öresund area

Marine ecosystem

How sensitive is Öresund's marine ecosystem? How does it react to releases of pollutants, including oil spills? The Øresund area is one of Europe's most sensitive and important ones from an environmental perspective.

The Baltic Sea, which includes the Öresund waters, is the largest body of brackish water (i.e. slightly salty water) on Earth.[25] The Baltic Sea's health has seriously deteriorated due to human activities, such as waste from industry, waste from urban areas and leftovers from fertilisers.

The marine ecosystem (fauna and flora) of the Öresund area has the following characteristics:

- shallow waters
- slow water exchange processes
- a relatively low level of biological activities
- beaches of great recreational value; they are vacation areas for many local and European residents, which provides service jobs in tourism and recreation
- 15 natural reserves (coastal and marine) – 12 Swedish and 3 Danish ones

[23] http://www.oresundnetwork.com/: "The Øresund Region - a selection of statistics, key figures and organisations". "The Øresund Region in figures", 2001
[24] http://www.oresundnetwork.com/: "The Øresund Region - a selection of statistics, key figures and organisations". "The Øresund Region in figures", 2001
[25] Scott A. Kocher 1995: Baltic Sea Pollution. Trade Environment Database (TED) Volume 4, Number 2, June, 1995.

- a number of areas of botanical and zoological interest on the Danish side; the coastal areas serve as feeding grounds for several species of marine and freshwater fish, and fishing is of economic importance for the area
- EU areas of habitats: one "Baltic sea protected" area, one "Convention on wetlands" area and a number of "EU bird directive" areas.

Environmental risks in Öresund may be expressed as a ratio between:
- coastline affected and the total coastlines exposed expressed in kilometres
- the amount of oil spilt into the sea and the volume of water exposed expressed in cubic meters, tonnes, and litres.

Coastlines[26]
How many coastlines are exposed? The Öresund coastlines are:
- mainland
  - Swedish coastline (Kullen-Skåre) = 162.5 km
  - Danish coastline (Gilleje-Hjörup) = 145.5 km
- islands
  - Ven = 13 km
  - Amager (Drogden) = 39 km
  - Saltholm = 17 km
  - Pepperholm = 8 (estimated)

Total coastlines estimated: 385 km

Water surface and volume
On the basis of Öresund map no. 929[27], the Öresund water surface was divided into 43 small areas. The surface and water depths of each area were measured. Four average water depths were calculated for each area (43 x 4 = 172 measurements). The following are some estimates concerning water surface and volume in Öresund.

Öresund's water surface is estimated at approximately 2,822.39 square kilometres (2.8E+09 or 2.8^9 m^2). The volume is estimated based on the average water depth (10.13 - 10.33 meters) and the surface. It is estimated at 3.0E+10 or 30^9 m^3.

Summing up
Öresund is a quite narrow sound with three and a half million people, most of them living at or near the sea. It is one of the areas in the Baltic with the highest number of inhabitants per square kilometre. It has 385 kilometres of coastline and a relatively sensitive marine environment.

[26] Coastlines are measured by means of MapInfo Professional program and the nautical chart of Öresund Nr 929.
[27] Ibid.

3.2 NAVIGATION AND WEATHER CONDITIONS

In this section the navigation and weather conditions in Öresund are described. Information on weather conditions is important, because it may help to answer the following questions:

- to what extent did weather hazards contribute to marine events?
- how did they affect the courses of marine events?
- how could they affect "consequences", for example oil dispersion?

The navigational situation is also of great importance for the risks when crossing or passing through Öresund. Identification and description of navigational hazards are of significant importance when analysing risks, because they are helpful in providing some answers to the above questions.

Depths and widths
Water depths vary from shallow 0.1 m to 26 meters in the northern part. The maximum water depth is 46 meters - east of Staffanbank outside Landskrona.

The southern part of Öresund is shallow, and ships may pass through one of the two channels, Flintrännan and Drogden. The new Öresund link also makes it more difficult and to a certain extent impossible to pass, except through one of the channels.

The water depth in the old Flintrännan (1990) was 7.4 m in an approximate width of 200 m. This allows ships with drafts of up to 7.0 m to pass Öresund in Flintrännan. Ships up to approximately 10,000 dwt could pass through Flintrännan fully loaded. Ships up to 50,000 dwt could pass partially loaded.

The new Flintrännan has a width of 370 m and a minimum depth of 8.5 m, which allows larger ships to pass. According to 1997 vessel traffic records, the largest ship size (that of an oil tanker) passing through Öresund was over 400 metres long[28] which corresponds to a ship of more than *200,000 dwt*.

There are no speed restrictions, and ships sail at a sea speed, but ships with a draft close to the minimum water depth reduce their speed.

Weather conditions
The following information on weather conditions in Öresund is obtained from the data set provided by the Swedish Maritime Administration (SMA). Conditions are described in the following order: visibility, winds, ice conditions and the state of the sea. Bad and severe weather conditions are hazardous to navigation in Öresund. Furthermore, some of these conditions may affect the course of oil spill events and the response to them.

Visibility
In 161 out of 244 (or 66%) records, visibility was > 10 km (good or excellent). Visibility was affected by fog and precipitation such as rain and snow. Often visibility was reduced by up to 0.5-1 km. Visibility reported was also very poor and in a number of cases it was reduced almost to zero. The months with the highest frequency of "poor visibility" (< 0.5 km) were January, March and April (18/30 or 60% of poor visibility records).

[28] Malmö VTS 1997

Winds
The categories of wind directions represented were: still, variable, and all directions (N, NE, E, SE, S, SW, W, NW). The most prevailing wind directions were SE, S, SW and W.

Wind forces varied from calm or still (0.0-0.2 m/s) to storm and hurricane. In a number of cases, strong winds of a force > 33 m/s were recorded. Wind forces in the range 1.6-13.8 m/s were dominant (75% of the valid cases). In approx. one fifth (19%) of cases the wind force was in the range 1.6-3.3m/s. The frequency of wind forces below 10 m/s was approx. 85%. N, NE, S, SW winds were the strongest (i.e. 20.8 m/s and above). Strong winds across the navigation route result in difficult navigation.

Currents
The directions of the currents are north and southbound, with northbound winds prevailing (62% of records). Speed varies from 0 to 3 knots or above, often influenced by the wind direction and velocity. Currents in the speed range 2-3 knots or above were recorded when wind forces were 10 m/s or above.

In Flintrännan, strong northbound currents run almost parallel with the navigation route. They have a minor influence on navigation conditions, while strong southbound currents at an angle of 17 to 30 degrees to the navigation route make navigation difficult, especially for ships navigating south.

Ice conditions
Due to low temperatures in winter, the water surface in Öresund had frozen only a few times (5 records) – either creating large packs of ice or causing the entire water surface to freeze. Ships were reported to sail in waters with drifting ice and in tight ice-slush (melting ice).

Waves – state of the sea
The state of the sea (i.e. the wave height in meters) varied from calm to moderate. Waves in the range 0.0-0.25 m were recorded at a frequency of 62%, while waves between 1.25-2.5 m accounted for approx. 27%. Waves above 4 m were recorded outside Öresund waters.

Combined weather hazards predominating in Öresund were: winds/currents; visibility/ currents; visibility/winds/currents; winds/ice. Statistics[29] have shown that weather hazards, either solely or in combination, contributed to approx. one fifth of all marine events that have occurred in Öresund during the period 1985-1999.

Summing up
Öresund has a relatively difficult navigation situation due to occasional strong currents and winds combined with the fact that the water level is low in many places, meaning that the ships have to follow certain routes/channels.

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[29] VTS Drogden and Swedish Maritime Administration 1985-1999.

3.3 VESSEL TRAFFIC AND PORTS

The marine transport of oil and related activities are the risk producers. What types and how many tonnes of oil (i.e. the inventory of oils, oil products and bunker oils) are present in Öresund? What are the oil-related activities that may affect marine environmental pollution? What are the present and future perspectives of oil traffic in Öresund? This section is an attempt to answer these questions.

There are many types and large quantities of oil at any time in the Öresund waters. The oil is present in the form of cargo and bunker oil. In addition to tankers carrying large quantities at a time, ships of all types, regardless of their size, may be liable to an oil spill, be it an accidental or a deliberate one. Large quantities of different types of chemicals and other dangerous substances and materials in a packaged form are also carried and handled in Öresund.

Knowing the types and amounts of oil in Öresund is important, because we can assess the level of the risk of oil spills based on the oil exposed and the oil spilt. The total amount of the oil exposed is a function of the total amount of the oil carried (i.e. carried as cargo and/or bunker oil) by all types and sizes of ships and the time they are within the Öresund waters and their vicinity. The oil exposure may be expressed in terms of tonnes/hours. With the data available at present, an accurate estimation of the amount of the oil exposed in Öresund is not possible. However, information provided in this section gives a general overview of the marine transport of oil and related activities in Öresund.

The oil is present and poses threats while it is: en-route or underway, handled - loaded, discharged, transferred and other activities (e.g. bunkering) - and stored. Risks of oil spills in connection with the storage of oil are beyond the scope of this study. However, the storage activity affects the oil traffic in the area. Some selected storage activities in Öresund are described. The following will be discussed:

- vessel traffic: categories of traffic, oil traffic - types and amount, ships carrying oil - types, sizes and flags
- related activities: port activities including storage and handling

3.3.1 Öresund's vessel traffic

Ships move in Öresund in all directions - east/west and north/south. Information provided in the case histories has shown that there are three main categories of vessel traffic. Traffic is classified on the basis of the direction of ship movements - the port of origin and destination. Each category has, somehow, its distinct characteristics in terms of the type, size and flag of ships. The main categories and some of their characteristics are:

- *north/south (N/S) bound* - ships passing transit through Öresund, mostly cargo and other types of ships, Swedish and foreign flags
- *Öresund's port(s) - north or southbound* - ships calling port(s) in Öresund and bound either north or south, cargo and/or passenger ships, Swedish and foreign flags
- *east/west (E/W) bound* - mostly ships sailing frequently and regularly between Swedish and Danish ports, cargo and/or passenger ferries, Swedish and Danish flags

North/southbound traffic

Figure 3.3. shows the north/south vessel traffic in terms of the number of ships in Öresund over the period 1971-1999 for ships over 50 brt. The number of ships is recorded in the north (Helsingör) and south (Drogden, which is the Danish side of Öresund) of Öresund. Ships passing transit through Öresund and ships calling on ports in Öresund and bound either north or south are included here. The number of ships operating in the east/west direction is not shown. In 1999 the north/southbound vessel traffic was approx. 40,000 ships – including both Drogden and Flinttrännan traffic.[30] The majority of the ships passed through Drogden. In 1991, during four months' observations, only 12.3% of the Öresund north-southbound vessel traffic passed through Flintrännan.[31] The figure for Flintrännan is estimated at approximately 5,000 ships for 1999.

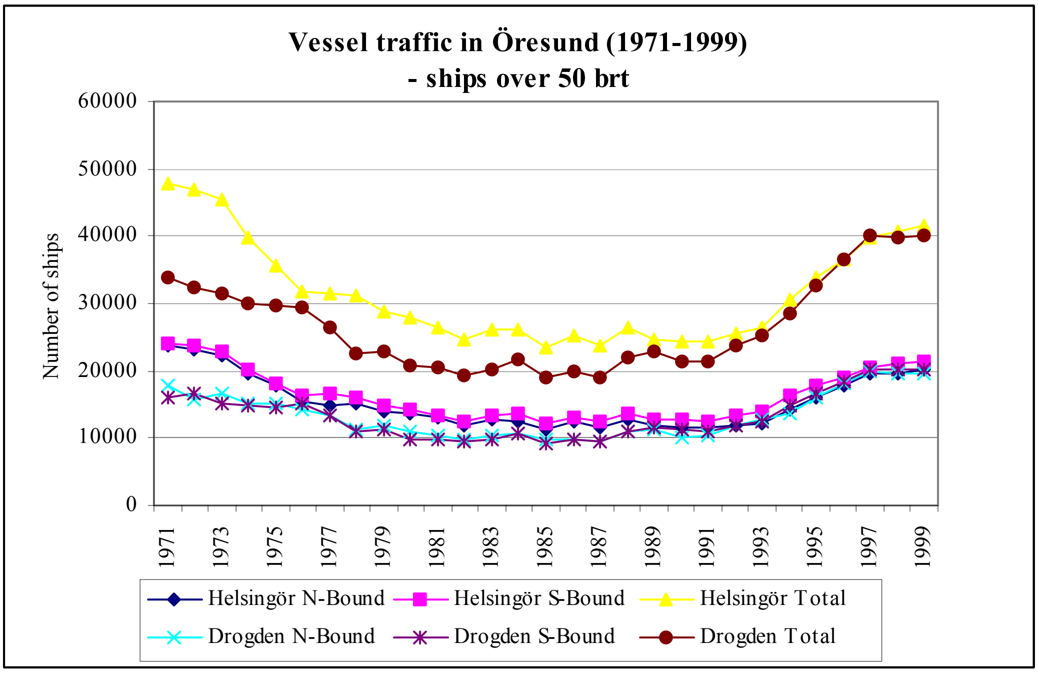

Figure 3.3: Vessel traffic in Öresund (1971-1999) for ships over 50 brt.[32]

East/westbound traffic

In the 1991 study, the east/westbound traffic was neither estimated nor predicted for the future. In 1998 east/westbound vessel traffic in Öresund has been estimated at 97,000 ships.[33] In 1999 ferry traffic between Sweden and Denmark was predominant as regards the number of trips as well as passengers.[34] This is compared to the north/southbound traffic. Because of the bridge, this number and, in particular, the traffic between Malmö-Copenhagen and Helsingborg-Copenhagen, has been reduced.

[30] Danish Maritime Administration 2000-05-03.

[31] P.Göran, T. Hägg 1998: Riskhantering och säkerhetsskydd: Översikt av regleringen av maritima risker från ett institutionellt perspectiv. Lund University Centre For Risk Analysis and Management 1998.

[32] Danish Maritime Administration (Danska Sjöfartstyrelsen) May 2000.

[33] Larsson, Everth (1998) *Maritima risker i Öresundområdet.* SUNDRISK-projektet. Lucram. Lunds Universitet. 1998.

[34] Annual Report 1999: Port of Malmö

The type, size and flag of ships and the amount/type of cargo carried are not shown, and neither are the amounts and types of oil, oil products, chemicals and other dangerous substances en-route at any time in Öresund.

3.3.2 Ports in Öresund

This section briefly describes the main ports located on both sides of Öresund, namely: Malmö, Copenhagen, Landskrona, Helsingborg, and Helsingör. The information presented here has mainly been acquired from: a) annual port reports b) national, regional and local statistics and c) other relevant internet web sites.

Port of Malmö
The port of Malmö handles all kinds of traffic, including passenger and cargo. The total volume handled increased during 1999 by 3%. Oil traffic made up 15% and 14% of the total volume in 1998 and 1999 respectively.[35,36]

Other important areas are line cargo and passenger traffic. In 1998 some ferry lines from Skåne to Denmark and Germany experienced an increased volume. In 1998 165,000 units were carried from Malmö to Germany (Travemunde). This was an increase of 9% in comparison with the previous year (1997). Others lines operating to these destinations reported drops.

In 1998, a total of 5.3 million people – approximately 14, 500 per day – crossed Öresund to and from the port of Malmö. The vast majority (approx. 5 million) of the passengers moved between Skåne and Denmark. Travellers used hydrofoil boats, catamarans and ferries for passenger/personal cars. In addition, there is feeder traffic to/from a number of Baltic ports. The fixed link across Öresund has led to a significant reduction in the sea traffic between Skåne and Denmark.

Oil traffic in the port of Malmö
The oil terminal of Malmö is one of the Swedish terminals for handling, storage and distribution of oils and chemicals. The port of Malmö is among the largest ports in Sweden for handling oil.[37] It handles around 1.5 million tons of oil and chemicals per year. Approximately 400 tankers call at the oil terminal annually. In addition, many other ships frequently call at this port for bunkering.

The total storage capacity of the oil terminal is around 1.1 million cubic meters. Storages of a capacity up to 270,000 cubic meters are owned and operated by a number of operators, including the port of Malmö itself.

35 Annul Report 1998: Port of Malmö.
36 Annual Report 1999: Port of Malmö.
37 http://www.malmohamn.se/, 2001

Storage capacity in the oil terminal is primarily used as transit storage for various types of oils. A large amount of oil comes from Russia and the Baltic states in summer for distribution to western and southern Europe during the winter season. In the future the port may become an important distribution centre for the Baltic region, including oil traffic.

Photo 3.2: The Malmö oil terminal accommodates large tankers.[38]

Port of Landskrona

In 1999 Landskrona Port had a turnover of 18 million SEK and about 20 employees. The company is 50% owned by Hydro Agri AB. There is regular ferry traffic to the island of Ven.

Port of Helsingborg

The city of Helsingborg, which is located on the most narrow point in Öresund right on the entrance to the Baltic Sea, has a large commercial port which has grown in size in recent years. The harbour is the second largest in the country and consists of four separate areas: the North, West, South and Bulk Harbours. The original harbour, called the North Harbour, is located in the city centre, and the other harbour facilities stretch 7-8 km southwards. Each of the four harbours is equipped to handle specialised types of shipping traffic: ferries, containers, general and bulk cargo including oil:

- RoRo/LoLo: West Harbour, South Harbour and Sound Terminal
- Unitized cargo: West Harbour and South Harbour
- General cargo: South Harbour and Ocean Terminal
- Bulk cargo: South Harbour, Bulk Harbour, Oil Terminal, and Grain Terminal

The port is administered by the Port of Helsingborg and has 250 employees. Helsingborg is one of the busiest ferry ports in the region. Every year 14 million passengers travel through the port on the ferries to Denmark and Norway.

The annual turnover of cargo is 10.5 million metric tonnes. The Port of Helsingborg has terminals for breakbulk, containers and all kinds of bulk cargo. The port is served by ferry services, container services and frequent feeder connections. Helsingborg has intermodal rail, truck and air connections.

The manufacturing industry plays a large and important role for the city. In the area operate a number of companies dealing with logistics, chemicals, medicine and food production, including: Kemira Kemi, Pharmacia&Upjohn, van den Bergh Food/Unilever and IKEA.

38http: www.malmohamn.se/, 2001

	Categories of traffic	1996		1997		1998		1999	
		Ton *	%	Ton	%	Ton	%	Ton	%
1	Bulk	1.73	19	1.81	19	1.82	18	1.91	18
2	Breakbulk	0.36	4	0.29	3	0.3	3	0.32	3
3	Containers	0.55	6	0.67	7	0.71	7	0.74	7
4	Train ferry	3.0	33	2.76	29	2.63	26	2.76	26
5	Car ferry	3.5	38	4.0	42	4.65	46	4.88	46
	Total	9.1	100	9.5	100	10.1	100	10.6	100

Table 3:1. Cargo traffic in the port of Helsingborg (1996-1999). Note: in million tons.*

	Port traffic	1997	1998	1999	2000
1	Total goods - million tonnes	9.5	10.1	10.6	9.9
2	Train and car ferry goods - million tonnes	7.2	7.3	7.3	?
3	Motor cars - millions	2.5	2,7	2.9	2.9
4	Passengers - millions	13.4	13.7	14.3	13.3

Table 3:2: Helsingborg port traffic [39]

Port of Helsingör
Most of the car ferry traffic from Helsingborg goes to/from Helsingör, and the port of Helsingör therefore shows almost the same figures as Helsingborg when it comes to car ferry tonnes and millions of motor cars and passengers. The port specialises in ferry traffic to/from Helsingborg and has no bulk, breakbulk or container activities.

Port of Copenhagen
In 1999 the port of Copenhagen had a turnover of more than 200 million DKK from port operations and about 370 employees. About 1/3 of the income comes from container handling and 1/5 from ferries. Other income sources for the port operations are: RO-RO, general cargo, bulk, cruise vessels and cars.

On January 1st, 2001 the ports of Copenhagen and Malmö merged their operational activities. The Copenhagen-Malmö Port AB then became the second biggest port in Scandinavia.[40]

Summing up
Öresund is one of the areas in the world with most ship movements with 40,000 ships/year in the direction north-south or vice versa and with other ships/ferries frequently crossing the sound in the direction east-west or west-east, which often leaves little room to manoeuvre. The Öresund link has contributed to this situation by creating substantial changes in the flow

[39] http://kommun.helsingborg.se/statistik/index.htm
[40] http://www.cmport.com, 2001

pattern, which in turn creates a new risk situation. Large quantities of oil pass through Öresund every day, and the oil traffic in the ports is substantial. Considerable risks are at hand.

3.4 SHIPS: TYPES, SIZES AND FLAGS

Table 3.3 shows the types and the numbers of ships which passed through Öresund (Drogden and Flintrännan) during 1990. The largest sizes of loaded ships were approx. 10,000 dwt and 13,000 dwt for Flintrännan and Drogden respectively. Approx. 89% of the traffic consisted of ships other than tanker ships. 83% of ships were "other" types of ships. Many of them may have been carrying dangerous goods in packaged form. 87.4% of the traffic passed through Drogden (on the Danish side). Only 12.8% passed through the Swedish side of Öresund.

Types of ships	**Drogden**		**Flintrännan**		**Öresund**	
	No.	%	No.	%	No.	%
Oil/oil product tankers	2216	11.86	169	6.27	2385	11.15
Chemical tankers	1071	5.74	103	3.83	1174	5.5
Other ships	15392	82.4	2425	89.9	17817	83.35
Total	18679	100	2697	100	21376	100

Table 3.3: Ship traffic in Drogden and Flint in 1990[41]

Regarding the dead weight of ships (dwt), the most frequent ship size passing through Öresund during 1989-1990 was ships with a capacity of 2,000-10,000 dwt.[42] The largest ship was over 100,000 dwt. That ship was in ballast when passing through. In Flintrännan the traffic of ships with a length between 170-200m dominated (58%).

In 1998 the number of arrivals and departures in Swedish ports of foreign-flagged merchant ships was almost five times the number of arrivals of Swedish-flagged merchant ships. Russian-flagged ships dominated vessel traffic in Swedish waters in the year 2000 with Norwegian and Swedish flags coming in second and third place respectively. [43]

Flags of ships that passed through Öresund during 1991 were: former Soviet Union (21%), Swedish (19%), Danish (14%) and German (9%).[44] The east/westbound vessel traffic, however, is mainly dominated by Swedish and Danish-flagged ships.

[41] COWIconsult 1992: Analys av risker för påsegling av bron. Doc.No. 22071-00, 1992
[42] Olyckor och haverier i anslutning till förbindelsen, VBB VIAK 1992: Underlagsrapport nr. 30, pg. 31, June 1992. Most of data on vessel traffic in Öresund were taken from a report produced by MRS Consultant in 1991.
[43] Transport Idag Nr. 2, 2000, pg. 10.
[44] Olyckor och haverier i anslutning till förbindelsen, VBB VIAK 1992: Underlagrapport nr. 30, pg. 31, June 1992

Summing up
Many different types of ships, sizes of ships and flags sail in Öresund. Many ships passing through Öresund sail under foreign flags. The possibility for the Swedish authorities to act is very limited, at least as long as there has not been an accident.

3.5 OIL AND OIL PRODUCTS: TYPES, QUANTITIES AND NUMBER OF SHIPMENTS

The following section provides some data concerning types, quantities and numbers of shipments of dangerous goods/cargo passing through Öresund.[45] Statistical data are not available on a regular basis for the traffic of oil and other dangerous substances and materials.

Almost half of the Swedish import carried with cargo ships is oil - 24 million tons. Some of it is refined and exported. In 1995 Sweden exported 9 million tons of refined oil. About 15 million tons of oil products are shipped between refineries and depots annually. Approx. 40,000 tons are en route every day in Swedish waters.

Large amounts of different types of oil pass through Öresund waters. Table 3.4 shows the types, numbers of shipments and quantities of oil and oil products transported through Öresund during 1988 (according to VVB VIAK 1990). The largest shipment was approx. 43,000 tonnes. Approx. 22,410 tonnes were en route each day in Öresund waters. On average, 3.4 tanker ships passed each day.

n	Types of oil/oil products	Quantity per year (tons)	Shipments per year (numbers)	Average quantity per shipment (tons)
1	Crude oil	2,441,605	57	42,835
2	Heavy oil	999,126	215	4,647
3	Light oil	2,382,184	478	4,984
4	Gasoline (bensin)	2,134,239	382	5,587
5	Other oil products	221,465	115	1,926
	Total	8,179,619	1,247	6,559

Table 3.4: Oil/oil products transported in Öresund in 1988 (Source: VVB VIAK 1990)

Given the increase in transport demands in general for each year (2.8% per annum), the amount of oil which may have passed through Öresund during 1998 could be estimated at approx. 32% (or approx. 2.6 million tons) more than in 1988, or the equivalent of 10.8 million tons.

The amount of oil present in Öresund may be even larger than what is estimated above. Table 3.5 shows tanker traffic in terms of ship types, size (length) and numbers in Flintrännan (i.e. the Swedish side of Öresund) during a period of one month (01.08.1997 - 01.09.1997).

45 Sjöfartsforum: Över Havet 1997.

No.	Ship type/size (length in m)	<15m	=15 <10 0m	=100 <200 m	=200 <400 m	=>40 0m	Total	
							Month	Year[46]
1	Tanker ships – oil/products	4	28	1		1	34	408
2	Gas carriers	6	4				10	120
3	Chemical tankers		8	1			9	108
	Total	10	40	2		1	53	636

Table 3.5: Tanker traffic for the period 01.08.1997 - 01.09.1997 in Flintrännan. (Source: VTS Malmö, September 1997[47])

On the basis of the above figures, tanker traffic in Öresund, including both Drogden and Flintrännan traffic, is estimated for 1997. The estimation is based on the fact that approx. 12% and 88% of ships passed through Flintrännan and Drogden respectively. In terms of the number of ships, tanker traffic has shown a significant increase in 1997 compared with 1988. Oil traffic has increased in Sweden, the Baltic region and world-wide. In 1997 the vessel traffic, including tanker ships, in Öresund has almost doubled compared to 1988 (Figure 3.4.).

No.	Ship type	Drogden	Flintrännan	Total – Öresund
1	Tanker ships – oil/products	3400	408	3808
2	Gas carriers	1000	120	1120
3	Chemical tankers	900	108	1008
	Total	5300	636	5936

Table 3.6: Tanker traffic in Öresund - Flintännan and Drogden - estimated for 1997.

The oil/oil products are also present in the area in the form of ships' *bunker oils*. Quantities and types of bunkers are not reported. The types of bunker oil vary. The quantity of bunker onboard a ship depends on the number and capacity of tanks carrying bunker oils. In turn, the number and capacity of tanks depend on the ship's size, type and traffic. It has been estimated[48] that the average number of tanks for bunker oil is 3 for all types of ships and sizes. This number varied from 1 to 5 tanks, and the capacity of tanks is higher for passenger ships.

The approximate amounts of bunker oil that may be carried by certain types of ships have been estimated.[49] Tankers, including oil and oil product tankers, chemical tankers and gas carriers, have a bunker oil capacity of between 200-900 cubic metres. Oil tankers of a size ranging from 60,000 to 80,000 dwt, which may pass Flintrännan in ballast, can carry up to 2,000 cubic metres of bunker oil. Cargo ferries operating in Öresund, some of them built for

46 Estimated
47 Data were provided by the VTS Malmö with help from Mr. Lennart Andersson, the head of department.
48 Consultants ApS (1992): Detail Specification of Traffic of Ships in the Sound, June 1992.
49 VBB VIAK 1992; Olyckor och haverier i anslutning till förbindelsen,: Underlagsrapport nr. 30, pg. 31, June 1992.

ocean going transport, have a large bunker oil capacity. They are estimated to carry up to 200 cubic metres at a time.

In addition, large amounts of oil, including chemicals and liquefied as well, are stored and handled in Öresund. There is a number of storages of oil and oil products along the coastlines of Öresund. For example, oil storing activities[50], which started in 1997, have developed in the port of Malmö. In 1998 oil traffic showed an increase in volume of 22% compared with the previous year (1997). In 1999 the volume of oil traffic in the Malmö oil harbour was around 1.5 million tons. Additional storage capacity is expected to be acquired in the future with the intention to further develop transit storage of oil for the international market.

Increasing oil traffic
At any time, with the exception of small craft, there are approx. 2,000 vessels en-route in the Baltic Sea.[51] A large proportion of large vessels that sail on the Baltic Sea are oil/oil product tankers. In 1997, 144 million tons of crude oil and oil products were handled by Baltic Sea ports, and a further increase is expected.[52] In this year alone, a total of 13,000 to 14,000 port calls in the Baltic Sea were made by oil tankers. The Baltic States – Latvia (20%), Lithuania (2-3%) and Estonia (8%), accounted for approx. one third of the total amount of oil handled in the Baltic.[53] Due to their geographical locations, the Baltic States serve as transit countries. The transport activities, including handling and storing, of oil/oil products make up a large share of the transport activities in the Baltic States. Oil traffic accounts for the following percentages of all goods transported/handled in ports: Estonia (50%), Latvia (50%) and Lithuania (15%). In recent years, the number of ship calls and the amount of oil handled/stored in these ports have increased. A similar trend is expected in the future.

The Russian oil export by tanker from the St. Petersburg region through the Baltic Sea is planned to increase by 30-40 million tons per year.[54]

Goods transport in Sweden is expected to increase by a total of 23 per cent during the period 1997–2010, measured in tonne kilometres.[55] This means that growth is expected to continue at approximately the same rate as during the last twenty-year period. Goods transport, including oil/oil products, by shipping in Sweden is expected to increase by 13 per cent during the period 1997–2010.

These trends will lead to an increase in oil traffic in the Öresund waters in the future.

Summing up
More than 10 million tons of oil and oil products probably pass through Öresund each year as cargo in about 1,500 different shipments with an average quantity per shipment of about 6-7,000 tons. This means that on average every day of the year there is a risk of a big oil spill occurring 3-5 times a day. To this should be added the risk of bunker oil spills. Those oil spills are lower in quantity but higher in frequency.

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50 Annual Report 1998: Port of Malmö.
51 Baltic Sea Environment Proceedings No. 64 B Third Periodic Assessment of the state of the Marine Environment of the Baltic Sea, 1989-93
52 Oil Handling in the Baltic Sea Area, 1996-2001, HELSINKI COMMISSION, 1998
53 2nd Baltic State of the Environment Report. 1999
54 Jörgensen, Carsten (1998) Environmental Study for the Baltic Sea. COWI. Denmark.
55 Follow up of the Swedish Transport Policy Objectives (2000). Institute for Transport and Communication Analysis. May 2000.

3.6 TRAFFIC OF OTHER TYPES OF DANGEROUS GOODS THAN OIL IN ÖRESUND

The traffic of packaged dangerous goods (PDG) interferes with the traffic of oil/oil products, posing additional risks to people, their property and the environment .

A collection of data on the traffic of packaged dangerous goods (PDG) has been made for the Baltic Area.[56] The Baltic Sea has been divided into 13 areas and the Öresund area was assigned number 4. Data covered all ports in the area during a period of two months – October and November 1990. Estimations have been made for the entire year. The following section presents the traffic of PDG through the Öresund area in one year.

- Quantity - 259,296 tons per annum. An average of 710 tons were en-route each day.
- Numbers of shipments - 26,574 shipments per annum. An average of 73 shipments were en-route each day.
- Average shipment - 9.8 tons.
- Classes – all classes are represented (classes 1 to 9), including marine pollutants.
- Types of packaging and cargo transport units - such as bags, barrels, drums, cans, cases, boxes, packages, cylinders, and tanks. Any of these packages might have been packed in containers or other units, except tank containers.
- Types of ships – PDG are carried by different types of ships including dry cargo, ro-ro, container, bulk carrier, and other types of ships.

Table 3.7 shows examples of shipments of packaged dangerous goods carried monthly (1990) in Öresund.

56 The Baltic Marine Environment Protection Commission, 1993: Study of the Transport of Packaged Dangerous Goods by Sea in the Baltic Sea Area and Related Environmental Hazards.

Class	UN Number	Name	Number of shipments per month	Quantity Tons per month
8	1789	Hydrochloric acid	50	1,200
3	1263	Paint	150	1,100
6	1935	Cyanide solution*	15	600
6	2312	Phenol, molten	15	600
8	1830	Sulphuric acid	25	600
3	1993	Flammable liquid	60	500
All	All	All packaged dangerous goods	2,200	21,600

Table 3.7: Examples of shipments of dangerous goods during an average month in Öresund in 1990.

*Cyanide solution
- Class 6.1 – poison (toxic)
- Marine pollutant - P
- Packaging group - I/II/III
- Subsidiary risk – non

Summing up
Besides the 10 million tons of oil, large amounts and shipments of other dangerous goods are passing through Öresund each year.

3.7 RISKS POSED BY DANGEROUS GOODS IN ÖRESUND

No major oil spill has been experienced in Öresund so far. However, it should not be considered improbable. The area is not only exposed to hazards from accidental/incidental oil spills. Furthermore, accidental oil spill events alone may not be liable for marine environment damages. The area is also exposed in other respects, hazards and types of dangerous cargoes. The following risk receptors are exposed to risks:
- Human safety and health risks, including individual and societal risks. A large number of people beyond the ship may be affected by the following hazards: fire, explosion and toxic fumes/gases.
- Risks to property, including infrastructure, properties, and bridge structure.
- Environmental risks, including chemicals and packaged dangerous goods.

In addition to the hazards caused by oil, both the population and the marine environment of the Öresund area are also exposed to chemicals carried in bulk and packaged dangerous goods. The latter present safety and health hazards, such as explosion, fire and toxic hazards.

Collision scenarios
Collision events are among the most frequent events in the Öresund area. The new navigation channel, expected to have a width of 370 m and a minimum depth of 8.5 m, may lead to an increase in the traffic of larger ships. Although Öresund water depths do not allow the passage of large tankers fully loaded, it is advisable to take certain pessimistic scenarios into consideration. Collision scenarios followed by these subsequent events may be expected:

- ships may be embedded in each other
- ships may subsequently sink
- under conditions of strong winds/currents ships may drift towards the shore while part of the cargo is lost at sea; there is a probability they may drift towards populated areas
- ships may be set afire and subsequently explode.

Collisions between fully or partly loaded tankers, including other ships carrying flammable liquid/gases and ferries, which may result in heavy casualties may happen in the Baltic Sea and Swedish waters. They may also be considered likely to occur in the Öresund waters. These waters are characterised by heavy ferry and other ship traffic.

Environmental risks
According to the Swedish Environment Protection Agency (EPA)[57], fish and seals are among the species that have suffered in the Baltic (i.e. in Swedish waters as well). There is evidence that the number of young seals with intestinal ulcers has increased. This could have been caused by unknown pollutants in their food chain affecting the immune system.

The marine environment of Öresund is very sensitive. Commodities other than oil/oil products which are carried in packaged form in "small" amounts but in large numbers represent considerable hazards that may pose risks beyond ships to human health, property, and the environment. How could the marine environment be affected by dangerous substances and materials, in particular by PDG?

The "value" of the site. Every site is valuable, because pollution is transported through the media of air and water and on land. However, this site is very sensitive. Pollution may have immediate and direct impacts on the environment and the local community.

The area affected. The area affected by substances and materials carried in packaged form may be larger than those affected by oil/oil products and other chemicals carried in bulk. This could be measured in terms of the area (e.g. coastlines or water surface measured in km, meter, or km/metre/mile square) affected per unit (ton, litre or kg) spilt. Case histories in other parts of the world have shown that marine pollutants lost at sea have not been confined to the immediate area of the release. Any release from packages with dangerous goods lost at sea in the vicinity of the area may affect the marine environment of Öresund.

Duration of the damage. Given the threats they pose to the marine environment, a number of substances and materials carried in packaged form are liable to cause long-lasting damages. Risks will be greater if PDG are lost at sea, as they may cause permanent damage to the ecosystem of the area. Toxic substances may accumulate and concentrate in biota, low and top level predators, for instance, fishes. Fish stocks are economically valuable for the people living in the region.

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[57] *Facts about Sweden's marine environment* (2001) Swedish EPA. 2001-03-05.

Local conditions
Exposure to risks of dangerous goods in Öresund is very much dependent on the local conditions of the area, such as waters, winds, visibility, the bottom of the sea, coastal line characteristics, and temperature. Causes, courses of events, frequency and consequences of accidents/incidents, among others, are affected by these conditions. The conditions in Öresund are as such that they may be favourable or unfavourable, depending on the circumstances. The judgement whether local conditions are favourable or not has to be based on a comparison with the local conditions of other areas.

If we know the effects of these conditions, we can take measures to prevent or reduce marine events or mitigate their consequences. How could the local environment affect causes, courses of events and their subsequent consequences? The following are some examples:

- spills may drift toward the Swedish coastline
- spills that have occurred in other areas may also affect Öresund's marine environment
- toxic fumes from ships with dangerous goods on fire may affect the local population.

With respect to the water contents, a few years ago the Swedish Environment Protection Board showed examples of bio-accumulation of some substances in organisms in the Baltic Sea. Such accumulation would make it difficult to assess the degree of contamination effects of substances and materials released at sea, including the Öresund waters.

Risks at ports
The following scenarios illustrate how dangerous substances and materials may present risks at ports in Öresund.

- Ships loaded with different classes and large amounts of dangerous goods may catch fire. The types and amounts of dangerous goods may not even be listed in the manifest. Heavy smoke and toxic fumes from a ship on fire may drift towards populated areas, exposing local residents. Individual packages or even the entire ship may explode.
- Water mixed with some environmentally hazardous substances and materials inside the ship's holds may cause environmental pollution.
- Packages, for instance tank containers, with toxic substances which could have been damaged prior to or during discharging, may be stored in the port area. Damages might have gone unnoticed and toxic gases/fumes may escape from the packages, exposing a large number of people ashore.

Summing up
There are many different kinds of risks connected to the transport of dangerous goods in Öresund. Since the focus of this study is on oil spills, we would like to stress the risk of accidents between two movable objects. This could of course increase the total quantity of oiled spilled, but there could also be severe effects resulting from combinations of dangerous goods. If, for instance, the two objects are an oil tanker and a tanker with a flammable liquid, the consequences could be much worse than if it had been two oil tankers.

Given the conditions of the area, such as shallow water depths, slow water exchange processes and a relatively low level of biological activities, the following consequences may be anticipated in case of spills of dangerous goods at sea: due to insufficient dispersion capability it may take time before the marine environment is fully recovered and marine lives of the area may be severely affected and some of them may even disappear.

3.8 CHARACTERISTICS OF ÖRESUND – A SUMMING UP

Öresund is one of the areas in the world with most ship movements. *More than 40,000* ships pass through the Sound every year in the direction north-south or vice versa. Other ships/ferries frequently cross the sound in the east-west directions. The ships carry goods, passengers and sometimes both, in huge volumes. Since Öresund is a quite narrow sound with a difficult navigation situation, many risks of different kinds are at hand. The Öresund area is also a densely populated area with many people living at the sound or quite near it. The consequences of an oil spill could therefore be severe to people, to the environment and to property. The consequences of a combined oil and other dangerous goods event could be even more serious.

4 OIL SPILL EVENTS IN ÖRESUND

4.1 A DETAILED RISK ANALYSIS MODEL

In Chapter 2 a basic risk analysis model was presented (Figure 2.1), which will now be developed into a more detailed risk analysis model suitable for analysing oil spill events in Öresund.

Based on their immediate causes, *oil spills* are divided into two main categories: a) “accidental/incidental” and b) “intentional or deliberate”, the latter being subdivided into "legal" and "illegal" spills. This study is primarily focused on the first category, i.e. "accidental/incidental" oil spills.

The categories of marine events that are directly responsible for (i.e. are the causes of) oil spills in Öresund are: grounding, collision, contact, machinery, fire/explosion, hull/ watertightness and foundering. Operational activities leading to oil spills are: loading, unloading, bunkering and others. Both types of events can be divided into the following main categories of *contributing factors*: human related, technical, weather/sea and others.

By looking at events, their causes and contributing factors we will map step by step (i.e. use the Fault Tree Analysis - FTA) what happened before the oil spill took place. But we will also look at what happened after the oil spill (i.e. use the Event Tree Analysis - ETA) to study the *consequences* of the oil spill. There could be negative consequences for human beings, for ecological systems and for property. This gives us a detailed risk analysis model, which is presented in Figure 4.1.

The rest of the chapter is mainly structured according to this model. The lines in the model indicate which parts of the model will be dealt with further on in this chapter.

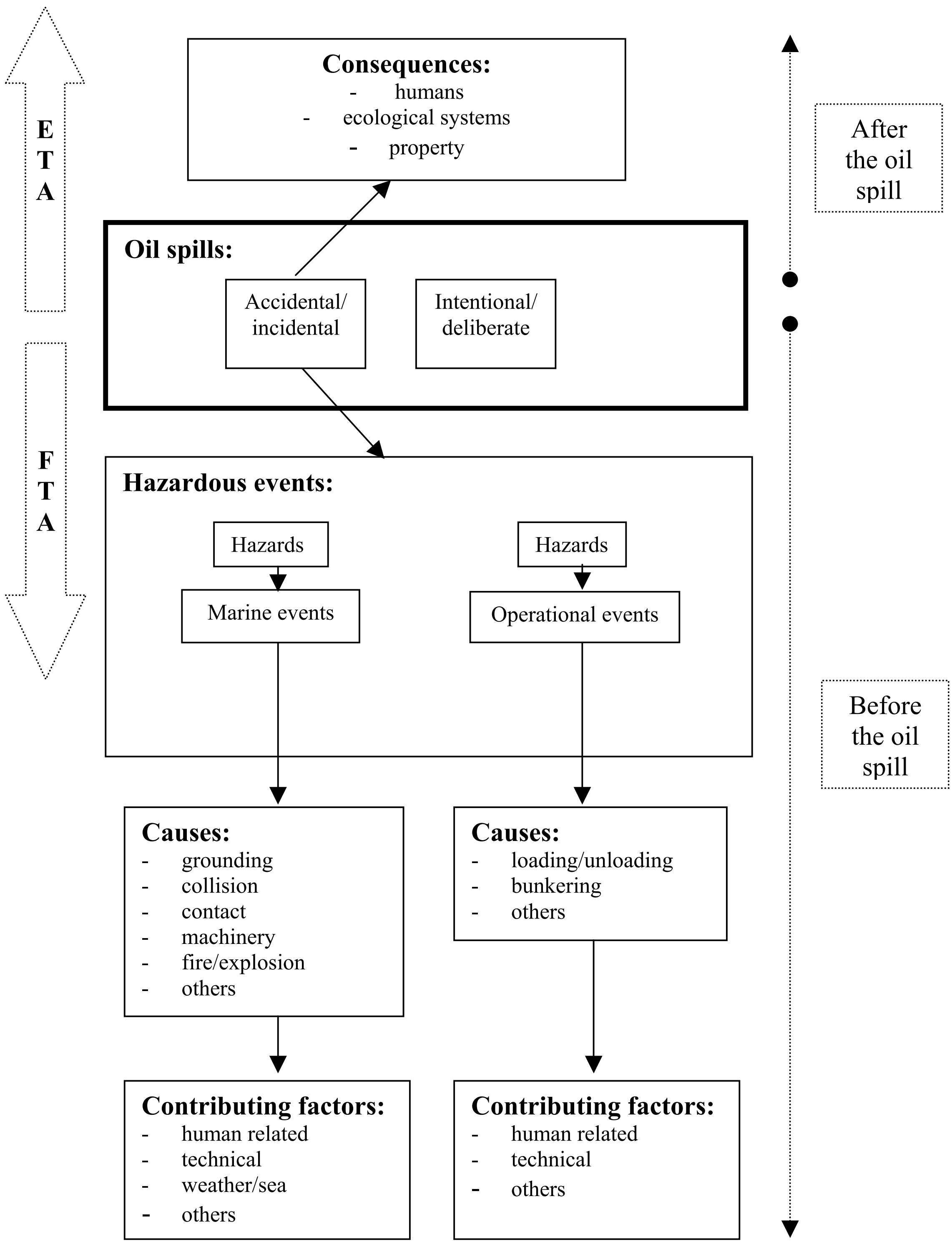

Figure 4.1: A detailed risk analysis model for the Öresund study.

4.2 THE 1991 RISK ASSESSMENT STUDY

The following are some of the key findings of the 1991 study.[58] 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 harbours have not been considered.

The oil spills were considered the main concern of the marine 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 4.1. shows oil spills reported to the Danish EPA (Mijöstyrelse - Environment Protection Agency) in 1990 and 1991. Oil spills in ports were not included. The table also shows the number of marine events (collisions and groundings) during the same period. Only one spill was due to marine events. The rest are not accidental oil spills i.e. not due to marine events.

	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 4.1: 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)

Table 4.2 shows that during the period 1973-1981 (9 years) 7 large ("major") oil spills occurred in Öresund. Four spills were accidental spills due to collisions and groundings. The "unknown" category (3 out of 7 spills) covered non-accidental spills most probably resulting from illegal discharges.

	Numbers	**Spill size (cbm)**
Collisions	2	200, 300
Grounding	2	40, 50
Unknown[59]	3	50,70, 200

Table 4.2: 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)

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.

58 COWIconsult 1992: Analys av risker för påsegling av bron. Doc.No. 22071-00, 1992

59 It was believed that oil spills falling in the "Unknown" category were illegal spills and not accidental.

By pooling data from two sources, the total number of collisions and groundings in Öresund during the period 1973-1981 and in 1990 and 1991 has been obtained, i.e. 50 collisions and 150 groundings respectively. Other types of events, such as fire/explosion, foundering and contacts were not considered. The probability of large oil spills for each category of event has been estimated by dividing the number of spills by the number of events for each category.

- Large oil spills per collision – 2/50 = 0.04 (i.e. 4% of the collisions led to major oil spills)
- Large oil spills per grounding – 2/150 = 0.013
- Large oil spills per collision and grounding – 4/200 = 0.02

The following sizes of oil spills from oil tankers were anticipated for the Öresund.

- In Flinträнnan large oil spills are anticipated up 500 tons, and up to 2,000 tons for the largest tankers.
- In Drogden large oil spills, twice as large as in Flintrännan i.e. 1,000 up to 4,000 tons, are anticipated.

The worst cases of oil spills were anticipated: 19,000 tons in Flintrännan and 50,000 tons in Drogden (Table 1.1).

4.3 ANALYSIS BASED ON RECENT STATISTICS

4.3.1 Some comments on databases and definitions

The following are the key findings and analysis of data sets obtained from the Swedish Maritime Administration (SMA) database. The data sets covered all types of marine events that occurred in the Öresund during the period 1985-1999, including all types of marine events that have, or are likely to have, led to oil spills. Other categories of events that had no bearing on oil spills, e.g. “decease/sickness/heart attacks” or “man overboard,” are excluded.

The data sets included only marine events recorded by the Swedish Maritime Administration (SMA). The SMA recorded a) events in the Swedish waters of Öresund, regardless of the ship’s flag, and b) events in Danish waters with ships flying the Swedish flag.

The total number of records in the SMA database was 370. They are kept on the number- of-ships- involved basis, which means that events such as collisions are recorded more than once depending on the number of ships involved. Excluding events such as “man overboard” the total number of marine events recorded by the SMA during 1985-1999 was 317. Of these, *239 events* occurred within the limits of the Öresund area as defined in this report, and 78 events were recorded outside this area. However, given similar conditions of event occurrences and potential threats of oil spills resulting from events occurring in the vicinity of Öresund, the latter events are incorporated for certain purposes of analysis, such as hazards identification.

Findings from empirical data available are discussed and presented in the following order: *oil spills* – described in terms of number, frequency, size and consequences, *hazardous events* which led to oil spills and *causes* and *contributing factors* of oil spills.

"Hazard" is defined as a situation, for instance a marine accident, which can cause or is likely to cause fatalities/injuries and/or damage.[60] Hazards may be regarded as being continuously present.[61]

The process of the hazards identification mainly consists of a qualitative review of possible events leading to release/involvement of dangerous substances or materials.[62] The hazards identification is based on the case histories of accidents and judgement.

By virtue of their hazards, such as fire, explosion, suffocation and toxic hazards, dangerous cargoes such as oil and oil products, chemicals and other dangerous goods are liable to cause harm to humans and to the marine environment and damage to property. Realisation of hazards should be necessary for dangerous cargo to cause harm. Many dangerous substances and materials may realise their hazards when released from their containment, e.g. spaces such as cargo holds and tanks or packages/units.

4.3.2 Oil spills

4.3.2.1 Intentional/deliberate spills

Intentional/deliberate spills are subdivided into legal (see MARPOL – Special area – Baltic Sea) and illegal. Illegal discharges of oil have been experienced in Öresund, but the present data available from the area (SMA 1985-1999 and Drogden VTS 1998) has not shown any. Such discharges may include, for example, cleaning of tanks or decks and discharge of oil-contaminated ballast waters.

An early study[63] has shown that 3 out of 7 of all major oil spills in Öresund reported to the Danish EPA during the period 1973-1981 belonged to the category of "unknown". Approximately one third - 320 out of 910 cubic metres - of the oil spilt under this period was classified in this category. This category covered non-accidental spills, presumably illegal spills. In recent years the number of illegal discharges may have been reduced, but they still remain a matter of concern. In 1999, large oil slicks were found on the shoreline between Malmö and Lomma. An illegal discharge from a passing ship was suspected.

4.3.2.2 Accidental/incidental spills

Accidental/incidental spills accounted for a considerable portion of oil spills in Öresund. They were attributed to: a) marine events – marine accidents/incidents (as defined by IMO) and b) operational activities. The latter category included oil spills resulting during operations such as loading/unloading of oil and bunkering. The present data sets provided by the SMA and VTS Drogden have not shown any oil spill of this category. However, according to the 1991 study, operational oil spills have occurred in the area. Thus, 1 out of 8 oil spills reported in

[60] HSE 1991: Major Aspects of Transport of Dangerous Substances, Advisory Committee on Dangerous Substances, Health and Safety Commission, HMSO 1991.
[61] Marshall V.C. 1987: Major Chemical Hazards, Ellis Horwood Limited, 1987.
[62] Report of a Royal Society Group Study Group 1992. Risk: Analysis, Perception and Management. Royal Society. 1992
[63] COWIconsult 1992: Analys av risker för påsegling av bron. Doc.No. 22071-00, 1992

Danish waters during the period 1979-1988[64] occurred while a ship was bunkering. The spill size was relatively large – 170 cubic metres or approx. 11% (or 170/1540) of the amount of the oil spilt under the period. This category of oil spills is dealt with more in detail in paragraph 4.3.8 of this report.

4.3.2.3 Analysis of 239 marine events

This section of the report is mainly confined to the analysis of accidental oil spills resulting from marine events. The main categories of marine events are identified and each of them is subjected to a detailed analysis. They have caused, or had the potential to cause, oil spills. Causes and contributing factors as well as courses of events are identified. Although they may vary in different areas and for different types of ships, causes and contributing factors were mostly identified on the basis of local data. However, some worldwide experiences have also been presented. The main categories of factors contributing to marine events were: human (ship personnel related factors), technical (man-made – in and outside ships), environmental (physical environment - marine environment i.e. weather/sea hazards) and other factors, including vessel traffic.

The categories overlap and their relations are very complex. Often, there has been a host of factors that have contributed simultaneously to an accident. It is very difficult, if not impossible, to codify and quantify some factors, in particular human related factors, since the human factor is very complex.

Categories of events. Table 4.3 and Figure 4.2 show the categories and frequencies of initial marine events. The following 8 categories of marine events are identified in Öresund: grounding, collision, contact, machinery, fire/explosion, hull/watertightness, listing/capsizing and the “others” category. The “other” category included events such as problems related to the ship structure (e.g. ramps, suspended deck), cargo shifting (e.g. trailers turned over onboard the ship), cargo losses overboard, ship’s cranes falling on the deck, ship’s anchor falling and damaging cables.

Marine events categories	Frequency	Percent	Valid Percent	Cumulative Percent
1. Grounding	104	43,5	43,5	43,5
2. Collision	37	15,5	15,5	59,0
3. Contact	35	14,6	14,6	73,6
4. Machinery	45	18,8	18,8	92,5
5. Fire/explosion	6	2,5	2,5	95,0
6. Hull/watertightness	3	1,3	1,3	96,2
7. Listing/capsizing	3	1,3	1,3	97,5
8. Others	6	2,5	2,5	100,0
Total	**239**	**100,0**	**100,0**	

Table 4.3: Categories and frequencies of marine events in Öresund 1985-1999.

[64] VBB VIAK COWIconsult 1992. Analysis av risker för pasegling av bron. 1992.

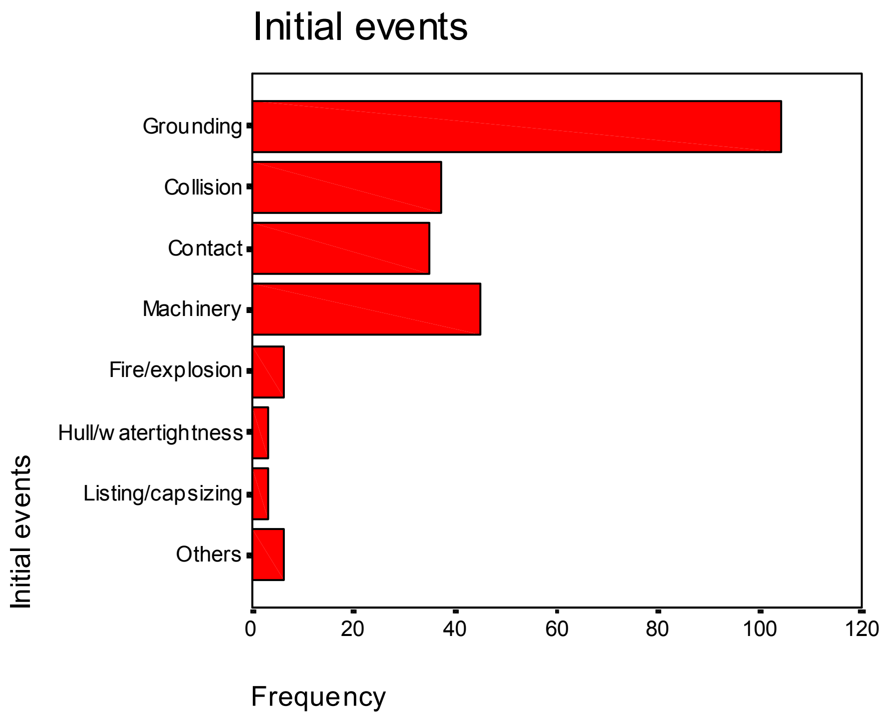

Figure 4.2: Categories and frequencies of marine events in Öresund during 1985-1999.

Frequency of events. Only four categories, namely grounding, collision, contact and machinery events, accounted for approx. 93% of all events. 59% of the events were grounding and collision, with grounding the dominant event (43.5%). The least frequent events were hull/watertightness and listing/capsizing. The frequencies of events were: grounding (104, or 43.5%), collision (37, or 15.5%), contact (35, or 14.6%), machinery (45, or 18.8%), fire/explosion (6, or 2.5%), hull/watertightness (3, or 1.3%), listing/capsizing (3, or 1.3%) and the “others” category (6, or 2.5%).

Distribution – years and months. Figure 4.3 presents the number and categories of marine events reported each year in Öresund during the period 1985-1999.

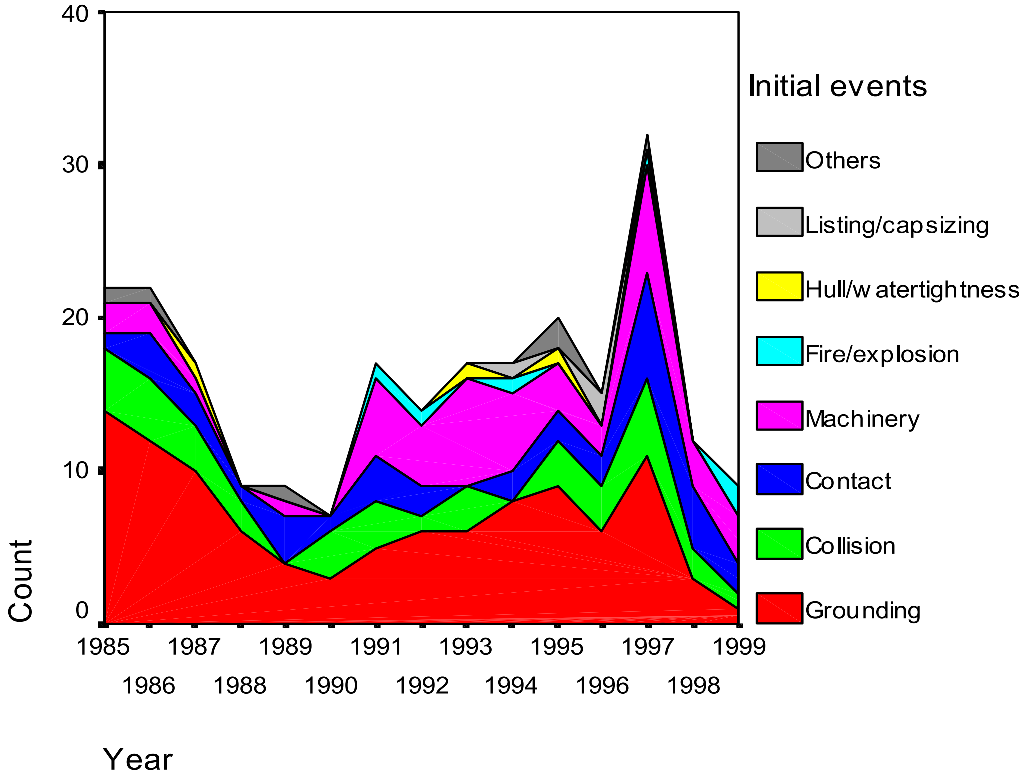

Figure 4.3: Number of events during the period 1985 – 1999

Year. During 1985, 22 events were reported to have occurred in Öresund. This number declined to 7 events in 1990. From 1990 until 1997 the number of marine events increased. In 1997 it reached a record level of 32 events, which is a 4.5- fold increase compared to 1990. This was attributed to the increase in the number of machinery failures, contacts and groundings. The number of machinery failures increased from 0 in 1990 to 7 events in 1997, as one or two ferry vessels operating in the regular traffic between Sweden and Denmark have repeatedly experienced machinery problems ("black sheep" ships). This increase may also be attributed to the construction of the Öresund Fixed Link.

In 1998 and 1999 the number of marine events in Öresund declined. Most categories of events have shown a decrease, in particular grounding events. The frequency of groundings declined from 11 in 1997 to 1 event in 1999. Grounding was the largest contributing factor (43.5% or 104/239) to marine events in Öresund.

Month. The frequency of events was slightly higher for the period February-March-April-May. 39.3% of the events occurred during this period, which is 6% above the average number for other periods. This was mainly attributed to grounding and contact events. In March the number of groundings was twice the monthly average.

Day of the week. Thursday has shown a slightly higher frequency compared to the other days of the week, accounting for 19.2% of the total or 4% above the average. The east/westbound traffic accounted for 47.8% (or 12% more than expected) of the number of events that occurred on Thursday. Approximately one fourth (25.9% or 22/85) of events involving ships in east/westbound traffic occurred on this day. Higher frequencies for the following days were observed:

- Grounding – Monday, Wednesday, and Thursday.
- Collision – Thursday, Friday.
- Contact – Thursday, Friday.
- Machinery – Monday, Thursday.

Initial and subsequent events. Crosstable 4.4 shows initial and subsequent events in Öresund (1985-1999). A marine event may consist of a chain of events, i.e. an "initial event" may be followed by one or more "subsequent events." Most of the marine events reported in Öresund were not followed by any subsequent event but were reported as "final" events. Some events in the categories of machinery, hull/watertightness and listing/capsizing were followed by only one subsequent event (i.e. a total of two). Approximately 76% (or 34 out of 45 cases) of machinery events (i.e. ships having machinery problems) ended up as either contacts (71% or 24/34) or groundings (29% or 10/34). In one case, a ship was reported to have foundered after listing and capsizing, while in another case a ship experienced leakage, as her hull breached due to corrosion, and subsequently listed and collided with another ship.

Table 4.4 shows the categories and frequencies of the "final" events (subsequent events). The frequencies of grounding and contact events have changed. Approximately 9% (or 10/114) of groundings and 41% (24/59) of contacts ("final" events) are attributed to machinery problems.

	Initial events	**Subsequent events**									**Total**
		Grounding	**Collision**	**Contact**	**Machinery**	**Fire/explosion**	**Hull/watertight**	**Listing/ capsizing**	**Others**	**Foundering**	
1	Grounding	104									**104**
2	Collision		37								**37**
3	Contact			35							**35**
4	Machinery	10		24	11						**45**
5	Fire/explosion					6					**6**
6	Hull/watertightness		1				2				**3**
7	Listing/capsizing							2		1	**3**
8	Others								6		**6**
	Total	**114**	**38**	**59**	**11**	**6**	**2**	**2**	**6**	**1**	**239**

Table 4.4: Initial and subsequent marine events in Öresund (1985-1999)

Vessel traffic and marine events. The vessel traffic in Öresund is divided into three categories, namely: a) east/westbound – mostly the regular ferry traffic between Sweden and Denmark; b) north/southbound to Öresund's ports – ships calling at ports within the Öresund area and bound either north or south; c) north/southbound through traffic – ships passing through Öresund. From 1971to1999, the last two categories of traffic (b and c) have been recorded (if over 50 brt) by the Danish Maritime Administration (Figure 3.3).

Crosstable 4.5 shows the frequency distribution of marine events (initial events) for each respective category of the vessel traffic in Öresund (1985-1999). Table 4.6 shows the contribution of each category of traffic to the total number of marine events (also illustrated in Figure 4.4) and to the total number of oil spills.

	Initial events	**Vessel traffic in Öresund**						**Total**
		(a) East/West bound		(b) Öresund port - N/S bound		(c) Through traffic - N/S bound		
		No.	**%**	**No.**	**%**	**No.**	**%**	
1	Grounding	12	14.1	59	55.7	33	68.7	**104**
2	Collision	17	20.0	11	10.4	9	18.7	**37**
3	Contact	22	25.9	12	11.3	1	2.1	**35**
4	Machinery	25	29.4	18	17.0	2	4.2	**45**
5	Fire/explosion	4	4.7	2	1.9	0	0	**6**
6	Hull/watertightness	2	2.4	1	0.9	0	0	**3**
7	Listing/capsizing	0	0.0	2	1.9	1	2.1	**3**
8	Others	3	3.5	1	0.9	2	4.2	**6**
	Total	**85**	**100**	**106**	**100**	**48**	**100**	**239**

Table 4.5: Categories of vessel traffic and marine events in Öresund (1985-1999)

	Vessel traffic	**Marine events**		**Oil spills**			**Numbers of ships estimated/recorded in 1998**
		No.	%	No.	%	s/e*	
(a)	East/West bound	85	35.6	4	11.4	0.047	**97000**[65]
(b)	Öresund port - N/S bound	106	44.4	20	57.2	0.189	**40704 (39909)**[66]
(c)	Through traffic - N/S bound	48	20.0	11	31.4	0.221	
	Total	**239**	**100**	**35**	**100.0**		

*Table 4.6: Marine events, oil spills and vessel traffic in Öresund (1985-1999). * Note: s/e is the ratio between the number of oil spills and the number of events for each category of vessel traffic.*

65 Estimated - see Everth Larsson 1998: SUNDRISK. Maritime Risker i Öresundområdet. Lunds Universitet 1998.

66 In 1998 Helsingör recorded 40,704 ships and Drogden recorded 39,909 ships. Sources: Danish Maritime Administration 2000.

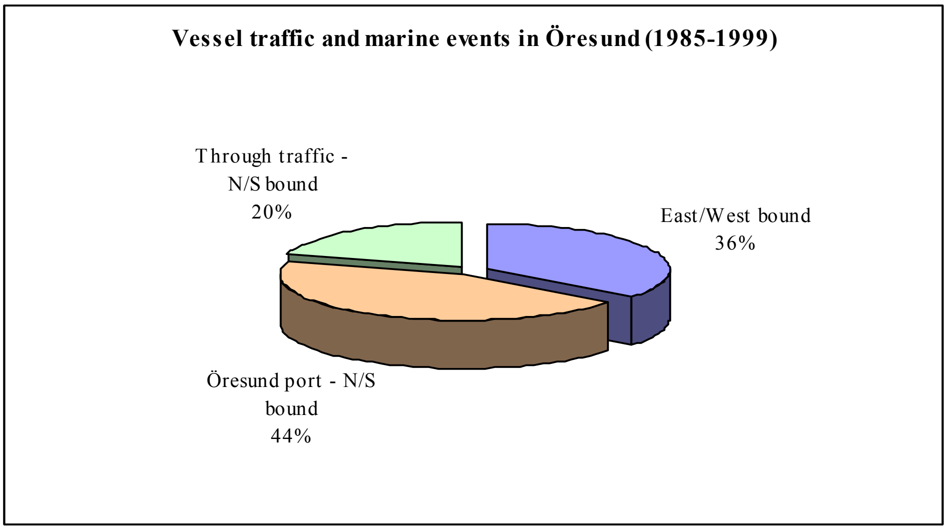

Figure 4.4 Vessel traffic and marine events in Öresund 1985-1999.

The following observations derive on the basis of the data presented above:

- Marine events involving ships of the categories (b) and (c) have shown higher frequencies than expected, i.e. proportional to the vessel traffic. They accounted for approx. 2/3 of all marine events in Öresund. By definition, the "expected" number is the number of cases that would be expected in the cell if the row and column variables were statistically independent or unrelated to one another. The total number of ships for all three categories of vessel traffic together is estimated at approximately 137,000 - or 71% or 97,000 ships for category (a) and 29% or 40,000 ships for categories (b) and (c) together. The "expected" frequencies of marine events involving ships of category (a) and categories (b and c) would have been 71% and 29% respectively, if "vessel traffic" and "marine events" variables were not related. Instead, the actual frequency of marine events involving ships of categories (b and c) is 64%. This is twice as much as the expected value (i.e. 29%).
- 88.4% (or 92 out of 104 records) of groundings involved ships of categories (b) and (c), and such events were over represented in these categories– 55.7% and 68.7% respectively.
- Among the dominant events in category (a) are machinery (29.4%), contact (25.9%) and collision (20%) events, where 64.4% of all the "machinery" events involved ships in category (a).

To a certain extent, the pattern of the frequency of marine events matched the pattern of changes in vessel traffic in Öresund. The vessel traffic may have influenced the frequency of marine events with the same sign, i.e. as the vessel traffic in Öresund increased, so did the number of marine events. However, the match is far from perfect. Between 1998 and 1999 the frequency of events reported has shown a decrease, despite the fact that the north/southbound vessel traffic in Öresund during this period increased. According to some other studies,[67] a similar tendency has been observed in other areas.

[67] Oil Spill studies by: International Tanker Owner Pollution Federation (ITOPF), United States Coast Guard (USCG), and Intertanko.

Due to the decrease in vessel traffic of category (a), a reduction in the number of marine events could be expected in Öresund. However, such a decrease could be compensated, if not outweighed, by the increase in two other categories of traffic (i.e. b and c).

4.3.2.4 A summing up of the 239 marine events

8 categories of marine events are identified in Öresund. Four of these categories alone, namely grounding, collision, contact and machinery events, accounted for approx. 93% of all marine events in Öresund. Grounding was the largest contributor (43.5% or 104/239), and the least frequent events were hull/watertightness and listing/ capsizing. During the period 1998-1999 the number of marine events in Öresund declined, in particular grounding events.

Marine events involving ships of categories (b) and (c) scored higher frequencies than expected (i.e. proportional to the vessel traffic). These categories contributed to approx. 2/3 of all marine events. Category (b) is: north/southbound traffic to Öresund's ports, i.e. ships calling at ports within the Öresund area and bound either north or south, and category (c) is north/southbound through traffic, i.e. ships passing through Öresund.

Most of the marine events in Öresund were reported as "final" events. However, some events, namely machinery, hull/watertightness and listing/capsizing, were followed by only one subsequent event (a total of two). The majority (approx. 76%) of machinery events ended up as either contacts or grounding.

4.3.3 Marine oil spills by different variables

Oil spills that occurred in Öresund during the period 1985-1999 are measured against the following categories of variables: year, size (i.e. the volume of oil spilt), types of ship, ship's hull materials, ship's age, ship's size, vessel traffic categories, and location. The number of oil spills in Öresund due to marine events is not very large, and consequently any inference should be treated with caution.

4.3.3.1 Oil spills by number

A total number of 41 oil spills events were recorded (only by SMA) during the period 1985-1999. Of these, 35 oil spill events are recorded within the Öresund area as previously defined. In one event, which was a collision event, both ships involved released oil after sustaining damage to the hull. A total of 36 oil spills is recorded in 35 events. Oil spill events account for 14.6% of all marine events (239 in all) that occurred in Öresund (1985-1999). This means that every seventh marine event led to an oil spill event where the oil was released from at least one of the ships involved.

The actual number of oil spills is larger, because this analysis does not include oil spills that occurred in the Danish waters of Öresund in which other ships than Swedish- flagged ships were involved. In addition, because of lack of information it was often uncertain (in19.7% or 47/239 of the cases) whether an oil spill had occurred after a marine event, in particular after a grounding. 53% (25 out of 47) of all unreported cases were groundings. It is unlikely for the "large" spills not to have been reported. "Minor" oil leaks cannot be ruled out, however. There were 157 cases where no oil spill was reported.

4.3.3.2 Oil spills by year

Figure 4.5 shows the frequency of oil spills due to marine events (1985-1999). Every seventh marine event (14.6% or 35/239) that occurred in Öresund was associated with an oil spill. On average approx. 2.3 oil spills were reported each year during the period 1985-1999 (15 years). Of these, one was a "large" spill. In recent years the number of oil spills has declined from 6 in 1995 to 0 in 1998 and 1999, despite the fact that the number of marine events has remained relatively high. This means that an increase in the number of marine events may not be correspondingly associated with an increase in the number of oil spills in the area.

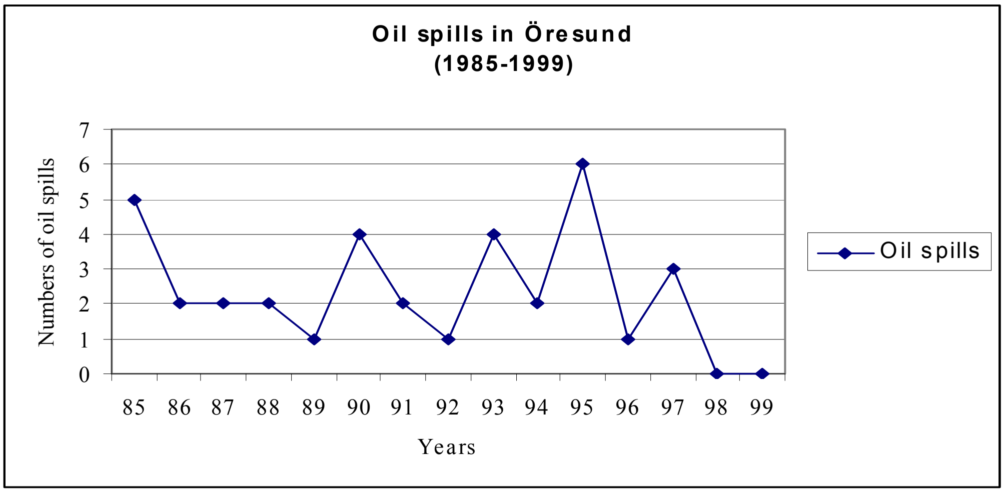

Figure 4.5: Number of oil spills in Öresund 1985-1999

4.3.3.3 Oil spills by size (volume)

Table 4.7 shows oil spills by size. The size of oil spills was usually unknown. They were often reported as "minor" (23 records) or "large" (12 records) spills. The size was quantified in four cases only. The largest spill recorded was 200 metric tonnes.

No.	Initial events	Spill sizes?		Total
		Minor	Large	
1	Grounding	16	5	**21**
2	Collision	2	3	**5**
3	Contact	2	3	**5**
4	Machinery	1	0	**1**
5	Hull/watertightness	2	0	**2**
6	Listing/capsizing	0	1	**1**
	Total	**23**	**12**	**35**

Table 4.7: Oil spills by size

Collisions and contacts were more likely to cause larger spills than groundings. Half of the large spills were due to collisions and contacts. This is explained by a) the position and extent of damage to the ship's hull and b) the number of ships involved. For example, in a collision in fog between two or more ships sailing at high speed, the impact force exerted is such that it can cause extensive damage to one or several cargo compartments in one or more of the ships involved.

4.3.3.4 Oil spills by type of ship

Figure 4.6 presents the categories of types of ships involved in marine events in Öresund (1985-1999). The total number of ships involved was 277 ships in 239 events, on average 1.16 ships per event. This was due to collision events. One collision event involved 3 ships.

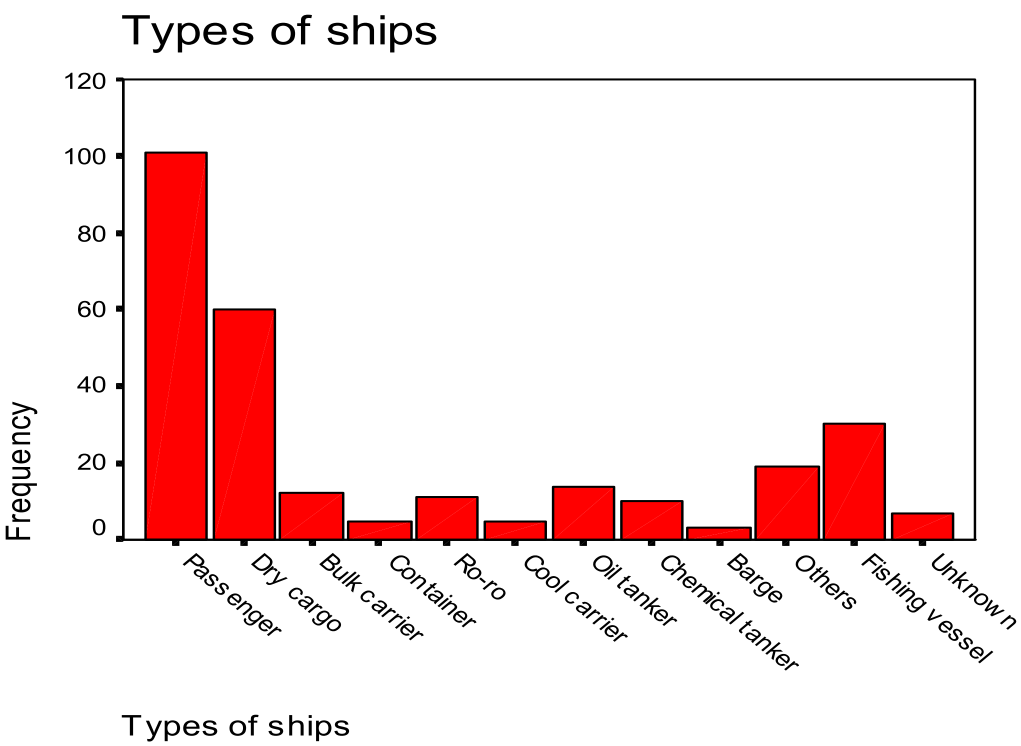

Figure 4.6: The frequencies of types of ships involved in marine events in Öresund (1985-1999)

Table 4.8 shows the oil spills ("large"/"minor") by ship types and the ratios between the number of spills and the number of ships per each type of ship. Approximately 13% of the ships (or approx. every eighth ship) involved spilt oil, including bunker oil, into the sea. The ship types that showed a higher frequency of oil spills were: cool carriers (0.6), chemical tankers (0.462), oil tankers (0.357), ro-ro ships (0.272) and container ships (0.2). They were mostly involved in the following categories of events: grounding (59.5% or 25/42), collision (16.7% or 7/42) and contact (14.3% or 6/42).

No.	**Types of ships**	**Spill size**				**Ships**		**Spills/ ships**
		Minor	Large	Total				
		No.	No.	No. of spills per ship type	As % of the total spills	Total no. of ships involved	As % of the total number of ships	The ratio of spills/ ships
1	Passenger	5	2	7	20	101	36.4	**0.069**
2	Dry cargo	3	2	5	14.3	60	21.7	**0.083**
3	Bulk carrier	1	0	1	2.9	12	4.3	**0.083**
4	Container	1	0	1	2.9	5	1.8	**0.200**
5	Ro-ro	2	1	3	8.6	11	4.0	**0.272**
6	Cool carrier	0	3	3	8.6	5	1.8	**0.600**
7	Oil tanker	3	2	5	14.3	14	5.1	**0.357**
8	Chemical tanker	6	0	6	17.0	10	3.6	**0.462**
9	Barge	0	0	0	0.0	3	1.1	**0.000**
10	Others	2	0	2	5.7	19	6.9	**0.105**
11	Fishing vessel	0	2	2	5.7	30	10.8	**0.066**
12	Unknown	0	0	0	0.0	7	2.5	**0.000**
	Total	**23**	**12**	**35**	**100**	**277**	**100**	

Table 4.8: Oil spills by ship types (1985-1999)

Öresund is largely exposed to risks of bunker oil spills. For the purpose of the analysis, the ships are divided into non-tanker and tanker ships, including both oil and chemical tankers. To what extent has each respective category of ship contributed to oil spills? Figure 4.7 shows the number of oil spills released in Öresund (1985-1999) by type of ship. The following observations may be made:

- Non-tanker ships accounted for 91.3% of the total number of ships involved and were responsible for 68.7% of oil spill events. 10 out of the 12 "large" oil spills were caused by non-tanker ships. Passenger and dry cargo ships accounted for approximately one third (34.3%) of oil spill events, or 20% and 14.3% respectively. 37.5% of groundings involved dry cargo ships. Furthermore, approx. 2/3 (65%) of dry cargo ships ran aground. A large proportion of machinery events is related to passenger ships (60% or 27/45).

- Only 8.7% of the total number of ships were oil and chemical tanker ships - 5.1% and 3.6% respectively. Nevertheless this type of ship accounted for approx. 1/3 (31.3%) of all oil spill events, where oil and chemical tankers were responsible for 14.3% and 17.0% respectively. This was significantly higher (approx. three times) than the percentage of tanker ships involved (i.e. 8.7%). 9 of 11 oil spills involving tanker ships were "minor" spills. Tankers, however, are liable to cause larger oil spills, fires and explosions. They were frequently involved in grounding and collision events - 66.7% (or 16/24) and 21% (or 5/24) respectively. Approximately every ninth collision in Öresund involved one tanker ship.

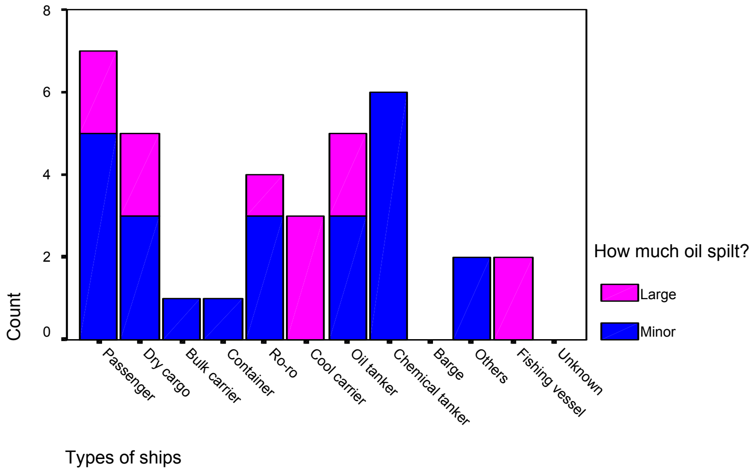

Figure 4.7: Oil spills by type of ship

4.3.3.5 Oil spills by ship's hull material

Figure 4.8 shows the categories and frequencies of the hull materials of ships involved in 239 marine events in Öresund. There are four categories of ship's hull materials, namely steel (85%), aluminium and other light materials (8%), wood (5%) and glass/fibre (2%). In a number of cases the hull material was not reported. The types of ships built with other materials than steel were:

- Aluminium and other light materials: passenger ships (16/19) and "other" ships (3/19).
- Wood: pleasure boats and small passenger ships (5/13), fishing vessels (7/13) and "other" ships (1/13).
- Fibreglass/plastic materials: pleasure boats (2/5) and fishing vessels (3/5).

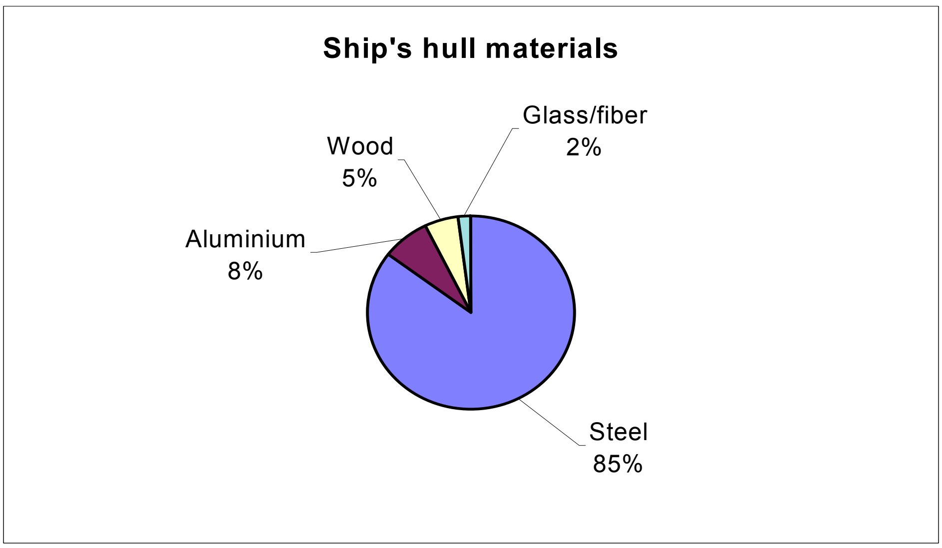

Figure 4.8: Ship's hull material

How did the ship's hull material affect oil spills? Table 4.9 shows that there is no significant difference between steel and non-steel materials. The probability of oil spills for ships with a steel and non-steel hull is 0.179 and 0.176 respectively.

No.	Oil spills	Hull material				Total
		Steel	Aluminium	Wood	Fibreglass	
1	Minor	20	3		1	**24**
2	Large	10		2		**12**
3	No leakage	138	16	10	2	**166**
	Total	168	19	12	3	**202**

Table 4.9: Oil spills by hull material

4.3.3.6 Oil spills by age of ship

Figure 4.9 shows the frequencies of age ranges of ships involved in marine events. The age of ships varied in range from "5 years or less" to "41 years or above." The youngest ships were less than one year old, and the oldest one was over 100 years old. In 36 cases the age was not reported. 22% of the ships involved were 5 years old or less, and 5% (14 out of 277) were above 41 years old. The average age was 19 years.

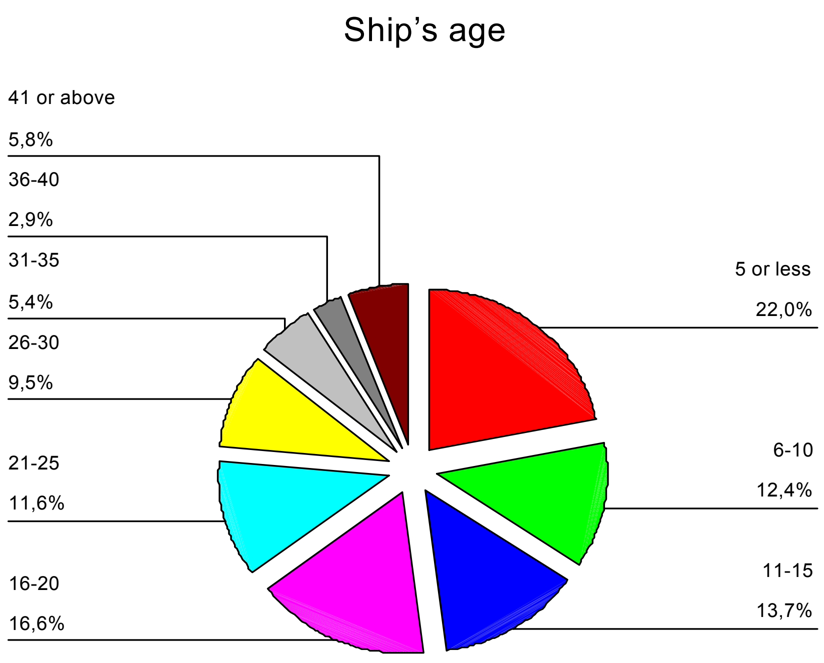

Figure 4.9: Ship's age.

- Passenger ships were younger than the other types of ships - 66% of the passenger ships were less than 15 years old. Half (7/14) of the ships that were 41 years old or more were small pleasure boasts.
- Most of the oil tanker ships (11 out of 14 tankers) were between 11 and 25 years old.
- 4 of 9 chemical tankers were only 5 years old or less.

Table 4.10 shows the age ranges of the ships, oil spills and the ratios between the number of spills and the number of ships involved in each age range respectively.

No.	Ship's age	Oil spills		Ships involved		The ratio spills/ number of ships
		Minor	Large	No.	%	
1	5 or less	5	2	53	22.0	0.132
2	6-10	2	1	30	12.4	0.100
3	11-15	6		33	13.7	0.182
4	16-20	5	2	40	16.6	0.175
5	21-25	2	2	28	11.6	0.143
6	26-30	1	1	23	9.5	0.087
7	31-35	2	2	13	5.4	0.308
8	36-40		1	7	2.9	0.143
9	41 or above	1	1	14	5.8	0.143
	Total	24	12	241	100.0	

Table 4.10: Oil spills by ship's age

In terms of contribution to the oil spill per ship involved, there are some differences among age ranges. The lowest value is observed for the range 26-30 years old and the highest for the range 31-35 years old. For the range 31-35 the ratio between the number of spills and ships was considerably higher compared to other ranges. More than half of the ships in this range (31-35 years old) were small dry cargo ships. The probability of being involved in a "large" oil spill was higher for ships 16 years old and above.

4.3.3.7 Oil spills by ship size (dead weight - dwt)

Figure 4.10 shows the frequencies of the different sizes (dwt) of ships involved in marine events. In 47% of the cases the ship size was unknown. The total number of valid cases was 169. A valid case is a case for which information on ship dwt was available, which excluded 12 of 35 oil spill events where this information was not available.

For the valid cases (169 cases), ship sizes varied between the range "499 dwt or less" to "10,000 dwt or above." Ships of smaller sizes (499 or less - 1499 dwt) have shown a higher frequency (22.4%) of involvement. Most of the ships were small passenger ships and dry cargo ships, and they were responsible for at least 5 oil spills in Öresund - 2 of these "minor" and 3 "large" oil spills. Grounding, collision and contact were among the most frequent events involving these ships. Improper manning, fatigue (e.g. falling asleep) and reckless behaviour (e.g. intoxication, running at full speed in poor visibility) were some of the factors contributing to the aforementioned events.

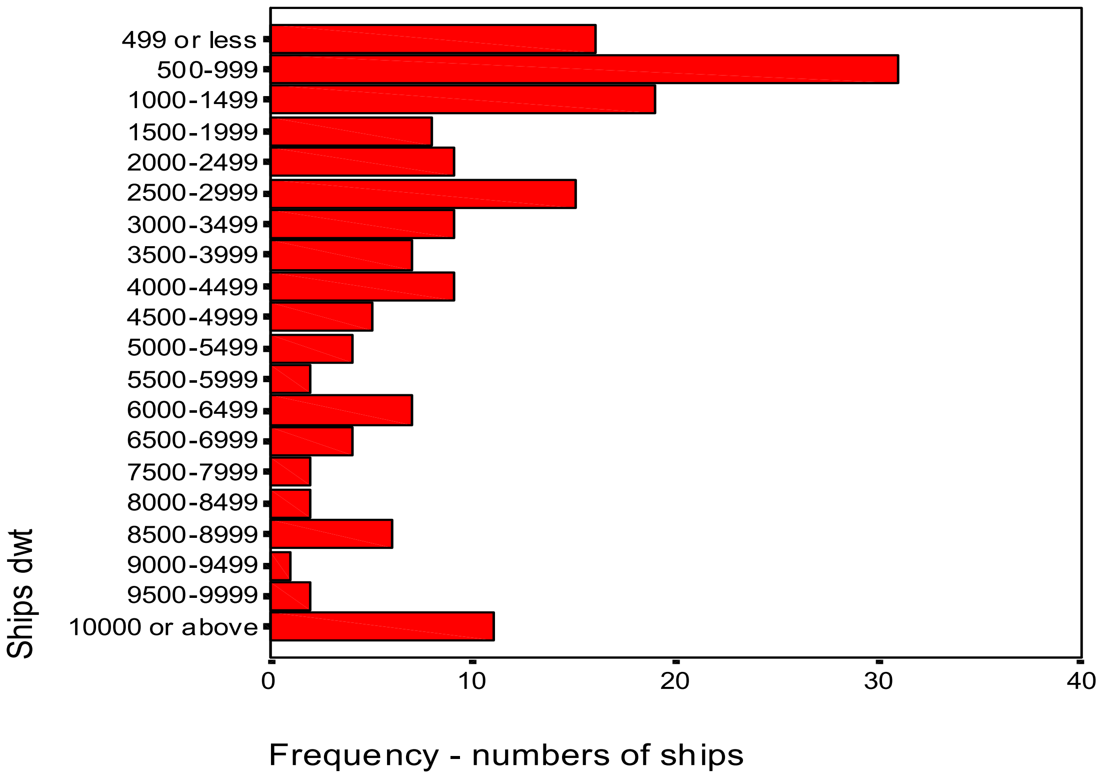

Figure 4.10: Ships dwt involved in marine events

However, compared to the total number of ships involved in marine events, middle and upper size ships tended to show a higher probability of causing oil spills, in particular "large" oil spills, than smaller sizes. The following may be some of the reasons:

- Larger ships were involved in groundings, collisions, and contact events.
- Due to larger masses, greater forces are exerted.
- A larger hull surface and a larger number of compartments are exposed to impact, including corrosion.
- Large ships carry large amounts of bunker and/or cargo oil.

The largest ship size involved was an OBO (oil/bulk/oil) carrier of 45,000 grt (or 75,000 dwt). It was involved in a contact event.

4.3.3.8 Oil spills by category of vessel traffic

As we have seen earlier in 4.3.3.2, in Table 4.6, vessel traffic in Öresund is divided into three categories; *(a)* east/west bound, *(b)* Öresund ports – N/S bound and *(c)* through traffic – N/S bound. To what extent has each category of traffic contributed to oil spills?

Two figures are presented below. Figure 4.11 shows the number of oil spills for each category of vessel traffic in Öresund. Categories (b) and (c) of the vessel traffic were the largest contributors to oil spills in Öresund (1985-1999). 31 out of 35 (or 88.6%) oil spills are attributed to these categories (*a* and *b* - 57.2% and 31.4% respectively). Category (a) contributed with only 4 oil spill events (or 11.4%).

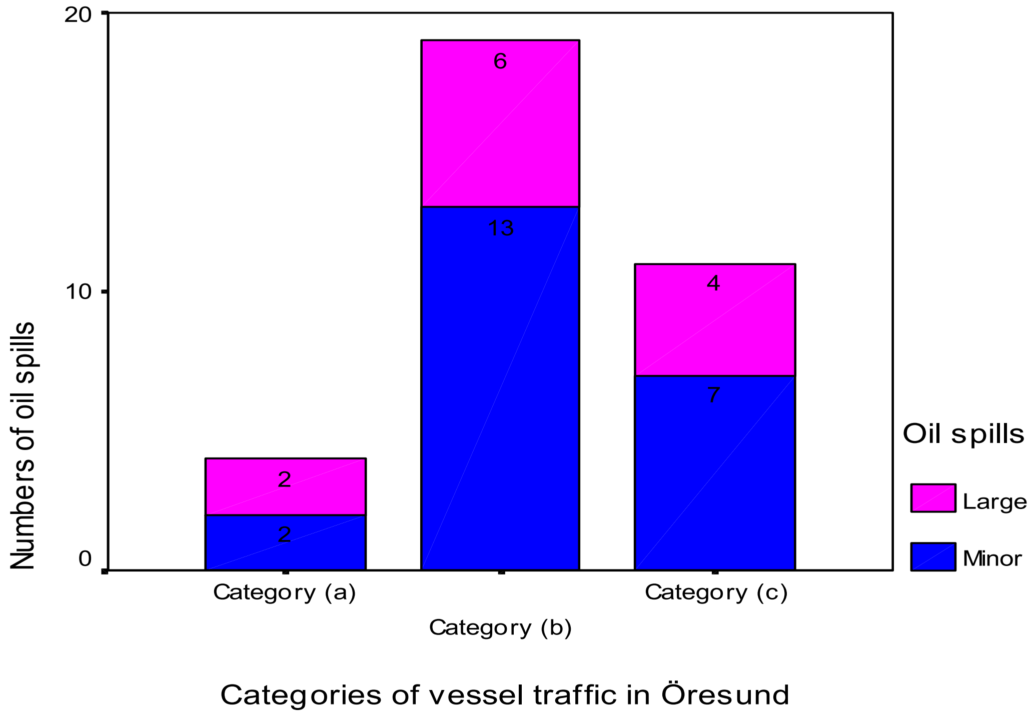

Figure 4.11: Oil spills for each category of vessel traffic in Öresund

Figure 4.12 displays clustered bars (values are expressed as % of the total) of marine events and oil spills for each category of traffic.

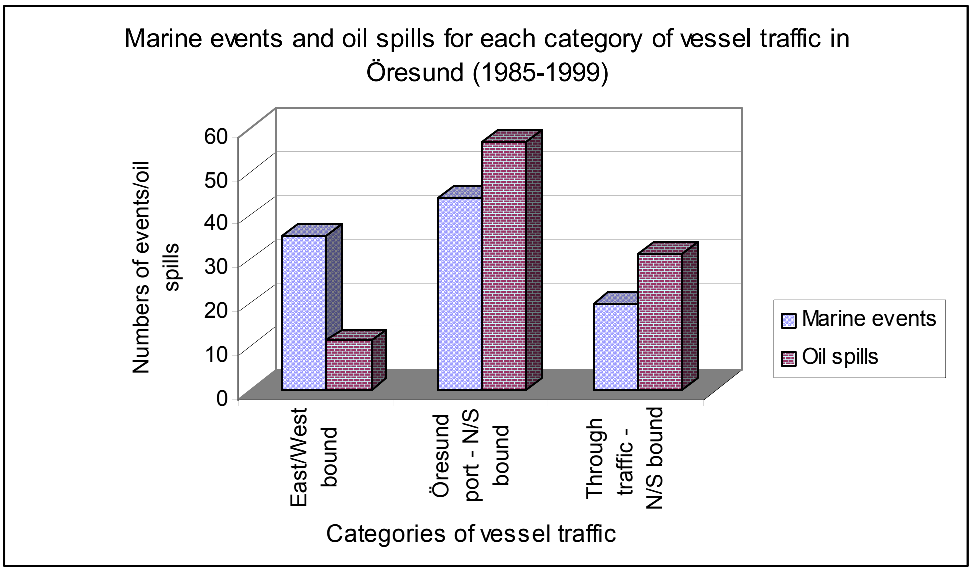

Figure 4.12: Marine events and oil spills for different categories of vessel traffic.

The number of oil spills attributed to category (a) is significantly lower than the expected value - i.e. proportional to the number of marine events and the amount of traffic in each category. Category (a) contributed to the total number of oil spills with a mere 11.4%, which is approx. 3 times less than the percentage (i.e. 35.6% of the total) of marine events attributed to this category. On the other hand, marine events attributed to categories (b) and (c) accounted for 64.4% of the total number of marine events, i.e. 44.4% and 20.0% respectively. And they were responsible for approx. 90% of oil spill events in Öresund. This could be explained by a) the large number of groundings and b) the type of ships involved in these two categories of traffic.

4.3.3.9 Oil spills by location

For the purpose of this study, the Öresund area as defined here has been divided into 24 locations. A name is given to each location. They are named after ports (e.g. Helsingborg, Landskrona), towns and cities, lights or light houses (e.g. Norde Röse, Falsterborev), islands (e.g. Ven), banks (e.g. Valgrundet, Flint, Lillgrundet), capes and channels.

Figure 4.15 shows the geographical distribution of oil spills in Öresund. It shows where and how often oil spills occurred in Öresund. The locations with a high number of oil spills recorded are: Malmö (4), Dragör/S. Röse (4) Domsten/Hittarp (3), Lillgrund (3), Falsterborev (3) and Middelgrund (3). In other locations the number varied from 1 to 2 spills. No oil spill has been recorded in the following locations, starting from the north of the Swedish coast: Höganäs, Helsingborg, Lomma, Köge, Helsingör, and Gilleleje/Hornbaek.

The series of graphs and tables below summarises the oil spills in Öresund from 1985 to 1999, in the following categories: oil spills by location, and types of ships and types of initial events for each location.

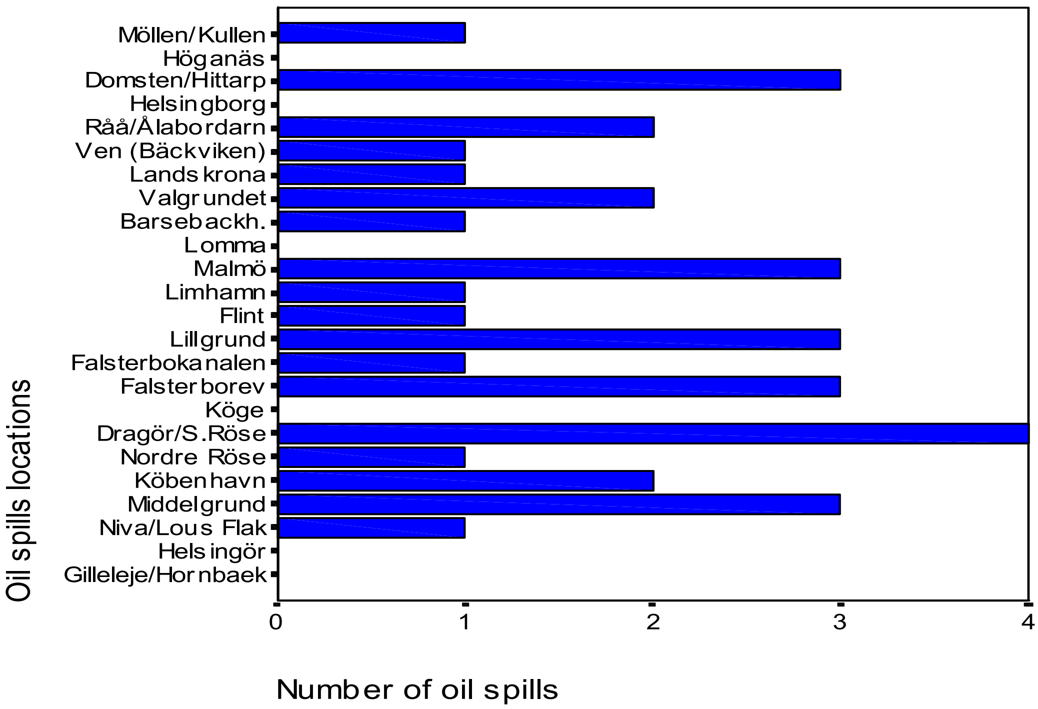

Figure 4.13: The number of oil spills by location

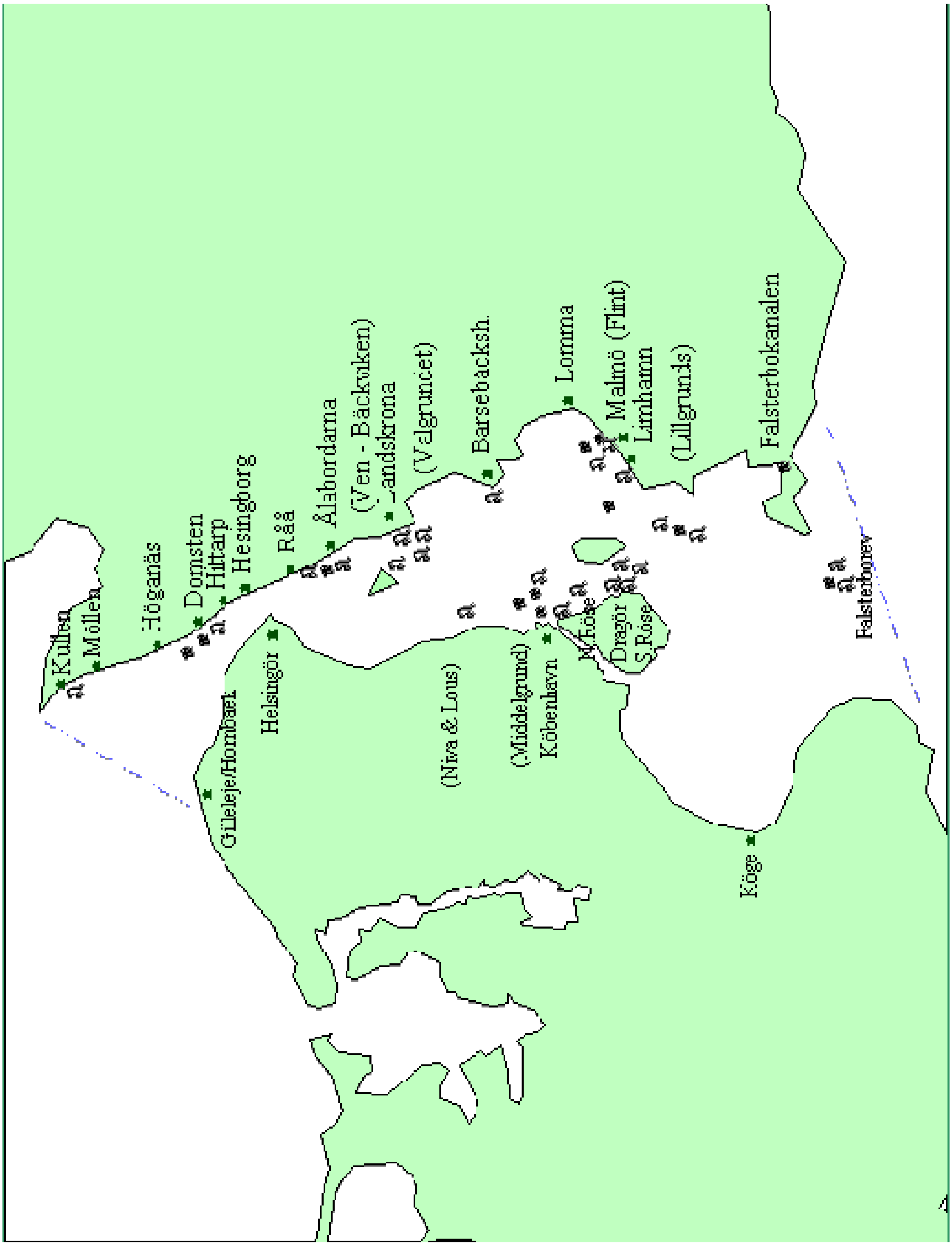

Figure 4.14: The geographical distribution of oil spills events in Öresund (1985-1999). Note: large and minor oil spills are depicted by full and dotted marks respectively

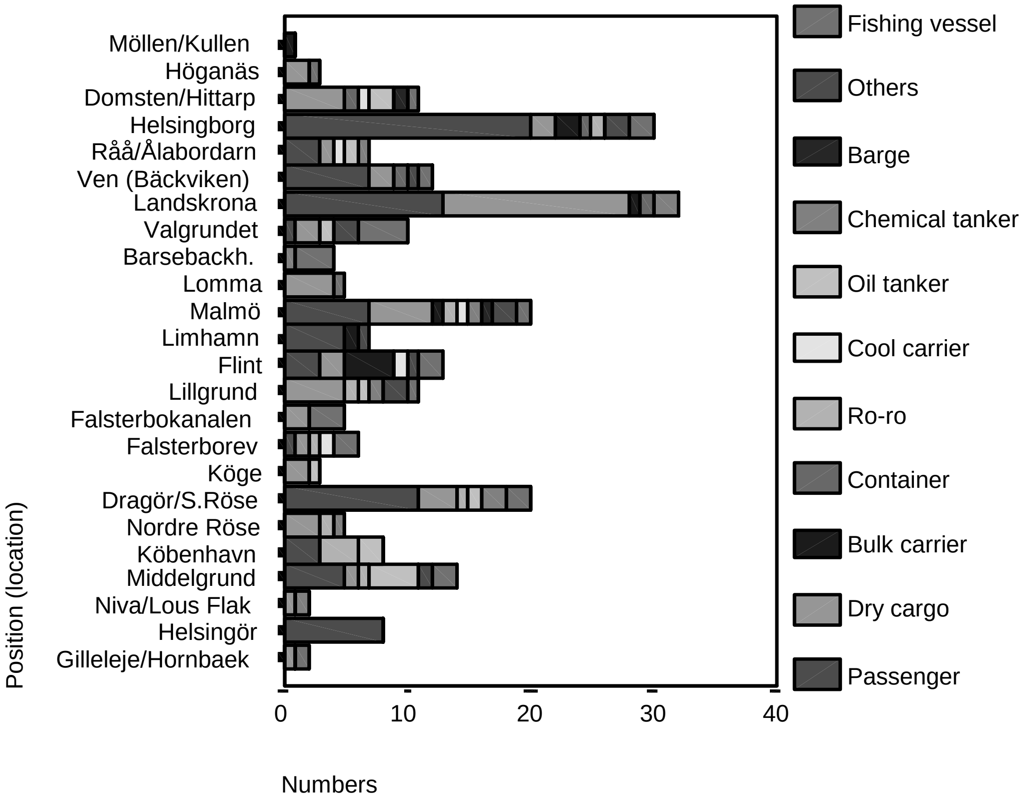

Figure 4.15: Types of ships involved by location

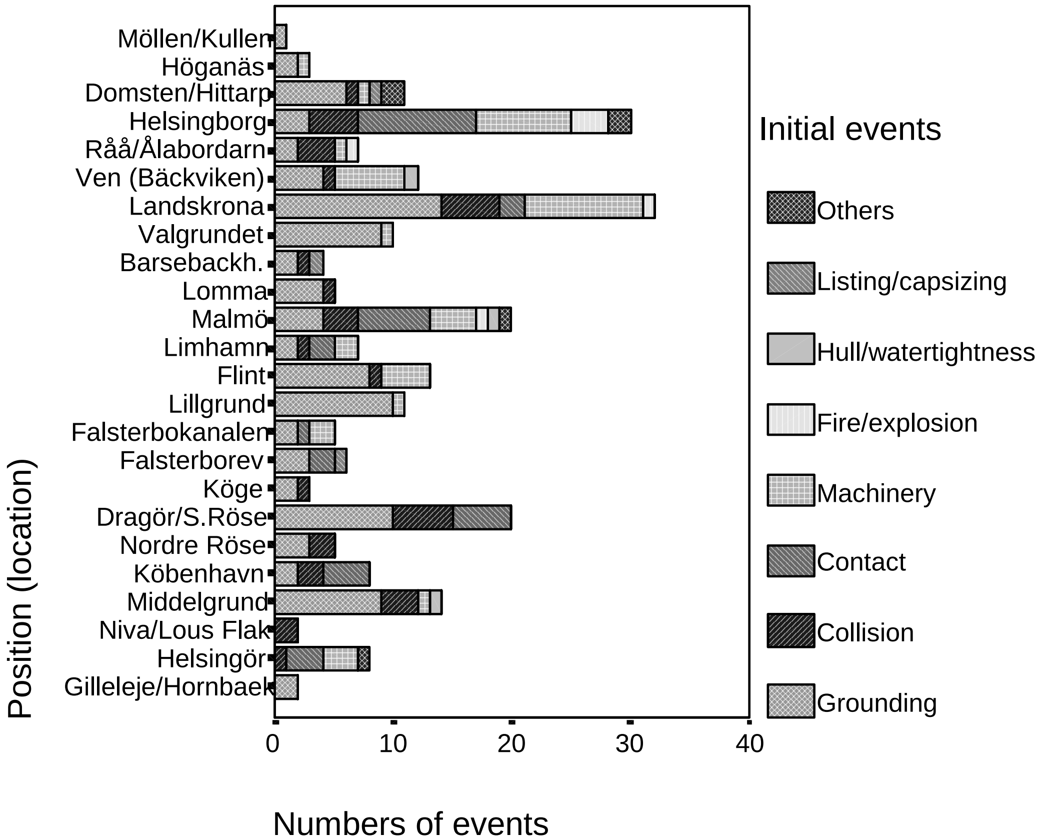

Figure 4.16: Initial events of marine events by location.

The following is an analysis of some locations with the highest number of marine events and/or oil spills. A detailed analysis has been provided in Table 4.12.

- *Möllen/Kullen* (M/K) - *Höganäs* - *Domsten/Hittarp* (D/H). This is the northern part of the Swedish coast of Öresund. The number of oil spills in this area was higher than expected. 15 events were recorded, of which 9 were groundings. 4 out of 9 groundings led to oil spill - 3 and 1 in D/H and M/K respectively. Groundings were powered groundings, i.e. ships running aground with their own engine. In more than one case, ships coming from the north and bound southwards have run aground at full speed. The personnel on duty, including watch-keeping officers and masters, have been unprepared to exercise due diligence while entering Öresund. After pressing and tiresome voyages they have fallen asleep.
- *Helsingborg*: 30 events are recorded and none of them have led to an oil spill. This was mainly due to the large numbers of contacts and machinery failures, leading to powerless groundings and "soft" contacts. The extent (amount) of forces exerted is essential which, in turn, depends on the speed and mass of the ship.
- *Landskrona*: 32 events are recorded, but only one of them caused an oil spill. The majority of events were groundings (14) and machinery failures (10). One of the groundings led to an oil spill.
- *Valgrundet*: 10 events, of which 9 were groundings leading to two oil spills. All groundings occurred within a radius of 0.5 miles NNE of the Valgroundet light buoy. The buoy marks the southern extension of a bank that stretches from Landskrona towards SSW approximately 3 miles. Water depths are shallow, varying between 0.7m, 1.7m and 2.2m. The bank is covered by a red sector of the Landskrona light (12 miles racon). Fishing vessels, "other" types, passenger, dry cargo, and tanker ships were among the types of ships that grounded in this area. More than half were small draft ships, such as fishing vessels and pleasure boats. Some of the reasons might have been: "cutting corners"; lack of knowledge of the water depths and their variations due to water tides and currents; given Landskrona's background, with too many lights, ships have probably lost their orientation by confusing lights. All ships that grounded in this area belonged to categories (b) and (c) of traffic.
- *Malmö - Limhamn*: 27 events are recorded - 20 and 7 events respectively, causing a total of 5 oil spills. Only 6 contact events in the port of Malmö caused 3 oil spills; of these two were large. Spills came from passenger and dry cargo ships. Both these types were the most frequent types of ships involved (14/20).
- *Flint - Lillgrundet*: 24 events - 13 and 11 respectively. The total number of oil spills was 4, of these 3 in Lillgrundet. The majority of events (18/24) in this area consisted of groundings, and all 4 oil spills were due to groundings.
- *Falsterbokanalen - Falsterborev.*: 11 events - 5 and 6 events respectively, causing 4 oil spills. 3 of the oil spills occurred in the Falsterborev lighthouse area. In one case, a cool carrier bound north hit the Blenhem light at full speed. The ship was seriously damaged and the light totally smashed. But no spilt oil has been reported. In another case, a passenger ship hit (17.5 knots) an unidentified object at sea at full speed. The ship's hull was damaged and the bunker oil spilt into the sea.
- *Dragör/S.Röse - Nordre Röse - Köpenhamn - Middlegrund*: 47 events - approximately 20% of all events, causing 10 oil spills (or 28.6% of spills). The majority of events (34/47) occurred in the areas of Dragör/S.Röse and Middlegrund - 20 and 14 events respectively. 24 out of 47 events were groundings (or 23% of all groundings) causing 7 oil spills. This indicates that ships are at high risk of running aground in this area and probably spilling

- oil into the sea. The probability of an oil spill after grounding is 0.30, which is 0.1 higher than the average (i.e. 0.20 or 21/104) of the Öresund area.
- *Helsingör*: 8 events are recorded, mostly collisions and contacts,, but none of them led to an oil spill. In all 8 cases passenger ships were involved.

The analysis has shown that oil spills in Öresund are related to the frequency/density of vessel traffic and the number of marine events. These relations are important, but not deterministic. The following Table (4.11) compares oil spills by marine events in three selected locations of Öresund, namely: Helsingborg, Helsingör and Landskrona.

Nr	Location	Marine events	Oil spills
1	Helsingborg	30	0
2	Helsingör	8	0
3	Landskrona	32	1
	Total	70	1

Table 4.11: The number of marine events and oil spills in three locations: Helsingborg, Helsingör and Landskrona.

One third of marine events occurred in these three locations (29.3% 70/239). 70 marine events caused only one oil spill (or 3% of all spills). For Helsingborg and Landskrona the number of events was 3- fold higher than the average value per location. The average value was approx. 10 events. The categories and frequencies of marine events in three locations were:

- Grounding - 17 events, of these 14 in Landskrona, one of them causing the only oil spill
- Collisions - 10 events
- Contacts - 15 events, of these 10 in Helsingborg
- Machinery - 21 events, of these 18 in Helsingborg and Landskrona
- Fire/explosion - 4 events, of these 3 in Helsingborg
- "Other" events - 3 events.

A higher frequency of marine events, but a lower frequency of oil spills, in these locations could be explained by the following interrelated factors:

a) narrow and shallow waters with very dense vessel traffic;
b) types of ships (Figure 4.15) sailing - there has been a large number of passenger/cargo ferries running regularly between Helsingborg and Helsingör;
c) types of marine events (Figure 4.16) - "machinery", "contact" and "grounding" events were the most frequent.

N	Position (location)	Initial events - Minor/Large Oil spills																			Total - spills and events	
		Grounding			Collision			Contact			Machinery		Fire/ explosion	Hull/ watertight		Listing/ capsizing		Others	Total events			
		s*	e*	s/e*	s	e	s/e	s	e	s/e	s	e	e	s	e	s	e	e	e		s	s/e
1	Möllen/Kullen	1	1	1.0		0			0			0	0						1		1	1.000
2	Höganäs		2			0			0			1	0						3		0	0.000
3	Domsten/Hittarp	1/2*	6	0.50		1	0.00		0			1	0				1	2	11		3	0.273
4	Helsingborg		3			4	0.00		10	0.0		8	3					2	30		0	0.000
5	Råå/Ålabordarn		2		1/1	3	0.67		0			1	1						7		2	0.286
6	Ven (Bäckviken)		4			1	0.00		0		1	6	0		1				12		1	0.083
7	Landskrona	1	14	0.07		5	0.00		2	0.0		10	1						32		1	0.031
8	Valgrundet	2	9	0.22		0			0			1	0						10		2	0.200
9	Barsebackh.	1	2	0.50		1	0.00		0			0	0				1		4		1	0.250
10	Lomma		4			1	0.00		0			0	0						5		0	0.000
11	Malmö		4			3	0.00	1/2	6	0.50		4	1	1	1			1	20		4	0.200
12	Limhamn	1	2	0.50		1	0.00		2	0.0		2	0						7		1	0.143
13	Flint	1	8	0.13		1	0.00		0			4	0						13		1	0.000
14	Lillgrund	2/1	10	0.30		0			0			1	0						11		3	0.272
15	Falsterbokanalen		2			0		/1	1	1.0		2	0						5		1	0.200
16	Falsterborev	1	3	0.33		0		1	2	0.50		0	0			/1	1		6		3	0.500
17	Köge		2			1	0.00		0			0	0						3		0	0.000
18	Dragör/S.Röse	4	10	0.40		5	0.00		5	0.0		0	0						20		4	0.200
19	Nordre Röse	1	3	0.33		2	0.00		0			0	0						5		1	0.200
20	Köbenhavn	1	2	0.50	/1	2	0.50		4	0.0		0	0						8		2	0.250
21	Middelgrund	1	9	0.11	/1	3	0.33		0			1	0	1	1				14		3	0.214
22	Niva/Lous Flak		0		1	2	0.50		0			0	0						2		1	0.500
23	Helsingör		0			1	0.00		3	0.0		3	0					1	8		0	0.000
24	Gilleje/Hornbaek		2			0			0			0	0						2		0	0.000
	Total	16/5			2/3			2/3			1			2		/1						
	Total	21	104	0.20	5	37		5	35		1	45	6	2	3	1	3	6	239		35	0.146

Table 4.12: Initial events and locations of oil spills in Öresund (1985-1999)

Note

- s* - oil spills
- e* - marine events
- s/e* - the ratio between the number of oil spills and marine events
- 1/2* - means 1 "minor" and 2 "large" oil spills.

4.3.4 Summary of the 35 marine oil spills

Accidental oil spills in Öresund (1985-1999) are measured against a number of attributes (variables). The analysis of oil spills in Öresund was based on data provided by the SMA.

- *The number of oil spills*. A total number of 35 oil spill events were recorded by SMA within the Öresund area. Every seventh marine event has led to an oil spill event or 14.6% of all marine events (293 events). In recent years, the number of oil spills has declined, despite the fact that the number of marine events has relatively remained high. The number of oil spills may be even larger.
- *Oil spill sizes*. One third of oil spills were reported as “large” spills. The size was quantified in four cases only. The largest spill recorded was 200 metric tonnes. Due to position and extent of damage on the ship’s hull and the number of ships involved, collisions and contacts were more likely to cause large spills.
- *Ship types*. A total number of 277 ships were involved in 239 events, on an average 1.16 ships per event. Öresund is highly exposed to risks of bunker oil spills. Non-tanker ships comprised 91.3% of the total number of ships involved. They were responsible for 68.7% of oil spill events. 10 out of the 12 "large" oil spills were caused by non-tanker ships. Tankers, however, are liable to cause larger oil spills, fires and explosions. Tankers were most likely to be involved in grounding and collision events. Due to fire/explosion hazards, a collision between a passenger ship and a tanker may cause a large number of fatalities and injuries.
- *Ship's age*. Older ships have shown a higher tendency to cause more oil spills, in particular "large" spills, than younger ships.
- *Ship's size*. Ships of middle and upper sizes have shown a higher frequency of oil spills than lower sizes (small ship). This could be explained by: the type of marine events involved, greater forces (impact) exerted, the hull surface and the number of compartments exposed, large amounts of oil carried as cargo and/or bunker oil.
- *Vessel traffic*. The categories (b) and (c) of the vessel traffic were the largest contributors of oil spills in Öresund (1985-1999). 31 out of 35 (or 88.6%) oil spills in Öresund are attributed to these categories.
- *Locations* with a higher number of oil spills recorded were: Malmö, Dragör/S. Röse, Domsten/Hittarp, Lillgrund, Falsterborev and Middelgrund. Approximately one third of all marine events occurred in the following locations: Helsingborg, Helsingör and Landskrona, but only one led to an oil spill. However, any large oil spill will affect the entire region regardless of the location of the spill. In addition, the Öresund area is also exposed to oil spills that may occur in its vicinity.

4.3.5 Hazards of marine events

Generally, for the accidental oil spills, the breach of the ship's hull in the way of the cargo and/or other oil containing compartments should be necessary for the oil to spill into the marine environment. However, the oil may also be spilt from a sunken ship. A sunken ship may not necessarily sustain damage to her hull. Marine events may be associated with one or a combination of hazards leading to oil spills. These hazards include:

Impact and friction. These are physical forces exerted in events like grounding, collision and contact. Such forces may cause a breach of the ship's hull, heat and open fire. A large number of oil spills in Öresund were due to damage sustained in the ship's hull. Case histories have shown that the frequency and the amount of oil spills in Öresund were dependent on a number of interrelated factors, including:

- *Extent of damage*. The extent of damage varied from insignificant or slight touching, minor to extensive damage. For example, according to case histories ships that have grounded, collided or contacted another object than a ship have sustained damage to a number of tanks. Sometimes, 3 or 4 tanks have been damaged simultaneously. In numbers of cases the entire ship's bottom has been heavily damaged. The extent of damage depended on the forces exerted. The latter, in turn, depended on: the type of events, speed, mass of the ship and the object of contact, for example, whether a ship has come into contact with sand, stone, concrete, or steel. The mass is a function of the size and the state of the ship. In an accident, a ship may be fully loaded, partly loaded, or in ballast.
- *Position of damage (impact)*. Where are damages sustained? They are sustained in different parts of the ship, but with reference to the ship's waterline damages are sustained above and/or below the waterline. According to a study carried out in the Baltic Sea[68], in 80% of collisions tankers sustained damage above the waterline. When a ship is fully or partly loaded and it is damaged above the waterline, the cargo above the lower edge of the hole will outflow. In cases when the cargo is lighter than the water or soluble and the ship sustains damage below the waterline, the water ingress fills the tank, lifts the cargo off and spills it out from the hole. But, if the cargo is heavier than water and insoluble, only that part of the cargo that is above the lower edge of the hole will flow out.
- *Compartment(s) sustaining damage*. One important factor is the probability of the following: a) the type of compartment(s) being damaged: cargo, bunker, oil, waste, ballast; b) the state of the compartment when damaged i.e. fully/partly loaded or empty; c) the type of ship in terms of a single or double skin. According to a study[69], double bottom tankers damaged in accidents have caused cargo release as much as 8 times less than single bottom tankers. The majority of ships involved in marine events in Öresund were single skin ships.

Fire/explosion. Fire may cause deterioration, which may subsequently lead to the breach or rupture of the ship's hull. Due to explosion a ship may be ripped apart. An entire ship may even explode and subsequently sink. Sources of fire/explosion on board a ship include: a) dangerous cargoes - by virtue of their hazards dangerous materials and substances, including cargo, bunker oils, and other dangerous substances and materials, for example paints, thinners or solvents are liable to fire and b) other sources of fire, such as fires due to electrical short circuits, heat, impacts and friction.

Hull/watertightness failures. Failures are caused by a variety of factors, including: corrosion, design problems, sea/weather hazards, poor maintenance, and operational faults or errors. Hull/watertightness failures may lead to: a) water ingress causing listing, capsizing and subsequent foundering of a ship and b) the leakage of oil/oil products or water and oil mixtures into the sea.

Foundering. A sunken ship releases oil into the sea through: pipes, vents, machinery, and the hull. The ship's hull may gradually deteriorate and crack after being submerged for a long time in the sea.

68 Baltic marine Environment Protection Commission 1990: *Study of the risks for accidents and the related environmental hazards from transport of chemicals by tankers in the Baltic Sea area.* March 1990.
69 Baltic marine Environment Protection Commission 1990: *Study of the risks for accidents and the related environmental hazards from transport of chemicals by tankers in the Baltic Sea area.* March 1990.

4.3.6 Marine events in Öresund: Causes and contributing factors

In this section, causes and contributing factors of some categories of marine events in Öresund are identified and analysed. This analysis is based on the local data. Two data sets obtained from SMA and VTS Drogden databases are collated and analysed. Because of problems related to data, quantification was not possible. The data sets are, therefore, analysed in a qualitative manner. Since the analysis is based on the local data, causes and contributing factors of marine events may, in some way, be "unique" for the Öresund waters. The following categories of marine events are discussed: grounding, collision, contact, machinery and fire/explosion.

4.3.6.1 Failure mode: Grounding

Öresund waters present risks for navigation. The margin of error is too narrow. Waters are relatively shallow. Navigation is limited in terms of the ship's draft and direction i.e. selection of courses. Fairways are marked and indicated on navigational charts. Ships are obliged to exercise due diligence while navigating through these waterways. Although all routes may not be marked or indicated on the charts, in particular for the east/west bound traffic, masters and officers are still obliged to select safe courses and to navigate safely.

In numbers of cases, the reasons for groundings were *unknown*. Sometimes, causes of groundings were simply reported as "wrong navigation or manoeuvring" of the ship.

Given their locations, groundings in Öresund can be divided into two categories: a) "off the course/track - fairway or waterway" and b) "on the course/track – fairway, basin" groundings.

a) "Off the course/track" grounding

A large number of groundings occurred while ships were underway, manoeuvring in ports or port approaches. The majority of groundings occurred "off fairways." Why did ships go off the fairway? The following were among the immediate causes:

- Taking deliberately or unintentionally a wrong course. For examples, ships were reported steering on the wrong side of the seamarks, including buoys and other marks, or passing on the wrong side of the lighthouse, for example, the Flinten lighthouse. Ships have grounded at this lighthouse.
- Drifting or sheering off the fairway.
- Forced to alter course and sheered off the fairway. For example, in order to avoid a collision with a small ship, large ships have been forced to alter the course.
- Delay or failure to alter the course altogether.
- Changing the course too early – "cutting corners."

One or combinations of the following factors were directly responsible or contributed to this category of groundings: *human related factors – navigational faults/errors; weather hazards; technical failure – other than machinery; "machinery" events and the "other" category.*

Human related factors – navigational faults/errors

- Unsafe manning - OMB (One Man Bridge). A single man lookout on the bridge navigating through a risky area. In numbers of cases they have fallen asleep. Probably, they were too busy with other activities than navigation. In one case, the master was in engine room to rectify something when the ship ran aground.
- Lack of or inadequate qualification, experience, or training. Examples:
  - Inexperienced mate alone on the bridge.
  - Master lacking appropriate training.
  - Poor or inadequate navigation practices. Examples:
    - Responsibility for navigation had not been clarified.
    - Failure to maintain constantly an accurate position or course.
    - Ordering or setting a wrong course. For instance, in one case, a course of 325 was set instead of 315. The wrong course might have been ordered to the helmsman or set to the autopilot. Mistakes detected too late.
    - Excessive speed - ships lost steering capacity due to high speed.
- Navigational aids such as marks, buoys, and lighthouses are in number of cases mistaken. Examples:
  - A buoy/mark had been mistaken for another. Watch-keeping officers have confused lighthouses and buoys.
- Ships have lost their orientation in poor visibility, strong winds and at night. Examples:
  - Masters and watch-keeping officers have lost visual and radar references.
  - Fairway makings were not seen on the radar because of cluttering.[70]
- Overreliance on the navigational equipment, such as autopilot and GPS. Example:
  - Ships steered by the autopilot have, in numbers of case, run aground.
- Avoiding collision. Ships have grounded while attempting to avoid a probable collision. Oncoming ships have been steered too far from their own side of the fairway and forced other ships to sheer far from or outside the marked fairway, and subsequently grounded. Larger ships have grounded when sheering for small ships, for example, fishing vessels, pleasure boats and barges. In one case, a ship came too close to a passing ferry. In order to avoid the collision, the ferry had to manoeuvre and went out of the fairway. She subsequently went aground.
- Falling asleep. Ships have run aground because watch-keeping officers or masters have fallen asleep. The following were some of the contributing factors:
  - Illness.
  - Fatigue. In one case, the officer had fallen asleep because of:
    - Too long working hours.
    - Too little sleep and irregular sleeping pattern during the day/week.
    - Comfort.
- Alcohol influence/intoxication. In one case, a watch-keeping officer fell asleep because he was influenced by alcohol.

The above factors have some other effects on the ship personnel impairing their abilities, for example, to judge, assess, control, decide and perform their duties. In one case a master, being intoxicated, lost control of his ship, which subsequently went aground. In another case, a ship went aground because the mate took the wrong side of the seamarks. The investigation revealed that he was very tired after a pressing voyage.

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[70] Clutter: unwanted echoes that confuse the observation of signals on a radar screen.

Weather hazards
Weather hazards, often in combination with human related factors, were either directly liable for or contributed to many groundings. The following implications of weather hazards are identified:

- Poor visibility due to heavy fog, heavy rain and snow. Sometimes the visibility has been reduced to nearly zero, causing:
  - Ships have been disoriented or drifted. They have lost their orientation and subsequently taken a wrong course. Ships have also drifted under the influence of currents and/or winds. At night and in heavy fog, masters have misjudged or been unable to judge the strength of the current.
- Ice - in numbers of cases being a heavy ice slush, causing:
  - Drifting of ships
  - Reduction of the ship's steering or manoeuvring capacity
  - Damaging and/or drifting of the navigation aids, such as buoys and other seamarks.
- Currents, causing:
  - Drifting of ships. In heavy fog, masters have misjudged the strength of currents.
- Winds, causing:
  - Drifting of ships. In a number of cases, winds are reported very strong (22-24 m/s). Masters, officers and/or pilots have misjudged the ship's steering or manoeuvring capacity in prevailing strong winds.
  - Clutters. Strong winds have caused cluttering.

Technical failure – other than machinery
Technical failures other than the "machinery" events, often in combination with human related factors, have contributed to a number of groundings. Failures are divided into: a) on the ship side and b) outside ship technical failures.

- On the ship side failures
  - Auto-pilot
  - Compass
  - Other navigational equipment

- Outside the ship failures
  - Failure of the navigation aids. Examples:
    - Missing or displaced buoys and marks. Buoys and marks have been reported missing or moved, in particular in fog and ice conditions. They may have sunk or drifted away.
    - Lights out. The lights of buoys have not functioned and it has been difficult to detect the lead line marked by the buoys amongst lights ashore.

"Machinery" events
At least one in four "machinery" events, that is events reported as initial events (see Table 4.4.), including engine and steering failures, led to a grounding.

Other
- Towing with a long cable. In one case, a barge came outside the fairway and subsequently grounded while she was towed through the fairway (Drogden) with a long cable.
- Deliberate grounding. A ship was deliberately grounded after hitting an unmarked wreck and taking on water.

b) "On the course/track – fairway, port basin" groundings

Grounding in the fairway
In a number of cases, ships are reported grounded in fairways. Fairways are assumed to be safer for navigation. The following factors may have contributed:

- Meeting deep draft ships have passed each other very closely. Probably, they have drawn away the water.
- Small under-keel clearance. Ships sailing with too little under-keel clearance because the ship's master or pilot have been unaware of the ship's exact draft or water depths in the fairway.
- High speed. High speed and small under-keel clearance may have caused a squat effect.
- Tides – low tides.

Grounding on unmarked waterways

- Selecting or maintaining unsafe courses. Masters and mates may have given small clearance to navigational hazards, such as shallow waters and wrecks. In one case, a ship went aground because the master misjudged the distance to shallow waters.

Port basin grounding

- In one case, a ship grounded inside the port basin as she broke moorings in hard winds and drifted over the port basin and blocked the port entrance.

4.3.6.2 Failure mode: Collision

Collision was the third most frequent event that occurred in Öresund during the period 1985-1999. Ships came into contact at different speeds and directions. The latter is the position of the contact or impact. The speed and direction have affected the extent of damage on one or both ships involved. Both speed and direction were generally unknown. Sometimes, the amount of speed has been given in qualitative terms, for example, "low" or "high" speed. Speeds at the moment of the impact varied from high speed (20 mph or higher), low speed, manoeuvring speed to touching or pressing. The points of impacts are: bow-bow, bow-stern, bow-side and side-side.

The following categories of causes and contributing factors to collision events in Öresund are identified:

Human factor – navigational faults/error

- Improper watch keeping or lookout, poor or no attention. Example: in the middle of the day and in good visibility a ship passed between a barge and a tug and broke the towing line.
- Taking and keeping the wrong side of the fairway. Example: a tanker collided with another ship that was sailing on the wrong side of the fairway.
- Reckless actions or behaviours, such as maintaining high speed. Ships are reported maintaining a high speed in heavy fog at the entrance of the port.
- Improper or wrong manoeuvring:

  - At sea. One or both ships involved in a collision have made a wrong manoeuvre. Example: in order to avoid a collision with another ship, probably a small ship, in fog, a tanker ship made a wrong manoeuvre and collided with a large chemical tanker.
  - At port. Many collisions have occurred in ports, including port basins and approaches, while ships were manoeuvring or at berth. Example: at departure from the port, when going astern, a ship came too far aft and hit another ship moored at the quay.
- Intoxication - due to alcohol consumption. Example: two ships, which were a passenger ship and pleasure boat, collided with each other. One of the ships was running at high speed in a wrong course. Her master was suspected of being influenced by alcohol.

Weather hazards

Weather hazards such as poor visibility, winds and currents contributed to a considerable number of collisions. Solely or in combination, the following weather hazards are reported to have affected collisions: winds, currents and poor visibility.

- Winds. Ships have lost steering/manoeuvring capacity. Caught by strong winds while manoeuvring in ports, ships become difficult to handle. They have drifted and hit other ships. In one case, a ship collided with another because the master of one of the ships was reported to have misjudged his ship's manoeuvring capacity.
- Winds/currents. Example: a ship drifted against a moored ship at the quay because a combination of strong winds and currents affected her manoeuvrability.
- Poor visibility.
  - In heavy fog ships have lost their orientation.
  - A ship's manoeuvrability capacity has been constrained by limited or no visual contact, lack of experience in using radar and other traffic in very confined waters.
  - Poor visibility associated with poor navigation practice and reckless behaviour. In one case, a ship was going at a high speed in heavy fog. She was on the wrong side of the traffic separation border when she collided with another ship.

Technical failures/problems

- Navigational equipment.
  - Autopilot. The autopilot has stopped functioning and this has been discovered too late.
  - Radar. The radar(s) did not function. In one case, a ship collided in a heavy fog when both of her radars did not function. The ship had two radars and they were probably out of order before she entered the area.
- "Hull/watertightness" events (Table 4.4.). Example: a dredger ship experienced water ingress from her hull, she listed and collided with another dredger ship.

Other

- Suction. Ships collided when passing each other too closely. Probably, they were suctioned against each other due to forces produced by pressure differences. In two cases, these types of ships were involved: a dry cargo ship collided with a bulk carrier, and a passenger ship collided with another passenger ship.
- The towing line broke. Example: the towing rope to a barge broke and the barge collided with another ship.

4.3.6.3 Failure mode: Machinery

Machinery failures or problems are divided into three categories: a) engine, b) propeller and c) steering system failures. The categories of failures and their contributing factors are:

a) Engine: main (propulsion) engine, auxiliary engine(s), electrical system

- Ships blacked out at sea or when arriving at the port.
  - Reasons were unknown, except in one case. In this case, first, one auxiliary engine broke down and later all seven stopped working resulting in a complete blackout. The ship blacked out because of an automation failure.
- Main engine(s) failed/stopped/broke down. Examples:
  - The lube oil pressure fell and a bearing seized
  - A fuel filter clogged
  - A cooling water hose broke
- Engine did not respond to the command for going astern. Examples:
  - Clogged filter prevented function
  - Control for going astern did not function
  - Low function of the gear for going astern
    - Leaking gaskets
    - Usage of the wrong type of oil

b) Propeller system

- Propeller shaft
  - The propeller shaft broke at sea
- Pitch[71]
  - Pitches failed
  - Built in reduction of the pitch did not work properly
- Thruster[72]
  - One or all thrusters failed
    - Fuse failure on one thruster probably a thyristor fuse was of a poor quality
    - Thruster blocked in the wrong direction
  - Thrusters did not work properly
    - The oil level in the thruster was low and the oil had air bubbles

c) Steering system

- Ships lost their steering/manoeuvrability capacity because the steering system failed completely or did not function properly, including:
  - Joystick did not function properly
  - Manual steering did not operate
  - Earth failure
  - Rudder
    - Rudder damaged
    - Rudder fell off because:
      - Rudder bolts had crackings

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[71] Pitch: the blade angle of a propeller or rotor.

[72] Thruster: an auxiliary propeller on a ship, capable of acting athwartships. Athwartships: from one side to the other of a vessel at right angles to the keel.

4.3.6.4 Failure mode: Contact

Ships contacted or hit (as initial events) objects while underway at sea or manoeuvring at the port approach and basin. They contacted the following objects: quays, lighthouses and breakwaters. The following categories of causes and contributing factors were identified:

Human factor – navigational faults/errors
- Improper or wrong manoeuvring.
  - Masters and pilots have made wrong manoeuvres. Some of the reported causes were:
    - Manoeuvre delayed
    - The rudder put on the wrong side
  - Inadequate qualifications, education or training
    - The Master has not being fully trained
  - High speed. Maintaining high speed while approaching or manoeuvring in the port in heavy fog
  - Alcohol intoxication
- Improper watch keeping - lack of attention
- Other external human-related factors. Example: A truck was left outside the quay line and pressed against the ship while she approached the quay.

Weather hazards
A large number of contact events are, in combination with human related factors, caused or influenced by weather hazards such as: winds, currents, icy conditions and poor visibility. How did these hazards contribute to contact events?

- Winds. Strong winds, in numbers of cases as much as 22 m/s.
  - Ships have drifted and pressed against quays, piers or mooring posts
  - Strong winds have prevented tugs from holding the ship while manoeuvring
- Winds/currents.
  - Causing drifting of the ship and affecting her steering capacity. Masters and pilots are reported to have misjudged winds and/or current strengths
- Ice/winds.
  - Causing drifting of the ship
  - Preventing tugs from holding the ship
- Poor visibility
  - Ships hitting the quay in poor visibility due to heavy fog

Technical failures – "machinery" events (Table 4.4.)
Ships have lost their steering/manoeuvrability capacity and subsequently contacted the quay. Machinery events have contributed to a considerable number of contact events.

4.3.6.5 Failure mode: Fire/explosion

Case histories have shown that the fire has initially started in the following ship's spaces: machinery, cargo spaces and accommodations. Fires in machinery spaces, which were often due to technical failures and hot work, had a higher probability than in the other ship's spaces. In numbers of cases, the fire has not been contained and subsequently spread to other spaces; sometimes the whole ship has been set on fire. The following types of ships are reported involved in fire: passenger, tanker, bulk carriers, and ro/ro ships.

Three main categories of causes of fires/explosion events are identified: “technical failure”, “hot work” and “other” categories. These categories are technical and human related. The category of “hot work” is more human related, which includes welding, cutting and other types of hot work abroad the ship.

Technical failures/problems - (friction, electrical faults, flammables). Examples:
- A bearing to the V-belt driver of the main engine burned
- Fan filters in the engine room have been on fire
- Oil pipes have been broken and the oil has sprayed onto a hot surface

Hot work
Fires/explosions have occurred aboard ships due to hot work carried out while the ships were at sea, berthed or in a shipyard. Explosions have occurred, for example, during welding in the cargo or machinery spaces. Alleged causes are:
- People have failed to appreciate the risks of flammable substances or materials
- No gas free test has been performed prior to the work

Other – deliberately or unintentionally setting fire in a ship. Example:
- A passenger set a fire in his cabin

Unknown
- For unknown reasons fires have started onboard the ship, especially in the engine room.

4.3.6.6 Summary of the causes and contributing factors of marine events

Most events were the result of a host of causes and contributing factors. They were due to one of, or a combination of, the following main categories: human, technical, weather/navigation hazards, and others, for example, vessel traffic density.

Human. Masters, mates, engineers, AB and pilots are, in many cases, reported as being responsible for marine events. Yet numbers of causes and contributing factors point to poor or improper management from the shore-based management. The following are among the categories of human related factors: unsafe manning; poor seamanship - e.g. improper/wrong navigation, manoeuvring; lack of training; reckless actions/behaviours - e.g. high speed in heavy fog; health/conditions - impaired personnel abilities due to illness, fatigue, intoxication; poor maintenance - hull, machinery and other ship's systems. Technical, weather and navigational hazard categories are often related to the human factor.

Technical. Technical failures/problems are divided into inside and outside ships. The following are the main categories: machinery - main and auxiliary engines, steering system, other systems; navigational equipment and devices such as autopilot, radar, lights, buoys; hull/watertightness - e.g. hull failure due to corrosion and poor maintenance.

Weather and navigational hazards. Weather hazards such as winds, currents, icy conditions and poor visibility, in association with poor insufficient judgement, have been responsible for many groundings, contacts and collisions. Öresund waters present risks for navigation. In combination with weather hazards and human related factors, confined waters (shallow and narrow) and the density of the vessel traffic make navigation in this area very risky.

In many cases, because of their shared influences, it is very difficult, if not impossible, to determine and allocate the amount of responsibility or influence of each category of causes and contributing factors. Furthermore, there are numbers of cases for which causes and contributing factors of marine events in Öresund are unknown because the case histories available do not provide sufficient information.

4.3.7 Consequences of marine oil spills

Marine events and oil spills. Oil and oil products could be involved along the course of events, if not involved in the initial event. Most of the categories of events had a potential to cause an oil spill. However, the following categories of events led to oil spills in Öresund: grounding (60% or 21out of 35 spills), collision (14.3% or 5/35), contact (14.3% or 5/35), hull/watertight failure (5.7% or 2/35), listing/capsizing (2.9% or 1/35) and machinery (2.9% or 1/35). In the first four categories of events the ship's hull breached (damaged due to the impact) or failed (due to corrosion) and the oil was spilt from the ship's compartment(s), including cargo and tank spaces, into the sea.

One listing/capsizing and one hull/watertightness event led to the ship's foundering. Sunken ships release oil even when their hull is not breached. For example, according to Reuter, in 1991 a pumping-out operation was planned to remove oil from a German warship that sank in 1940. Oil booms were prepared in case of a sudden major oil leakage. About 50 litres of oil were estimated to be leaking daily from the sunken ship. There are many similar cases around the world.

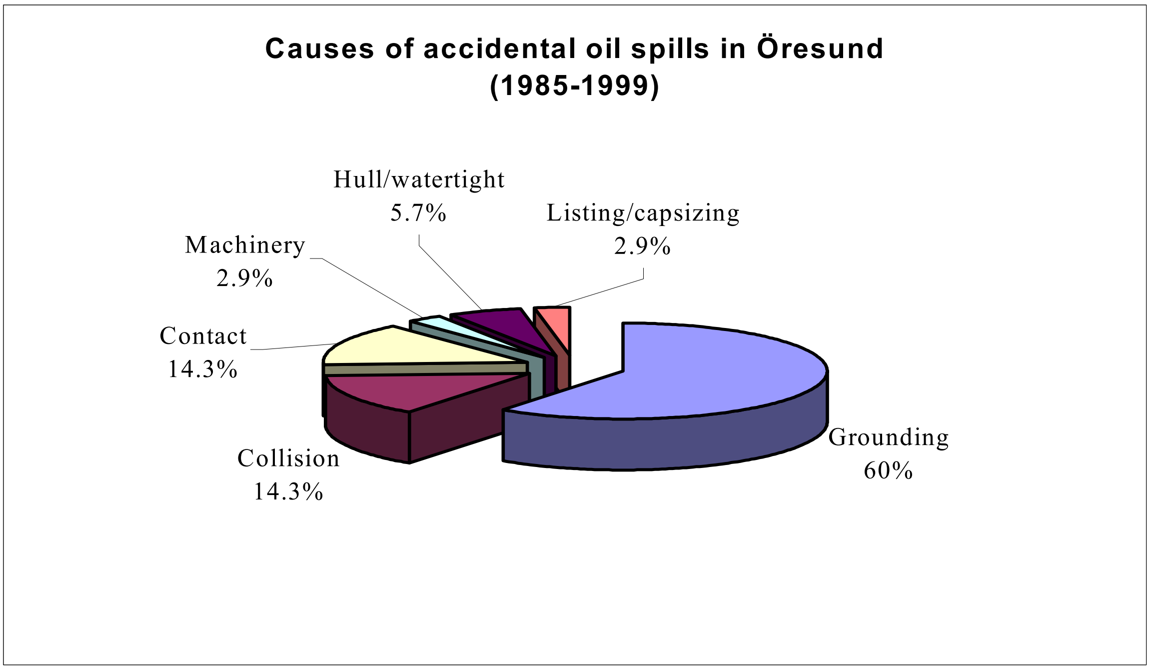

Figure 4.17: Causes of accidental oil spills in Öresund 1985-1999.

Groundings contributed 60% (21 out of 35 spills) to the total number of oil spills, which was 16% higher than the expected percentage. The expected and actual values are computed by the SPSS program. Groundings contributed 43.5% to the total number of events. Every fifth grounding (20% of all groundings) is associated with an oil spill. However, collisions and contacts had the potential to cause larger spills.

No.	**Initial events**	**Spills**		**Spills/events**	
		No. of spills	As % of the total spills	No. of events	Spills as % of events
1	Grounding	21	60	104	20
2	Collision	5	14.3	37	13.5
3	Contact	5	14.3	35	14.3
4	Machinery	1	2.9	45	2.2
5	Fire/explosion	0	0.0	6	0.0
6	Hull/watertightness	2	5.7	3	66.7
7	Listing/capsizing	1	2.9	3	33.3
8	Others	0	0.0	6	0.0
	Total	35	100	239	

Table 4.13: Oil spills and initial marine events in Öresund (1985-1999)

Ships could have been damaged after fire/explosion, but none of them has been reported associated with an oil spill.

The present case histories available do not provide any information on the impact of oil spills into Öresund's marine environment. To what extent has the environment been affected? No fatality and/or injury has been reported to have been caused by oil i.e. by virtue of the inherent dangerous properties of oil and oil products, such as: fire, explosion, and suffocation.

In order to explore the impact of oil spills in the marine environment, experiences from other areas are collected and presented in this report (Chapters 6 and 7). The case history described in Chapter 7 demonstrates how and to what extent the marine environment of the Öresund area could be affected by an oil spill. This case concerns the collision between a tanker ship and a bulk carrier ship. The collision occurred on the 29th of March 2001, at about 00.15 hrs., in the western part of the Baltic Sea, Kadet Renden, 54º43º, 19'N 012º35,01'E, which lies between Denmark and Germany, approximately 90-100 km south-west of the Öresund area. A large amount of oil spilt from the tanker ship, which seriously affected the marine environment and its inhabitants.

4.3.8 Operational oil spills

This section deals with the category of "operational" oil spills. This category consists of incidental oil spills that have occurred during: loading, unloading, bunkering, transfer or other activities.

Neither the Swedish (SMA) nor the Danish database contained records of operational oil spills in Öresund. In order to explore this category of spills, including identification and analysis of their causes and contributing factors, another database has been used. This database consists of 167 case histories mostly involving operational oil spills, i.e. oil spills resulting from events other than marine events. It covers oil spills occurring in Baltic Sea ports during the period 1979-1998, including:

- Denmark - Copenhagen and Frederica
- Sweden - Gothenburg, Brofjorden, Stockholm, Nynähamn and Malmö
- Poland - Gdansk
- Lithuania - Kleipeda
- Latvia - Ventspils
- Estonia – Tallinn

There are also some other ports for which the country is not specified.

The types of oil, oil products and water/oil mixtures reported spilt were: gas oil, petroleum products, diesel oil, fuel oil, heavy fuel, crude oil, hydraulic oil, lubricating oil, waste oil, sludge water, and water with oil.

4.3.8.1 Oil spills in Baltic Sea ports

A total number of 167 oil spill events are reported (or recorded into the database) in Baltic Sea ports during the period 1979-1998, where the majority (95%) of spills fall under the category of operational oil spills. From 1991 to 1997 the number of oil spills reported has increased significantly. Better oil spill recording in the region may have contributed to such an increase. In 1998 the number of spills declined to 9 compared to 48 spills in 1997.

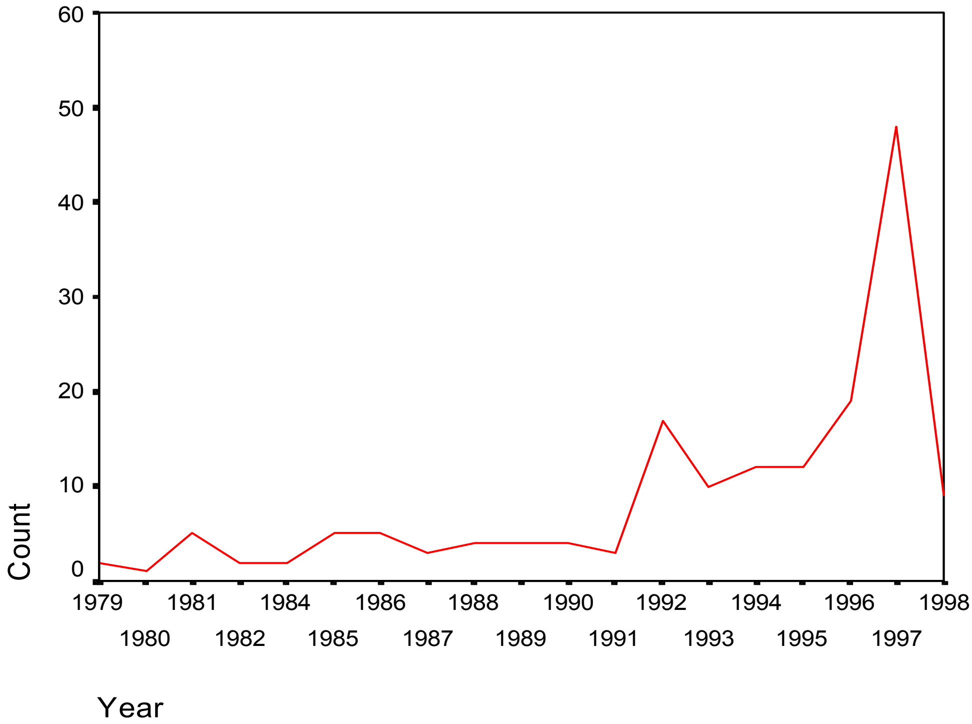

Figure 4.18: Oil spills in the Baltic Sea (1979 – 1998)

Oil spills are reported in the following countries: Sweden (43.1%), Denmark (11.4%), Poland (11.4%), Lithuania (15.0%), Latvia (4.8%), Estonia (3.6%), "Other" (10.8%). The "other" category included ports with unspecified countries, perhaps some of them may be Finnish ports. Oil spills that may have occurred in Russian and former East Germany ports have not been recorded in the database. The differences in the frequency distribution could be, among others, explained by the following factors:

- Oil spills in some former Eastern Europe countries are only reported in the last ten years, from 1989 onwards.
- The influence of the volume of oil and oil products imported, exported and handled. For example, the large number of operational oil spills in Swedish ports may be explained by the fact that Sweden imports and exports large amounts of oil and oil products. In 1995 Sweden imported 24 millions tonnes of oil, and some of it was refined and exported. In 1995, 9 million tons of oil was refined. Approximately 15 million tons of oil products are shipped between refineries and depots annually. In addition, for the purpose of distribution to other parts of Europe and beyond, a large amount of oil is stored in some Swedish ports, such as the port of Malmö.

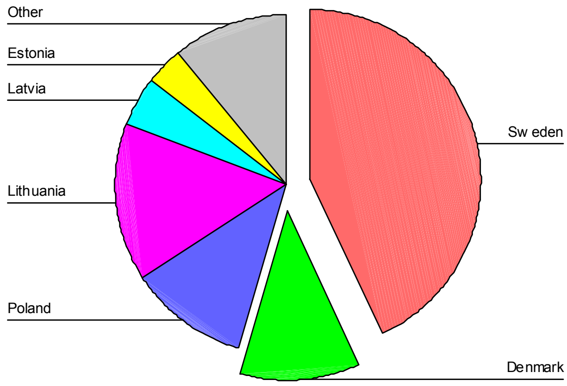

Figure 4.19: Oil spills distribution in the Baltic Sea (1979-1998).

4.3.8.2 Operational oil spills in Öresund ports

According to the database, approximately 10% (or 16 events) of all oil spills in the Baltic Sea area are reported in Öresund during the period 1979-1998. All spills were operational oil spills, except one. In this case, the oil spill resulted after a collision between two ships - between a Swedish tanker and a Polish unspecified ship type. The tanker, which was loaded and sustained damage to her hull, spilt her cargo of approximately 75 tonnes into the sea. This is the only case (out of 16 cases) recorded in all three databases i.e. Baltic Sea, Swedish and Danish databases.

Operational spills were due to technical and operational failures or errors during the following categories of activities: loading (2), unloading (9), bunkering (2). In two cases, the activity was not specified. The majority of spills (15 out of 16 spills) were reported in the port of Copenhagen (Denmark) (Figure 4.20). The amount of oil spilt per event varied from 10 litres to 90 cubic metres (cbm) (Figure 4.21). Some other findings are:

- Ships' flags involved: Swedish (4), Danish (3), Finnish (2), Panamanian (3), "others" (4).
- Types of oils spilt: heavy fuel, fuel, gas and lubricating oils.
- A total amount of approx. 125.3 cbm of oil was spilt in 14 events. In two events the amount was unknown. On an average 8,952 litres of oil was spilt per event. The largest amount recorded was approximately 88 cbm. This was due to a collision event.
- The total amount of oil attributed to operational oil spills was 37,090 litres. On an average 2 853 litres of oil was spilt per event. The largest amount of oil spilt was 15 cbm. This was due to bursting of a flexible rubber hose during unloading. The oil spilt into the harbour.

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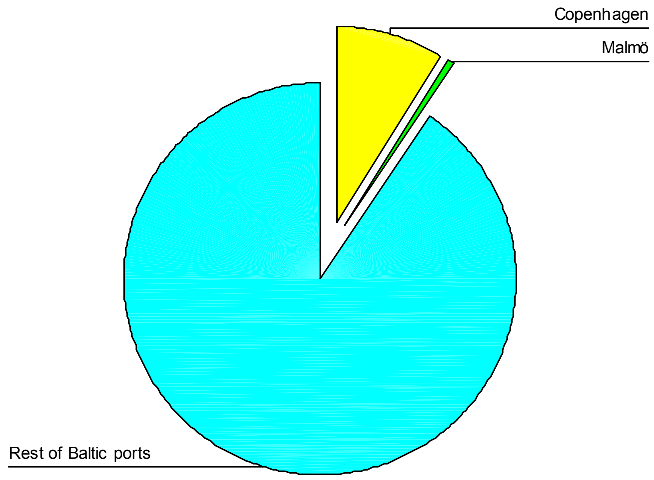

Figure 4.20. Oil spills in Öresund (1979-1998)

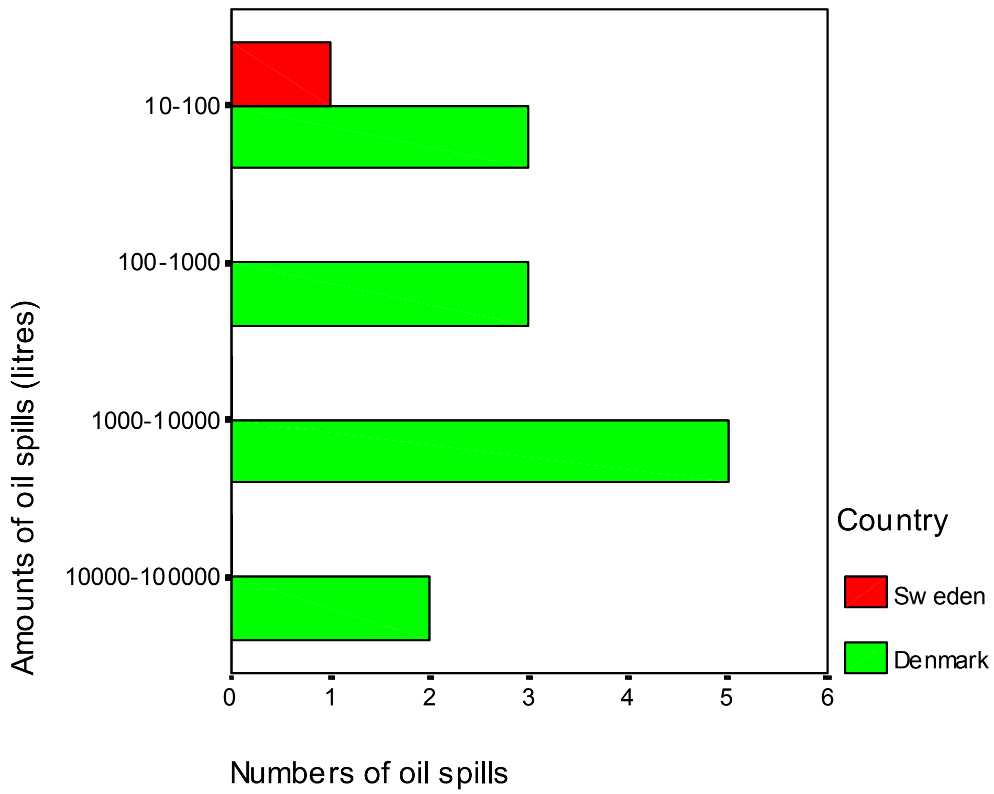

Figure 4.21: The number of operational oil spills in Öresund (Copenhagen and Malmö) by the amounts of spills (1979 - 1998)

4.3.8.3 Causes and contributing factors of operational oil spills

In this section, some of the causes and contributing factors of operational oil spills in Baltic Sea ports, including Öresund ports (Copenhagen and Malmö) are presented. This provides some learning experiences for Öresund. Oil spills into marine environments have been experienced on both ship and shore sides. In a number of cases, the oil has been spilt either on board ships or on shore, but without being spilt into the sea. Oil spills are categorised based on activities: a) loading, unloading or transfer, b) bunkering and c) "other." The "other" category consisted of oil spills that did not fall into the first two categories. Each category is further subdivided. Subdivisions are based on technical and operational failures or errors on both ship and shore side systems. Categories of causes and contributing factors of operational oil spills are as follows.

a) Loading, unloading and transfer

Hoses, hose coupling and pipes

- Bursting of flexible rubber hoses on the ship or shore sides, mostly on the ship side, during unloading and unloading due to: e.g. unauthorised hose, fast closure of valve or high pressure.
- Bursting/breaking/opening of hose coupling. In a number of cases, hoses on the loading/unloading arm had come off. Coupling on the ship/shore sides has failed, for example, due to a loose coupling or a faulty check valve. Hoses have been, for example, broken during unloading of machine room slops.
- Bursting/leaking of pipe systems on the ship and shore sides due to: e.g. corrosion and poor maintenance, bad repair and high pressure. In one case, a leakage from a gas oil underground pipe caused a large spill into the sea.
- Leakage on drainpipes
- Ships spilling slop oils from the engine room during discharging to the shore facilities.

Pumps

- Leaking pumps due to high pressure.

Gaskets, valves and seals

- Leaking gaskets and valves failed due to: e.g. defects, poor maintenance, valves did not open sufficiently fast and high pressure.
- Valve operation error: e.g. valve forgotten or not being opened, or wrong valve opened.
- Defective seal.

Overfilling of cargo tank

- Overfilling of the cargo tank due to: e.g. poor communication between ship and shore personnel. In one case, a ship started pumping oil without informing people ashore.
  - High pressure in the cargo tank.
  - Reverse flow from the terminal. Oil has flowed backwards to the ship and the tank overfilled because of: e.g. a re-circulation valve in the discharge line was opened, the valve spindle has been broken or the valve between tanks has been closed.

b) Bunkering

- Overfilling of tanks during bunkering
  - Valves
  - Unintentional opening of valves
  - Wrong valves opened during bunkering
  - Broken valves on bunkering ships
  - Sampling valves left open on the fuel oil line
- Hoses bursting while bunkering.

c) Others

- Leakage in the ship's hull: e.g. leaking ballast water pipelines passing through cargo tanks.
- Discharging water ballast mixed with oil into sea: contaminated ballast system, leakage between cargo and ballast tanks.
- Seawater from the main engine is pumped out through a hose left uncleaned after unloading of the cargo oil.
- Leakage via high-jet.
- Leakage of gas oil on the ship's deck because scrubbers[73] have leaked.
- Hydraulic oil leaked out from the jetty fire monitor operating system.
- Ballast transfer.
- Unknown sources of oil spills. Ships are reported discharging oil while underway, in road, ports or shipyards. Deliberate oil discharges are suspected.

4.3.8.4 Summary of the operational oil spills in Baltic Sea ports

Operational oil spills are experienced in Öresund. The amount of oil spilt in a single event was relatively smaller compared to spills due to marine events, such as groundings, collisions and contacts. Operational spills have posed a lower environmental risk. However, because of the risk of ignition, which may subsequently be followed by an explosion, this category may present serious threats to people, the environment and properties ashore. In 1979 a tanker ship (Betegeuse) blew up while discharging oil in the terminal (Ireland). 50 people, including shore and ship personnel, were killed due to the explosion. Extensive damage was caused to the terminal and the oil spilt from the ship caused widespread marine pollution.

Operational oil spills have occurred during loading, unloading or transfer, bunkering and other activities. Spills were due to technical and operational failures/errors on the ship and shore side systems. Technical failures/errors were: hoses, hose coupling, pipes, pumps, valves, gaskets, and seals. Operational faults were: negligence, errors, ignorance, poor communication, and poor maintenance.

[73] Scrubber is an apparatus that is used for purification

4.4 OIL SPILL EVENTS IN ÖRESUND – A SUMMING UP

The analysis is based on statistical data obtained from the Swedish Maritime Administration (SMA). Data covers all types of marine events that occurred in the Öresund waters and beyond during the period 1985-1999. The sample included only marine events recorded by the Swedish Maritime Administration (SMA). It did not include marine events occurring in Danish waters, where ships flying flags other than the Swedish flag were involved. The total number of records contained in the database was 562. By applying certain criteria, the sample was adjusted for analysis of risks from oil spills. The sample contained 239 marine events. Empirical data were analysed, presented and discussed based on the risk analysis approach.

A range of hazards that cause, or likely to cause, oil spills in Öresund was identified. Oil spills were divided into accidental or incidental and intentional spills. Illegal discharges are experienced in Öresund, but the current data available have not shown any. Accidental/ incidental oil spills are subdivided into: a) oil spills caused by marine events (as defined by IMO), such as grounding, collision, contact etc. and b) operational oil spills. The second category covers oil spills due to loading, unloading or transfer of oil, and bunkering. Data acquired from Swedish and Danish databases have not shown any oil spill of this category.

Risk analysis was mainly confined to accidental oil spills resulting from marine events. The main categories of marine events are: grounding, collision, contact, machinery, fire/explosion, hull/watertightness and listing/capsizing. The first four categories comprised 93% of all marine events in Öresund. In the last two years (1998-1999), the number of marine events in Öresund has declined, in particular grounding events.

Oil spills in Öresund are measured against a number of attributes. A total number of 35 oil spill events were recorded (by SMA only) within the Öresund area. Every seventh marine event led to an oil spill. The number of oil spills is even larger. One third of the oil spills are reported as “large” spills. The largest spill recorded was 200 metric tonnes. In recent years, the number of oil spills has declined, despite the fact that the number of marine events has relatively remained high.

Grounding was the single largest contributor of oil spills in Öresund (60% or 21/35). However, due to the position and extent of damage on the ship’s hull and the number of ships involved, collisions and contacts were more likely to cause large spills.

Marine events involving ships of the categories (b) (“Öresund port – N/S bound”) and (c) (“Through traffic or N/S bound”) of the vessel traffic in Öresund shown higher frequencies than expected (i.e. proportional to the vessel traffic). 31 out of 35 oil spills in Öresund are attributed to categories (b) and (c).

Öresund is largely exposed to risks of bunker oil spills. Non-tanker ships comprised 91.3% of the total number of ships involved in marine events and they were responsible for 68.7% of oil spill events. 10 out of 12 of the "large" oil spills were caused by non-tanker ships. Tanker ships, however, are liable to cause larger oil spills, fires and explosions. Tankers were most likely to be involved in grounding and collision events. Due to fire/explosion hazards, a collision between a passenger and a tanker ship may cause a large number of fatalities and injuries.

Older ships have shown a slight tendency to cause more oil spills than younger ships. Upper sizes (larger ship sizes) have shown a higher frequency of oil spills than lower sizes (smaller ship sizes).

Locations with a higher number of oil spills recorded were identified. However, any large oil spill will affect the entire region regardless of the location of the spill. In addition, Öresund is also exposed to oil spills that may occur in its vicinity.

The main categories of causes and contributing factors of marine events were: human (ship personnel related factors), technical (man-made in and outside ships), environmental (physical environment including weather and sea hazards) and other factors, including vessel traffic.

5 MAJOR WORLD OIL SPILL EVENTS

5.1 WORLD OIL POLLUTION INTO THE SEA

Oil spills are divided into deliberate and accidental/incidental ones. Accidental and incidental oil spills have occurred during transportation, causing serious damage to the marine environment. Figure 5.1 shows all the sources of oil spills that have contributed to marine environment pollution. Shipping has contributed with approximately 25%.[74]

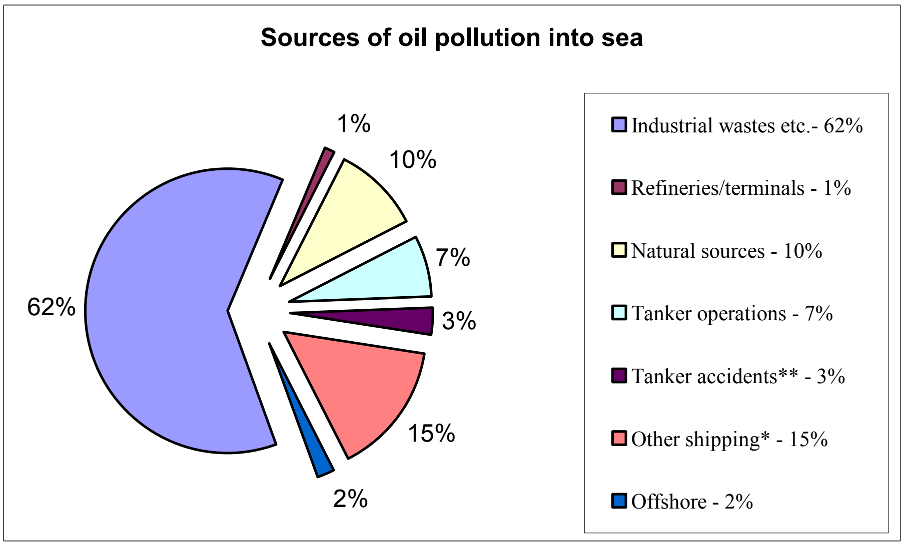

*Figure 5.1: Sources of oil pollution into the sea, Source: UN Environment Programme (UNEP), 1990. Note: the "other shipping *" category of oil spill sources includes: non-tanker accidents, bilge and fuel oil, dry-docking. "Tanker accident *" updated for 1997 (Intertanko).*

According to the US Department of Transportation (DOT 1996), an accident can be defined as any unexpected event that disrupts or interferes with the orderly progress of a certain activity or process. Accidents are associated with unwanted consequences, such as: loss of life and injuries to people, whether they are involved or not; loss of and damage to goods; loss of and damage to properties; other economic losses. They range from catastrophic to "near missings" events.

Although accidents constitute a minor part only of the total oil pollution, they could have very severe consequences due to the fact that they happen without any warning, that the quantities could be substantial and that they can take place in sensitive areas.

It is not our ambition to investigate worldwide oil pollution at sea. This study focuses on the Öresund area and on accidental and incidental oil spills. We only want to include statistical information and other kinds of information on oil spills on a worldwide basis that could be used in analysing oil spill risks in the Öresund area. We have therefore chosen to study only *major* worldwide oil spills.

74 UN Environment Programme (UNEP), 1990 and Intertanko April 2000.

We have chosen cases from different parts of the world that have resulted in major oil pollution events during the period from 1967 until March 1996[75,76,77]. They were selected on the basis of the information available and the extent of their consequences, such as large numbers of fatalities/injuries, extensive damage to the environment, large amounts of oil spilled, and large amounts of liability claims involved. In total, 25 cases were selected and are presented in Appendix 2. Unless otherwise stated, data from this database are used in the discussions below.

5.2 HAZARDS

The consequences of major oil spills were dependent on the hazards released. Oil/oil products may produce one or more hazards in a single event. The following hazards were identified from case histories of major oil spills:

- environmental hazards– in almost all cases
- fire hazard – in many cases followed by explosions
- explosion hazard – in 10 cases, where 8 out of 10 explosions followed other events, mostly grounding and collision events
- fumes/smoke from tankers on fire (3 cases).

A number of complex factors and conditions have influenced the consequences of major oil spill accidents, including: a) energy, e.g. fire, explosion, b) concentration and density, e.g. toxic clouds, c) the distance between the source of the hazard(s) and risk receptors (humans, the environment, properties), e.g. accidents occurring in the open sea were unlikely to cause life losses ashore, d) type of media or environment, such as water, air, and land, affecting the transmission, dispersion, and absorption of the hazards released and e) population characteristics, e.g. density, health, indoor or outdoor conditions.

5.3 CAUSES OF EVENTS

Table 5.2, presenting data acquired from the International Tanker Owners Pollution Federation Ltd (ITOPF) 2001, shows that oil spills are of various sizes, ranging from less than 7 tons to 700 tons and above. On the basis of their immediate causes, oil spills are grouped into "operational" and "accidental." The "others" category includes spills that do not fall in the two previous categories and for which information is not available. Probably, some of them are the result of illegal releases. Large numbers of oil spills, mainly from tanker ships, have occurred as the result of operations, such as loading, discharging and other operations. The majority of oil spills are less than 7 tons. Grounding and collision events have caused larger spills, involving quantities in excess of 700 tons.

[75] International Tanker Owners Pollution Federation Ltd (ITOPF) 2000.
[76] Lloyd's of London Press, UK 1999
[77] Drewry Shipping Consultant, UK - http://www.drewry.co.uk/drewry/ 2000

Nr.	CAUSES	<7 tons		7-700 tons		>700 tons		Total	
		number	%	Number	%	number	%	number	%
1	**OPERATIONS**								
1.1	Loading/unloading	2763		297		17		3077	
1.2	Bunkering	541		25		0		566	
1.3	Other operations	1165		47		0		1212	
	Total	**4469**	**57.5**	**369**		**17**	**5.6**	**4855**	**53.1**
2	**ACCIDENTS**								
2.1	Collisions	159		246		86		491	
2.2	Groundings	221		196		106		523	
2.3	Hull failures	561		77		43		681	
2.4	Fire & Explosions	149		16		19		184	
	Total	**1090**	**14.0**	**535**	**50.1**	**254**	**83.0**	**1879**	**20.5**
3	**OTHERS/UNKNOWN**	2217	28.5	163	15.3	35	11.4	2415	26.4
	TOTAL	**7776**	**100**	**1067**	**100**	**306**	**100**	**9149**	**100**

Table 5.1: Accidents/incidents of spills by cause, 1974-2000 (ITOPF 2001)

Table 5.2 shows the frequency of initial events leading to 25 major oil spills. Approximately one third (32%) of major oil spills were due to groundings. However, some accidents may, somehow, be attributed to the inherent hazardous properties of oil and oil products. 16% of major oil spills were associated with fires and/or explosions.

	Initial events	Frequency	Percent
1	Grounding	8	32.0
2	Machinery	4	16.0
3	Hull	2	8.0
4	Fire/Explosion	4	16.0
5	Collision	4	16.0
6	Foundering	3	12.0
	Total	25	100.0

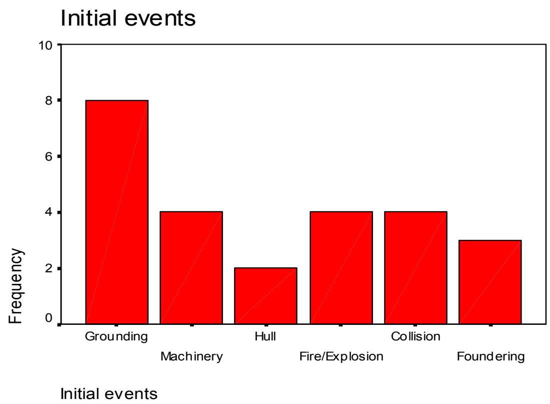

Table 5.2: Frequency of initial events.

Although it does not refer to major oil spills, Table 5.2 shows that oil spills that may result in major oil spills have also occurred during operations such as loading, discharging, bunkering and other activities.

	Initial events	Initial events – frequency	Subsequent events– 1 (SE 1)			Total of SE1	Subsequent events –2 (SE2)		Total of SE2
			Explosion	Grounding	Fire		Foundering	Explosion	
	Grounding	8	1		3	4	1	1	2
	Machinery	4		3	1	4	1		1
	Hull	2			2	2		2	2
	Fire/ Explosion	4	2			2			
	Collision	4			4	4		3	3
	Foundering	3							
	Total	**25**	**3**	**3**	**10**	**16**	**2**	**6**	**8**

Table 5.3: Initial and subsequent events of major oil spills

5.4 RISKS OF MAJOR OIL SPILLS

Major oil spill events have posed high risks to people, to the environment and to property. The frequencies and consequences of these events are given below. The extent of consequences depended on a number of factors, including: the amount of oil released, the location of accidents and the number/type of ships involved.

5.4.1 The amount of oil released

The amount of oil spilt in an accident includes oil lost to the environment, burnt or remaining in a sunken vessel. The following are some results in terms of the amount oil spilt.

- The total amount of major oil spills over the period 1967-1996 (a 30- year period) was 2,495,400 tons. This amount may be even larger. In a number of cases, the amount of bunker/oil aboard the ship was not taken into account. In one case, information about the amount of oil spilt into the sea was not available.
- The rate of major oil spills was 0.83 events per year with an average amount of oil of 83,180 tons spilt per year. The largest amount of oil spilt in one year was recorded in 1991, when an amount of 480,000 tons of oil was spilt in three events only.
- The average amount of oil spilt per event was 99,816 tonnes. Among the largest amounts of oil spilt in one single event were: "Atlantic Express" (1979) the West Indies – 270,000 tons; "ABT" (1991) Angola – 260,000 tons; "Castello de Bellver" (1983) South Africa – 250,000 tons.

5.4.2 Location of events

48% of the events occurred in European waters, in Western Europe (36%) and the Mediterranean (12%) respectively. Grounding events were the most frequent events, where 5 out of 9 groundings occurred in Western Europe.

Events	**Western Europe**			**Mediterranean**	**USA**	**REST**	**Total**
	NR.	%	%				
Grounding	5	55.6	62.5		2	1	8
Collision	0	0.0	0.0	2	1	1	4
Machinery	2	22.2	50.0			2	4
Fire/Explosion	1	11.1	25.0	1		2	4
Hull	1	11.1	50.0			1	2
Foundering	0	0.0	0.0			3	3
Total	9	100		3	3	10	25

Table 5.4: Location of events

5.4.3 Number and types of ships involved

The total number of ships involved was 29 in 25 events, an average of 1.16 ships per event. This was due to collision events. Two or more ships may be involved in a single collision event. Other types of ships involved in collisions were:

- tanker (VLCC) – resulted in the largest oil spill ever recorded
- dry cargo ship
- bulk carrier
- ferry – resulted in one of the worst casualties in marine history.

5.5 ENVIRONMENTAL, HUMAN AND PROPERTY RISKS

5.5.1 Environmental risks

Damages to the marine environment varied from potential threats to moderate to widespread pollution with grave consequences. In several cases "environmentally sensitive" areas were gravely affected.

In many cases, the assessment of damages concerned short- term and apparent effects. The behaviour of many dangerous substances in the marine environment is complex, and consequently it may experience relatively long- term effects.

Examples of types of damage:

- fish farms
- shellfish beds
- fishing grounds
- amenities.

Examples:
- 1,000 square miles of oil spill slick (Magellan Strait, Chile 1974)
- 20 miles of beaches polluted (Portugal, 1975)
- oil traces found on beaches in 1989, approximately 10 years after the oil spill (France, 1978)
- 3,000 fishermen affected by oil spill (La Coruna, Spain, 1992).

Pollution/contamination may have an impact beyond the marine environment. Examples:
- black oily rain from fire caused damage to crops and freshly shorn sheep (South Africa, 1983)
- oil spray blown ashore contaminated farmlands. (Shetland Islands, UK, 1993).

5.5.2 Property risks

Properties ashore were also affected. Examples:
- explosions causing damage to a town (La Coruna, Spain, 1976)
- explosions causing damage ashore; fire continued for weeks, further explosions causing more damage (Bosphorus, Turkey, 1979)
- tanker blew up while discharging, causing extensive damage to the terminal. (Ireland, 1979).

5.5.3 Risks to people

This part examines risks to people from events involving major oil spills. This is based on the analysis of the 25 case histories of major world oil spills 1967 –1996 (Appendix 2).

Major oil spills posed individual and societal risks. Individuals at risk included; a) employees (workers) - crew members or onboard ship personnel and port workers, including other employees; b) members of the public, including passengers onboard ships, personnel and passengers on the other ship involved in the accident, and people ashore. The latter group has been exposed to involuntary risks.

Societal risks consisted of the sum of risks to crewmembers of ships, passengers and other people ashore. The latter were mostly people living in the vicinity of the port area and waterways (i.e. local societal risks).

Human risks are measured as an annual fatality rate. The total number of people killed in events leading to major oil spills over the period 1967-1996 (30 years) was 336, but this figure may be higher than has been reported. In addition, injuries resulting from these events were not shown. In three cases, smoke from burning oil affected local inhabitants badly. Fatalities were due to the following hazards:
- fire/explosion
- suffocation
- foundering due to fire/explosion.

Categories of fatalities and their respective frequencies are:
- crew (both ships) – 173 or 51.5%
- passengers – 143 or 42.6%
- personnel ashore – 20 or 5.9%.

The following shows the fatality rates expressed in the number of people killed per year, the event and ship involved. The fatality rates are valid only for the events involving major oil spills.

Fatality (total) rate:
- 11.2 per year
- 13.44 per event
- 11.58 per ship involved.

Crew fatality rate:
- 5.77 per year
- 6.92 per event
- 5.97 per ship involved.

Passenger fatality rate:
- 4.77 per year
- 5.72 per event.

Personnel ashore fatality rate:
- 0.24 per year
- 0.8 per event.

The worst case, which caused the highest number of fatalities, was a collision between a tanker (Agip Abrozzo) and a ferry (Moby Prince). The tanker carrying 80,000 tons of light crude oil was struck by the ro-ro ferry while she was at anchor off Livorno (Italy). The ferry caught fire, and all the people onboard perished at sea. The collision was due to crew negligence.

In another case, a tanker ship (Betelgeuse) blew up whilst discharging oil in the terminal, where 50 people died due to explosion. There is reason to believe that a number (an estimated 20) of the fatalities were shore/terminal personnel. The explosion also caused extensive damage to the terminal, and the oil spilt from the ship caused heavy pollution.

5.5.3.1 Fatalities and initial events

Over one third (36%) of events were associated with fatalities where collision events posed a higher risk to people. Collisions were characterised as:
- having a higher frequency than other events; all collisions were associated with fatalities (constituting 44.4% of all fatal events)
- having a higher magnitude of fatalities (i.e. the number of fatalities in a single event): ranging from the interval 30-99 to and 100 or more.
- contributing to approx. 73% of the total number of fatalities.

	Initial events	Fatal events	Fatalities (numbers)	Contribution to fatalities (%)	Fatal events/ Total events (%)
1	Grounding	1	6	1.8	4.0
2	Hull	2	31	9.2	8.0
3	Fire/Explosion	2	53	15.8	8.0
4	Collision	4	246	73.2	16.0
	Total	9	336	100	36.0

Table 5.5: Fatal events and fatalities

Why did collisions pose higher risks to people? Some of the reasons were the number of ships involved, the hazards released, and the time sequence of the events.

- Two or more ships were involved, and in one case the “other” ship was a passenger ship.
- All collisions were followed by fire and/or explosion.
- Sequences of events, i.e. the chain of events from the initial event through subsequent event(s) and to the final event, happened too fast. People were unable to leave the ship safely.

5.5.3.2 Geographical distribution of fatalities

The number of fatalities in European waters (Western Europe and the Mediterranean) was higher than in other waters. Approx. 80% of fatalities were reported in these waters. Among the reasons were:

- a higher frequency of events (48%) and subsequently fatal events (55.6%)
- one event involved a collision between a tanker and a passenger ship; European waters are characterised by heavy passenger and cargo/passenger traffic, which interferes with the traffic of dangerous goods, including oil and oil products.
- 1979 and 1991 were the worst years with 296 or 88.1% of fatalities. Both these years had a higher frequency of events.

	Location	Fatal events	Fatalities (number)	Contribution to fatalities (%)	Fatalities per event
1	Western Europe	3	86	25.6	28.7
2	Mediterranean	2	185	55.0	92.5
3	USA	1	32	9.6	32.0
4	Rest	3	33	9.8	11.0
	Total	9	336	100	

Table 5.6: Fatality distribution

5.6 MAJOR WORLD OIL SPILLS – A SUMMING UP

There are numbers of sources that contribute to oil pollution of the marine ecosystem. The contribution of shipping is approximately 25%. Large oil spills in sensitive areas in connection with a tanker accident with severe consequences pose extra high risks. Fortunately, no major oil spill has occurred in Öresund yet.

This section, which was based on the analysis 25 case histories, examined some of the major world oil spills that occurred during the period 1967-1996. The purpose of the analysis was to provide some lessons to be learned from these worldwide experiences. What caused and contributed to a major oil spill? What could be expected in the case of a major oil spill?

Most major oil spills were due to marine events, such as groundings, collisions, hull failure and machinery problems. In a number of cases, there are reasons to believe that oil and oil products, by virtue of their dangerous properties, have caused major oil spills events, such as fires and/or explosions. Statistics have shown that major oil spills may also result from operational failures or errors, such as loading, discharging, and bunkering activities.

Oil spill events have posed high risks to people, to the environment and to property. The extent of their consequences was, among other things, dependent on the hazard(s) released, the amount of oil involved, and the risk receptors exposed. As many as a quarter of a million tonnes of oil have been spilled in one single event. Major oil spills have posed individual and societal risks. Approximately 50% of fatalities were passengers and people ashore. The magnitude of fatalities was high. The largest number of fatalities in one single event was in the range between "30-99" to "100 or more". Due to fire/explosion hazards, collisions were responsible for approx. 3/4 (or 73%) of all fatalities associated with major oil spill events. In a number of cases large "environmentally sensitive" areas were gravely affected. The fauna and flora of the marine environment , and people dependent on them, have experienced relatively long-term effects. Due to fire, explosion and toxic fumes hazards, not only the marine environment, but also properties and people ashore have been affected.

6 THIRD-PARTY CLAIMS

6.1 THIRD-PARTY CLAIMS IN SOME MAJOR WORLD OIL SPILL EVENTS

It will nearly always be possible to take measures that would reduce risks further, but the costs might outweigh the expected benefits. Risk quantification allows comparing the costs and benefits. To weigh costs and benefits against each other explicitly requires measuring them in common units. The only common unit suggested has been monetary value. In the absence of explicit cost-benefit analysis, different decisions have meant that very different amounts have been spent to save life at the margin (Mooney 1977[78], Martin 1986[79])

The following discussion deals with the consequences of major oil spills events in monetary terms. It tries to answer the question: how much money (in US$) will have to be spent on claims for each ton of oil in case of a major oil spill event ?

In our database of over 25 major oil spills in the world (see Appendix 2), only 10 have figures for claims. In the other cases, claims have not been indicated. According to the data presented in Table 6.1, the total amount of money claimed over the period 1967-96 for consequences of events involving major oil spills was US$ 2,881 million.[80] The total amount of claims for 24 events was estimated at US$ 4,589 million.

In several cases claims for compensation have been lodged in courts. Some liable claims are final. In other cases final decisions have not been taken, because litigation continued for many years. However, such claims are taken into account when estimating the total amount claimed and the claim per unit (tons or kg) of oil spilt. Due to various problems related to estimations, the figures present a high degree of uncertainty and have to be treated with caution.

Claims of affected interests, i.e. those affected by the accidents, are higher than both cargo and ship claims. The amount of the "interests" claims was 10 times higher than the "cargo" and "ship" claims together.

Although relatively small amounts of oil have been spilled, there are numbers of cases that have resulted in higher claims. Claims on cargo and ships were excluded when indicated. Some of the factors that had influenced higher claims were:

- sensitive areas e.g. fishing farms
- countries
- amounts of oil released
- fatalities and/or injuries
- property damage ashore.

[78] Mooney, G.M. (1977) *The value of human life*. Macmillan. London.
[79] Martin, A. (1986) *"Evaluating the nation's risk assessors: nuclear power and the value of life". Public money 6*(1), 41-45.
[80] The total amount of claims may be $ 5,881 millions if the "Exxon Valdez" liable claims have reached to $ 4 billion.

Costs (claims) were:
- clean- up
- fines
- compensations, e.g. deaths/injuries, third-party property damage, loss of business
- others, e.g. evacuation and legal fees.

Claims resulting from accidents consisted of a large number of claims for compensating “economic loss.” These are losses suffered by people whose properties were damaged by contamination as a result of the oil spill.

Table 6.1 shows the estimated costs of 10 major oil spills, the amounts of oil spilt and the average amounts of money per ton oil spilt. Some of these amounts may represent the "real total cost" estimated for each respective accident. They may neither be the total admissible claims estimated nor expected to be paid or paid by funds of oil spill accidents. The "total cost" may exceed both admissible claims and claims paid or expected to be paid.

The average amount constitutes the risk costs, which are the costs per unit of oil spilt for major oil spills only. Risk costs are expressed as the costs for one ton of oil spilt (US$/ton). Furthermore, they are the costs incurred by marine transport as a result of the presence of dangerous cargoes. The costs estimated above may serve as a basis for the estimation of risk costs per unit of exposure for oil/oil product releases involving marine transport. In addition, they may also be used to estimate risk costs for all classes of dangerous goods. Risk costs may be expressed as a unit of a currency (e.g. a certain number of dollars) per unit of exposure, such as ton-miles or unit-loads (e.g. container), shiploads. This unit cost is an average that applied to all shipments transported over a sufficiently long period of time. These shipments may be of a commodity, a group of commodities, or all “classified goods” (i.e. classes 1 to 9).

Ship’s name	Year	Events	Position	Location	Tonnes ,000	Claim Million	USD	
							$/tons	$/kg
Torrey Canyon	1967	Grounding/ Explosion	NW Europe	UK	120	16	130	0.13
Urquiola	1975	Grounding/Fire / Explosion	SW Europe	Spain	108	62	570	0.57
Amoco Cadiz	1978	Machinery/ Grounded	NW Europe	France	232	380	1,600	1.6
Betelgeuse	1979	Explosion	NW Europe	Ireland	80[81]	120	1,500	1.5
Exxon Valdez	1989	Grounded	USA	Alaska, USA	37	1,000 – 10,000	27,020 – 270,200	27.02– 270.2
Agip Abruzzo	1991	Collision/ Fire/ Explosion	MED	Italy	80	50	620	0.62
Haven	1991	Fire/Explosion	MED	Italy	140	728	5,200	5.2
Aegean Sea	1992	Grounding/ Fire/ Foundered	SW Europe	Spain	72	175	2,430	2.43
Braer	1993	Machinery/ Grounded	NW Europe	Shetland Islands, UK	85	175	2,060	2.06
Sea Express	1996	Grounded	NW Europe	Milford Haven, UK	65	175	2,690	2.69

Table 6.1: Ten major world oil spills 1967-1996.

[81] Estimated

6.2 A CASE HISTORY - THE "EXXON VALDEZ"

Facts about Exxon Valdez[82]

- *Event*: grounding.
- *Spill date*: 03.24.1989
- *Ship*: type – tanker ship, flag – USA flag, built in 1986 (3 years old), dwt - 211,000 tons.
- *Oil*: type 1, description – North Slope crude, quantity (volume of spill reported) – 240,500 barrels (or approx. 37,000 tons).
- *Location of event*: P. William Reef, Alaska, USA.
- *Consequences*
  - Number of fatalities: 0
  - Biological losses: fatal 36,471 birds, 1,016 otters, and 114 eagles.
  - Impact on habitat and coast: oiled 1,000 square miles, 350+ miles shoreline.

Claims have not been made official but have been estimated to be between US$ 1-10 billion (US$ 2.5 billion for environment clean- up – unconfirmed). Compared to nine other cases, the Exxon Valdez claims are remarkably high, considering the facts that Exxon Valdez had a) the lowest quantity of oil spills (of 10 oil spills – see above table); b) no fatalities and injuries; c) the magnitude of the environmental impact may be similar to numbers of other cases, given the fact that all other 9 oil spills occurred in European waters, in NW and SW Europe and in the Mediterranean. It is important to remember that claims of such magnitude could and will be expected in the USA and other countries.

6.3 CLAIM COSTS

Since the magnitude of the claims in the Exxon Valdez accident is extremely high, and since we do not know at all what the final claims will be (in the range between US$ 1 – 10 billion), except that they will be extremely costly, the case of Exxon Valdez is excluded from the database. Nine other cases are presented in Table 6.2. The amount of claims per one tonne of oil spilt in the case of a major oil spill is estimated on the basis of the total amount of oil spilt and the total amount of claims/costs estimated.

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[82] World-wide Tanker Spill Database 1999.

Ship's name	Year	Events	Location	Tonnes ,000	Claim Million	USD	
						$/tons	2001 costs
Torrey Canyon	1967	Grounding/ Explosion	NW Europe - UK	120	16	130	688
Urquiola	1975	Grounding/Fire/ Explosion	SW Europe - Spain	108	62	570	1,872
Amoco Cadiz	1978	Machinery/ Grounded	NW Europe - France	232	380	1,600	4,336
Betelgeuse	1979	Explosion	NW Europe - Ireland	80	120	1,500	3,650
Agip Abruzzo	1991	Collision/ Fire/ Explosion	MED - Italy	80	50	620	804
Haven	1991	Fire/Explosion	MED - Italy	140	728	5,200	6,746
Aegean Sea	1992	Grounding/ Fire/ Foundered	SW Europe - Spain	72	175	2,430	3,060
Braer	1993	Machinery/ Grounded	NW Europe-Shetland Islands, UK	85	175	2,060	2519
Sea Express	1996	Grounded	NW Europe - Milford Haven, UK	65	175	2,690	3,030
Total				**982**	**1,881**		
Average				**109**	**209**	**1,867**	**2,967**

Table 6.2: Estimated claims of nine major world oil spills 1967-1996.

Risk costs of oil spills have increased due to a) the price inflation b) the "social inflation", which is the change in the legal and regulatory climate over time. The social inflation is due to changes in the legal environment that would increase the number of lawsuits resulting from oil spills. Claims per ton oil spilt are adjusted for the price inflation for the year 2001. The adjusted average value is estimated at approximately US$ 3,000 per ton oil spilt.

6.4 "SOCIAL DISTURBANCES"

Any disturbance related to accidents involving dangerous goods might increase risk costs. There are numbers of unpleasant experiences where accidents involving dangerous goods have caused "social disturbances", including:

- Massive evacuation. Evacuations may be organised or unorganised, where people may even run away in panic.
- Business activities temporarily or permanently closed.
- Rallies and strikes.

Disturbances may evolve by deteriorating rapidly and getting out control. They may take a regional or national character. The following factors may contribute to such disturbances:

- Massive explosion or threats
- Toxic fumes/gases or threats
- Environmental damages or threats
- Extent of damages or threats.
- People may be ill informed by the media, which can further "fuel" disturbances.

- Mishandling of the situation by the responsible authorities.

6.5 POSSIBLE THIRD-PARTY CLAIM COSTS IN ÖRESUND

Tables 6.3-6.5 below show the liability claims (costs) for some scenarios of oil spills in the Öresund area.

In Table 6.2 based on world statistics, the claims of nine major oil spills per ton were estimated to be US $ 3,000 per ton of oil spilt. Together with statistics from Öresund, this figure has been used to calculate potential claims for oil spills in Öresund per year for different types of events as well as the total. The claims in Table 6.3 are estimations based on actual oil spills reported[83] in Öresund during the periods 1973-1981 (9 years) and 1990-1991 (2 years). Operational and small accidental oil spills are not included.

Events of major oil spill	**Total oil spill (tonnes)[84]**	**Average oil spills per year (tonnes)**	**Claims/costs of oil spills per year in Öresund ($)**
Collisions	450	41.0	123,000
Grounding	81	7.4	22,200
Unknown	288	26.1	78,300
Total	819	74.5	223,500

Table 6.3: Estimated costs based on actual large oil spills per year for different types of events in Öresund.

The claim figures from Table 6.2 are also used to calculate claims of typical anticipated scenarios of oil spills (Table 6.4). The typical scenarios are the same ones that were chosen in the 1991 study.

[83] *Analys av risker för påsegling av bron* (1992). COWIconsult, VVB VIAK: Underlagsrapport Nr 32. Doc No. 22071-001.

[84] The amount of oil spilt is expressed in tonnes. 1 cbm (cubic meter) is multiplied by 0.9.

Locations	**Typical scenarios - spill sizes in tonnes**	**Claims/costs ($)**
Flintrännan	500	1,500,000
	2,000	6,000,000
Drogden	1,000	3,000,000
	4,000	12,000,000

Table 6.4 Öresund: Anticipated costs of oil spills of typical scenarios.

Finally, the figures from Table 6.2 are used to calculate the claims of worst anticipated scenarios of oil spills (Table 6.5). The worst scenarios are the same as were used in the 1991 study.

Locations	**Worst Scenarios – spill sizes in tons**	**Claims/costs (US$)**
Flintrännan	19,000	57,000,000
Drogden	50,000	150,000,000

Table 6.5: Anticipated costs of oil spills of worst scenarios in Öresund.

As mentioned earlier, the 1991 study has underestimated the worst scenarios in Öresund. Their calculations are based on the assumption that a single partly or fully loaded tanker ship may be involve in an accident and release its entire cargo and bunker oil. The scenario of a collision between two tankers of the mentioned sizes has not been taken into account. In such a collision one or both ships may be set on fire, explode and release the entire cargo and bunker oil. The maximum amount that may be released in such an event is estimated at 38,000 tons and 100,000 tons for Flintrännan and Drogden respectively, which is twice as much as the amount estimated in the previous study. A collision between two large tanker ships may be very rare, but not improbable. Thus, the worst scenario of an oil spill in Öresund may cost US$ 300 million. The maximum amount (i.e. the limited liability) of compensation available for oil spill damage under two conventions (see Table 2.1) is lower than the costs estimated for the worst case scenario of an oil spill in Öresund. These conventions are the 1992 International Convention on Civil Liability for Oil Pollution Damage (1992 CLC) and the 1992 International Convention for Fund Compensation for Oil Pollution Damage (1992 Fund Convention).

Based on these claims, one may establish risk costs of oil spills in the area under different conditions. It may help people involved in risk management to determine how much money should be spent to reduce, transfer or retain risks of oil spills in Öresund and other parts as well.

6.6 SUMMING UP

The risk costs of "large" oil spills, which include accidental spills and illegal discharges each year in Öresund, is estimated to be US$ 223,500. This figure is higher than what has been estimated because it does not include "operational" oil spills resulting during loading, discharging, and other activities. This amount of money should be claimed from liable party(ies) causing oil spills and invested each year for prevention, reduction and mitigation of oil spills risks. The costs of the worst-case scenario of an oil spill in Öresund, which is a probable collision between two partly loaded tankers at Drogden releasing the entire cargo/bunker oil (i.e. 50,000 + 50,000 = 100,000 tons) into the sea, are estimated to be US$ 300 million.

7 BALTIC CARRIER/TERN – A RECENT CASE OF SEVERE OIL SPILL IN THE VICINITY

This is a brief account of the events following the collision between two ships. The collision occurred on the 29th of March 2001 off the southern coast of Denmark. It was followed by an oil spill that affected the Danish marine environment seriously.

The narrative description of this case is based on the preliminary report issued by the Division for Investigation of Maritime Accidents of the Danish Maritime Authority and other national and local sources of information that covered the event.

7.1 A NARRATIVE DESCRIPTION OF THE EVENTS

On the 29th of March 2001, at about 00:15 hrs, a collision occurred between two ships: a tanker named the BALTIC CARRIER and a bulk carrier named the TERN. Table 7.1 presents the particulars of the two ships involved.

Ships	**Ships' particulars**
Baltic Carrier	Type: Chemical/oil Tanker Registration: Marshall Island Construction year: 2000 Tonnage: 22,500 brt Crew: 19 crewmembers with valid certificates. Classification Society: Det Norske Veritas - valid certificates and classification papers.
Tern	Type: Bulk Carrier Registration: Limassol, Cyprus Construction year: 1973 Tonnage: 20,362 brt Crew: 22 crewmembers with valid certificates. Classification Society: American Bureau of Shipping - valid certificates and classification papers.

Table 7.1: Data about the Baltic carrier/Tern oil spill accident

The collision occurred in the western part of the Baltic Sea, Kadet Renden, 54º43º,19'N 012º35,01'E, between Denmark and Germany - approximately 90-100 km south-west of the Öresund area. A large amount of oil was spilt from the tanker ship, which affected the marine environment and its inhabitants. No fatality/injury was reported.

The tanker was loaded with 33,000 tons of fuel oil and had departed from Muga (Tallinn). The ship's draft was 10.6 M (in freshwater). Her destination was Milford Haven in the south of England. The route was planned to pass Kadet Renden and north through Storebælt. The bulk carrier was loaded with raw sugar in bulk (Cienfuegos, Cuba) and destined for Ventpils in Latvia.

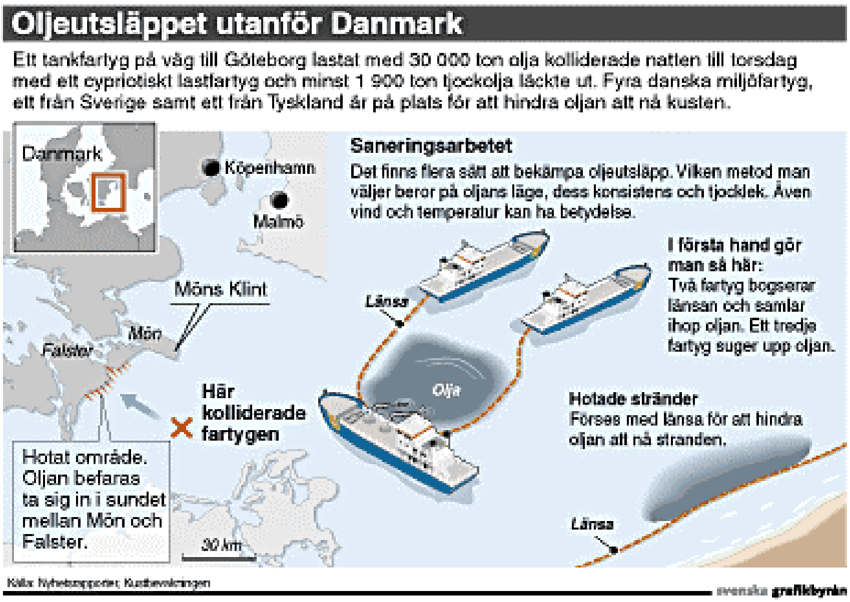

Photo 7.1: The oil spill off the southern Danish coast. Source: Nyhetsrapporter, Kustbevakningen 30 March 2001.

At the time of the collision the bridges of both ships were properly manned. On watch duty on the bulk carrier were the first mate and an AB (able-bodied seaman) as helmsman, and on the tanker were the master, the second mate and an AB.

The ships were approaching each other on opposite courses in the separated DW traffic route (deep-water traffic route) to the south of Møn. They were supposed to pass each other port to port at an appropriate distance. Shortly before they were going to pass each other the steering gear of the tanker ship failed. The ship lost control and turned to port, crossing ahead of the bulk carrier. The preliminary investigation indicated that the failure was caused by a technical defect in the steering system. A collision was unavoidable. The bulk carrier hit the tanker on the starboard side, penetrating starboard tank No. 6, which contained approximately 2,700 tons of fuel oil.

After the collision, the ships were under threat of fire, but fortunately it did not break out. No casualty or injury was reported. The ships drifted together for 15–20 minutes before the bulk carrier reversed and pulled free from the tanker. In order to lift the starboard side for the purpose of reducing the pollution, the tanker pumped ballast water into the port side. Due to the collision the bulk carrier was severely damaged in the bow, where the forepeak tank is located.

Photo 7.2: The tanker's hull holed after collision with the bulk carrier ship. Source: AP

7.2 THE IMPACT OF THE OIL SPILL

Only one of the 12 tanks of the tanker ship was breached in the collision. The tanker had a double hull. It was estimated that 2,700 tons of oil were spilt into the sea, and oil slicks drifted towards the Danish coast. This was the largest oil spill the country had experienced.

Less than 24 hours after the accident, a large part of the oil spill was in a 100 X 30 meter slick, and by that time it was only 20-30 meters from the coast (Falsters). According to Jørgen Rasmussen, who was responsible for the Danish rescue team operation, the worst scenario that they might face was the division of the oil slick into numbers of smaller slicks affecting a larger area.

A large part of the oil spilt submerged below the water surface, making the anticipation of drifting and its impact uncertain. In addition, this also made it difficult for the response team to contain, collect, and clean up the oil spilt.

The oil affected the Danish coastline, including the southern part of Møn, the northwestern part of Falster and two small islands - Bogø and Farø. The full impact of the oil spill on marine life and biota has not yet been assessed (at the time when this report is produced).

The coastlines are inhabited by thousands of birds. The Danish bird society (Danmarks ornitologiska förening) estimated that there were around 10,000 birds in the area. On the morning of the 31st of March, two days after the accident, many dead swans were found on the coastline. It became very difficult to estimate precisely how many birds were affected (killed/contaminated). However, a large number of birds are assumed to have been affected. According to the Danish authorities (Räddningsverket), between 100 and 200 birds were estimated dead after being smeared (covered) with the oil.

Photo 7.3: The Danish rescue team dealing with the consequences of the oil spill. Source: Sören Steffen/AP

7.3 THE OIL SPILL AND RESPONSE OPERATIONS

Immediately after the collision, six ships specialised in cleaning up oil - Danish, Swedish and German ships - were sent to the scene. The response team fought against oil both at sea and along the coastlines. Many volunteers (approx. 200 men) from the local communities were also engaged in cleanup operations.

A helicopter followed drifting oil slicks. Floating booms were used to contain the spill. In order to prevent or minimise potential oil damage, groups of people laid out floating booms at various places along the coastline.

Photo 7.4: The response team collects oil at Faro. Source: Søren Steffen/AP

The response operations were mainly constrained by the weather conditions. During the first day, strong winds and high seas (up to 4 meters high) made it impossible to collect any oil from the sea. The team expected to collect the oil that had reached the Danish coast within a week. Between the 30th and 31st of March, the Danish response team managed to collect approximately half of a 400 cubic meter oil slick, which was between Zealand (Själland) and Falster. The oil was pumped into a tanker ship and then sent away for disposal.

Because of the thickness of the oil, it became very difficult to pump up the oil that had thickened due to low temperatures, in particular during the night. In order to collect the oil, the response team had to warm it up first.

In order to avoid similar accidents in the future, a number of organisations, among others the WWF and the Danish Pilot Association, requested that piloting should be made obligatory for all ships passing Danish waters.

7.4 LESSONS TO BE LEARNED FROM THE EVENT

The event demonstrated that containing and collecting oil spilt at sea is very difficult. Due to the prevailing weather conditions, i.e. strong winds, high seas and strong currents, at the time of the event, the oil slicks drifted towards the Danish coastline and affected it seriously. Other areas, including Öresund's coastlines, could also have been affected by the oil spill. Within a few days oil slicks could have reached Öresund. Similar events are likely to occur in the south of Öresund. Each year approximately 100,000 ships, which enter or leave the Baltic Sea via the Kiel canal, Stora Bält or Öresund, pass the south of Skåne.[85] Such events pose potential threats to the Öresund area. The oil could be driven by SSE, S, SW and SSW winds, which are dominant in the area, and seriously affect the fragile marine environment.

The event showed that a thick and submerged oil spill is very difficult to deal with. Given the environmental conditions, such as low temperatures and ice conditions, and given that various types of oil are carried through and nearby the area, more effective and efficient methods and means should be sought for containing, collecting and cleaning up oil spills in Öresund.

The lives of many birds could have been saved. Large concentrations of birds in the areas that were expected to be threatened could have been dispersed. Therefore, methods and means should be found to scare and "evacuate" birds, and other inhabitants as well, away from the area immediately after an event that may lead to an oil spill has occurred. The birds have to be kept temporarily away from the affected area. Some of the following means could be used: small low-flying aircraft, fast light boats, all-terrain motor vehicles and fixed devices installed in the most exposed and/or sensitive areas.

[85] http://www.mil.se/marin/mdo/sjoc.htm, 2001

8 SOME MEASURES FOR INCREASING SAFETY

There are two information sources for this chapter. The main source is the previous chapters, including references to the findings in other Sundrisk projects. The other source is some interviews with persons who are or have been active in the area of maritime safety.

8.1 SOME APPROACHES TO IMPROVE SAFETY

The aim of risk management is to prevent and control undue risks. There are various measures (approaches and means) to deal with risks. Table 8.1 presents the main categories of these measures. The "non-regulative" category includes any voluntary risk-prevention or reduction measure. The suggestions provided in this part of the report, which are not presented in any particular order, fall into one or a combination of the following categories.

<table>
<tr><th colspan="2" rowspan="2">Categories</th><th colspan="2">Measures</th></tr>
<tr><th>Regulative</th><th>Non-regulative</th></tr>
<tr><td rowspan="2">Measures</td><td>Preventive</td><td colspan="2" rowspan="2">- Technological: e.g. hardware, software, IT.
- Methodological: e.g. risk-related data and information, methods, techniques and tools for casualty investigation and risk analysis/assessment/management.
- Operational/functional: e.g. cargo handling, navigation, piloting, pollution prevention response.
- Managerial: e.g. risk management, ship-shore management.
- Economic: e.g. market-based economic incentives that prompt desired changes in industrial decisions and people’s behaviour.</td></tr>
<tr><td>Control/remedy</td></tr>
</table>

Table 8.1: Categories of safety measures

8.1.1 Preventing or reducing major contributors of oil spills

Collision, grounding and contact events have a higher probability of exposing the Öresund area to “major” oil spills causing fatalities and severe damage to the marine environment than other categories of events. These events were responsible for the majority (89% or 31/35) of oil spill events in Öresund. 11 out of 12 "large" oil spills were due to groundings, collisions and contacts. Events such as fire, hull/watertight failures, listing/capsizing and "other" events have shown a lower frequency of occurrence. In order to prevent major oil spills in Öresund, efforts should be concentrated on *prevention or reduction of groundings, collisions and contacts or a minimisation of their effects*.

8.1.2 Database improvements

Öresund is made up of partly Danish, partly Swedish and partly international waters. Both on the Danish side and, especially, on the Swedish side, responsibility for the safety in Öresund is distributed among different authorities depending on what risk aspects are considered. The statistical information is also split up into different databases, and there are differences in the routines as regards what information should be collected, how it is collected and how it is structured. This makes it *difficult to get a total grip of the safety situation in Öresund.*

A large part of this study is based on local empirical data collected from three different databases, each of them providing a data set. For the purpose of risk analysis, these data sets were pooled together. However, they were pooled for the purposes of qualification (exploration) only. Quantification of all data in one single data set was not possible. The databases were incomparable and each of them has shortcomings such as insufficient data and lacking or missing data. A considerable number of variables and cases displayed various degrees of missing data, ranging from a few to a large number of missing data. Variables with a large number of missing data were: "ship's particulars" (e.g. size, age), "weather hazards", and "consequences", e.g. extent of damage and leakage. The extent of the consequences was simply limited to the fact that an oil spill had occurred. With a few exceptions, the amount and type of oil spilt into the sea were not reported. The amount of oil spilt is expressed in qualitative terms only, for example- "minor" and "large" spills. The impact of oil to the fauna and flora of Öresund has not been shown in the databases.

Data-related shortcomings affect the entire risk management process, including analysis, the outcomes of analysis, evaluation and decision-making. By examining empirical data from the three databases mentioned above, categories and subcategories of causes and contributing factors of events leading to oil spills in Öresund were identified. However, because of data limitations, it was not possible to allocate the amount of influence of causes and contributing factors for each category of events. It is always possible to take safety measures that could further reduce risks, but such measures could be so expensive that they exceed the expected benefits. The employment of effective and efficient measures requires the identification of the most influential factors (i.e. quantification) of risks, which, in turn, is possible if more and better data are available.

The best and easiest way to retrieve empirical data for risk analysis is to retrieve data from one single database. One single oil spill database could be created for the Öresund area. Large federal countries consisting of many states, for example the USA, record all events leading to or having the potential to lead to oil spills in one single database. The creation of *a joint maritime risk database for Öresund* is therefore recommended. If this is not feasible, the databases of either side should, at least, be comparable.

In the context of regional standardisation of statistics, Danish and Swedish statistics ought to be *collected and structured in the same way* to be easily comparable. Why is this feasible for marine events and other related statistics? First, IT developments provide a good opportunity to overcome a number of technical barriers. For example, the Internet may allow double records of compatible data on each respective database. Another alternative is the usage of a single main frame (database), where both sides may store data independently. Today computers allow the storage of large amounts of data. Secondly, both countries, Sweden and Denmark, share common interests, among others for "safer and cleaner seas." Thirdly, the present and historical relationships between the two countries are such that they make co-operation and co-ordination much easier.

The oil spill database(s) should be a part of a larger database containing records of all events, including all categories such as accidents, incidents and "near missings", involving: a) marine transport/navigation; b) marine transport related activities, such as loading, unloading, bunkering, storage and other activities; c) all dangerous materials and substances: oil, oil products, chemicals and other dangerous goods carried in packaged form (class 1-9).

Compared to some other databases, local databases, in particular the Swedish Maritime Administration database, are among the best. However, they have their own limitations and still need further improvements. The following improvements for getting *better and more data and information* are suggested:

- Avoid missing data. As mentioned earlier, numbers of variables/cases had missing data to various degrees. Whenever practically possible, efforts should be made to complete variables/cases with all the information requested. For example, the amount and type of oil or dangerous substances spilt should be recorded in each and every case.
- Additional data/variables. Additional variables may be designed and incorporated into the database(s). Such variables will improve the measurement of risks to the environment, people and property of oil and other dangerous cargoes, including the following variables:
  - the amount and types of cargoes/bunker oil carried aboard
  - the size of the area affected expressed, for example, in km (coastal lines), square metres/km (surface of the sea)
  - the fauna and flora affected
  - estimated risk costs.

Other important data and information not necessarily related to marine events should also be gathered and incorporated into the database(s):

- Vessel traffic in Öresund
  - types, sizes, flags, and numbers of ships;
  - types and quantities of cargoes and bunker oil;
  - directions of traffic – north/southbound, east/westbound and others.
- Ports/terminal activities
  - Ship calls: numbers, types, flags and cargo.
  - Cargoes handled and stored: amounts and types.

Data should be gathered on a regular basis and recorded in a specially designed database. Organisations such as the Coast Guard, statistics institutions, port authorities and shipping companies may also contribute to this database. The data should be readily accessible and used in conjunction with risk analysis, assessment and management.

Why a better database?

- ***More and better data***
  - ***Better risk analysis/assessment***
    - ***Better risk management – decision- making***
      - ***Safer and cleaner waters – in a cheaper way***

Figure 8.1: Database improvements

In order to take full advantage of experiences of marine events in other parts of the world, *definitions and concepts should be adjusted* or aligned to those of major international and national organisations that collect, compile and analyse marine events, including organisations such as the International Maritime Organisation (IMO), Lloyd's Register of London, Insurance Clubs (e.g. P&I Club, UK), the US Coast Guard and Den Norske Veritas (DNV).

When creating such a new information system the latest new technology should be used. At the present time, much statistical information is accessible to users only after a number of months. Today's technology makes it possible to reduce this to days if the system is constructed in appropriately and if people in the organisations concerned have all agreed upon *rapid updating* and act accordingly.

Rapid updating becomes more important when we have new circumstances , e.g. changing flows. Since its opening, the Öresund link has considerably changed the traffic flows crossing Öresund, in terms of both cargo and passenger traffic. The need for authorities, transportation firms, companies, researchers and others to obtain an accurate view of the new risk situation quickly and efficiently is also changing considerably. Such a need will exist for years to come, because the opening of the Öresund link will have an impact for many years to come. Rapid updating of the joint database is, therefore, quite important. So is *easy access*. To be able to have access to the information in the database online, by the Internet for example, is advantageous.

To sum up: the development of a joint, well structured, rapidly updated, and easily accessible maritime risk database for Öresund should be considered *very important*.

8.1.3 Better navigation aids in Öresund

Findings suggest that a large number of marine events resulting in oil spills in Öresund are due to navigation related problems. In combination with other causes and contributing factors such as human, weather and technical problems on the ship side, the navigation aids in Öresund may have contributed to a number of groundings and collisions.

There have been too many groundings in Öresund, accounting for 43.5% of all marine events. They have contributed to 60% of the total number of "accidental" oil spills in Öresund. The locations with the highest number of groundings are Landskrona, Valgrundet, Flint, Lillgrund, Dragör, and Middelgrund. Approximately 9% of the groundings occurred within a very confined area with a radius of 0.5 nautical miles NNE of the Valgrundet lightbuoy.

Ships have often grounded because they have lost their orientation, in particular in bad weather conditions, such as poor visibility, strong winds and high seas. Strong winds and high seas have caused cluttering effects on the ship's radar. Masters and watch-keeping officers have lost visual contact and radar references. Because of the cluttering effects, fairway marks or lights have not been seen on the radar. In a number of cases, because of many different lights in the background, such as the lights of towns and cities, masters or officers have mistaken or mixed up marks, buoys, and lighthouses. In a number of cases, failures of navigation aids, such as missing or moving buoys and marks or lights of buoys extinguished are reported to have contributed to groundings.

Measures which may improve navigation in Öresund, may include:

- better light houses, buoys, marks, for example, by improving the size, shape, arrangements, lights and sound characteristics;
- additional lights and marks, if necessary;
- regular maintenance and control of the navigation aids.

8.1.4 Better control and monitoring of the navigation situation

Knowing the basic facts about where a ship is, its speed, where it is heading, the name of the ship and its cargo must be of the utmost importance to all parties concerned, not only to the ship itself but also to other ships coming in its way and to authorities responsible for maritime safety. *Efficient sea supervision is essential* for safety at sea.

In his study, Olsson (1999) has looked at different sea supervision systems. Such systems are becoming more frequent today. They are used in marine areas with heavy traffic and a difficult navigation situation. The systems can be more or less advanced and more or less compulsory. One type of frequently used system is the vessel traffic system (VTS).

Both Swedish and Danish VTSs could play a key proactive role in accident prevention. This requires constant surveillance and control of the situation in the Öresund waters and their vicinity, which, in turn, facilitates immediate responses. State-of-the-art radars, cameras, communication devices, patrol boats and other means can be used to:

- identify and provide assistance to ships that have lost their orientation;
- identify, communicate with and provide immediate assistance to ships experiencing machinery problems/breakdowns; ships should be advised to report any defects, damage, deficiencies or other limitations, such as failure or breakdown of steering gears, propulsion plants, electrical generating systems, essential shipboard navigational aids and other problems that may affect safety and the marine environment; the category of "machinery" was the second most frequent category of events in Öresund (19% or 45/239); over 75% of these events led to either groundings or contacts; one fourth of the

"machinery" events led to grounding; given the favourable weather conditions in Öresund characterised by relatively low or calm seas, immediate and effective assistance can prevent ships with machinery problems from running aground, contacting or colliding with other ships;

- identify and promptly seize ships acting recklessly; reckless behaviour and actions, such as maintaining a high/excessive speed, sometimes in very poor visibility conditions, have been responsible for a number of groundings and collisions leading to oil spills and threatening the lives of many people;
- identify improper navigation; communicate and advise proper navigation, if necessary intervene by sending fast patrol boat(s) to the scene; the purpose is to prevent or remedy situations that are often reported to have caused or contributed to groundings and collisions, such as:
  - ships failing to set and maintain an appropriate course; they have, either knowingly or unknowingly, been keeping the wrong course; the wrong course may either be given to the helmsman or set on the autopilot;
  - ships steering too far from their own side of the fairway;
  - ships steering on the wrong side of the fairway; sometimes, in order to avoid a possible collision with small ships, for example yachts or fishing boats, large ships including tankers and ferries have been forced to manoeuvre and sheer off the fairway and have subsequently run aground;
  - ships changing their course too early ("cutting corners") or too late, or even failing to alter their course altogether.

Öresund is an area with heavy traffic and a somewhat difficult navigation situation. At present, there is one VTS active in the Helsingborg-Helsingör area and one outside Malmö (VTS Flint). During the construction of the Öresund link two VTS systems, VTS Drogden and VTS Flint, were active between Malmö and Copenhagen. The experiences were good, but the costs of keeping the systems going 24 hours a day every day around the year were also high. VTS Drogden was closed down when the construction work was finished on the Danish side at the end of the 90s. VTS Flint was closed down in the spring of 2000 but was opened again after a couple of weeks, although in a less ambitious version.

One problem that was experienced by VTS Flint was that on some of the ships the crew's knowledge of the English language was very poor, which created communication problems between VTS and the ship.

A land-based supervision system that could cover the whole of Öresund and guide ships through Öresund would be costly but would also increase safety in Öresund. One way of reducing the costs could be to collaborate with the already existing military VTS systems in the Öresund area.

8.1.5 Giving away free of charge equipment for transponder systems

In the long run, very advanced new technology like *transponders* on each ship that automatically send information via satellites will make it possible for each individual ship to get precise information about what other ships are in the area, their exact position, where they are heading, their speed, the size of the ships, their cargo, how to contact them and so on. The supervision of the sea could then be conducted mainly by the ships themselves. The introduction of such a system has been decided upon by IMO recently and will gradually take place. This will lead to a substantial increase in safety in Öresund.

Even today some of the ships in Öresund have transponders. This is of course good, but the full effect on safety will only be in force when all ships are equipped with transponders. This will probably take a long time, since some countries, e.g. Russia, the Baltic States and Poland, will not be able to afford to invest in transponder systems for many years. At the same time, this is where we find most of the potential risks, because many ships from these countries are old and some of them may be in bad condition. To give away new transponder systems could be an effective way to quickly raise the safety level in Öresund.

But why should Swedish taxpayers pay for something that should be paid for by the shipping lines themselves? Because the taxpayers could get much more value for their money, i.e. increase in safety, than if it was spent inside Sweden. This is the same kind of argument that has been used in the efforts to make the Baltic sea a cleaner and healthier sea by helping countries like Russia, the Baltic States and Poland to build new and more efficient water-purifying plants. Another example is Swedish assistance when it comes to increasing safety in nuclear power plants in Eastern Europe.

8.1.6 A mandatory ship reporting system

A ship reporting system (SRS) means that all the ships entering or leaving a certain area have to report this to a special information centre. Öresund is a very sensitive sea area of great environmental and social importance. The purpose of the SRS is to enhance navigational safety and thereby minimise the risks of maritime accidents and the resulting pollution and damage to the marine environment. The SRS may also provide the ability to respond more quickly in case of a marine accident.

The SRS should be designed so as to contribute to safety and marine environment protection. The areas of coverage should include the Öresund area, as defined in this study, and its vicinity. Three points of reporting could be designed at the entrances to the Öresund waters marked by lighted buoys located at a distance of 5-10 miles outside the area's limits: a) one buoy in the north and b) two buoys in the south - one in the SW and the other in the SE.

The SRS should interact with shipping and enable an exchange of information. On arrival at these points, ships should be requested to provide information concerning: ship details, IMO number, draught, cargo information, i.e. the quantity and type of cargo, destination etc. The SRS, in return, should provide vessel traffic information and other navigational safety-related details.

The ETA (the estimated time of arrival) at the entrance buoys should be notified 24 or 48 hours in advance. Ships should contact the station at least 1 hour prior to arrival at the buoy. They should continuously be in contact with the shore (VTS) while passing the area. Either the master or the chief officer should be responsible for the reporting. Fines could be imposed on ships failing to report and/or maintain constant communication with the shore station.

The SRS could be operated under joint arrangements between the Swedish and Danish authorities. The system has to be manned and operated on a 24 hour-a-day basis.

How may the SRS enhance navigational safety? By communicating, interacting, and exchanging information with ships the SRS will play a proactive role in enhancing safety in the area. People running the SRS may be able, for example, to:

- ensure that the bridge is properly manned throughout the passage; it should be requested that the bridge of the ship should be manned by at least two persons; one of them should be either the master or chief officer; for small ships, such as yachts and fishing boats, the master or the second person in command has to be present on the bridge, since is difficult for a single person on the bridge to navigate safely through a risky area such as Öresund. While navigating, many things should be done, sometimes simultaneously, e.g. maintaining an appropriate look-out, maintaining and changing the course appropriately, checking out the vessel's position, communicating and handling unpredicted situations;
- advise hand steering; over- reliance on the navigation equipment, such as the autopilot and GPS, is a problem; in many cases, ships steering with an autopilot in Öresund have run aground;
- prevent watch-keeping officers and masters from falling asleep; in a number of cases, ships have run aground, in particular in the northern part of Öresund, because officers or masters have fallen asleep; being under the obligation to report at the designated reporting points and maintaining contact while transiting through Öresund, watch-keeping officers, master and other personnel will stay alert;
- detect unfit bridge personnel; communication may reveal whether the bridge personnel are fit and personnel unfit due to intoxication, for example, may be detected; in order to prevent marine accidents caused by reckless actions by intoxicated people, Swedish and Danish authorities should carry out regular checks on ships' personnel for alcohol consumption, targeting in particular fishing vessels and small pleasure boats.

The more ships that report to an SRS in Öresund, the safer it would become. Therefore, it is recommended that such a system should be mandatory for at least certain categories of ships passing and/or calling at port(s) in the Öresund area.

8.1.7 Free pilot service

Pilots are available on a 24-hour basis at several places along the Öresund coast. The pilots are experts on the navigational conditions in Öresund and can therefore, in co-operation with the crew, who are experts on their ship, contribute to a safer passage through Öresund. Today, pilot assistance is compulsory for very large ships and recommended for some other types of ships. It is costly to employ a pilot, and many ships avoid that cost, although they could benefit from the assistance. Lowering, or even eliminating, the pilot fee would probably mean that many of the ships passing Öresund might ask for pilot assistance. The presence of a pilot on board a ship may also eliminate some of the communication problems between the VTS central and the ship. Therefore, it would increase safety in Öresund.

8.1.8 Traffic separation

Head-to-head situations are a big problem. Traffic separation is one way to reduce the risk of head-to-head situations that is being increasingly used. One example is the English Channel, where the number of accidents has decreased substantially since the introduction of traffic separation in the channel in 1971 (Dover Strait). Today traffic separation in Öresund exists in the Falsterbo area and in the narrowest part of Öresund (the Helsingborg- Helsingör area). An area of traffic separation for the whole of Öresund with, for example, the northbound traffic on the Swedish side and the southbound traffic on the Danish side, would more or less eliminate the risk of head-to-head collisions.

One disadvantage of this proposal is that for many of the ships the passage of Öresund would take somewhat longer, because there will be an increase in the distance that they have to travel. Another disadvantage is that traffic separation would affect the present shares of piloting and also bunkering and other supplies between the Swedish and Danish sides. Today most of the traffic and thus of the piloting and bunkering is on the Danish side, and the Danish side naturally wants to keep its market shares. But this problem can be solved by closer co-operation between the Danish and Swedish sides, for instance by creating joint organisations that operate in the whole Öresund area. One example of a measure taken in this direction is that from 1 January, 2001 the Malmö and Copenhagen harbours are acting as one big harbour operated by a new organisation owned by the two harbours. The consequences of traffic moving from one side of Öresund to the other then become less severe, since the total turnover for the new joint organisation is not affected.

8.1.9 An international conference for a new "Öresund Treaty"

The main objective of the Öresund Treaty (Öresundstraktatet) was to guarantee free passage for all ships without having to pay any customs. In the treaty safety matters were not considered, although they are important. In several cases, ships have run aground, later been floated or been pulled free by their own power and left the area without reporting. There are also cases when ships passing through Öresund have kept completely silent and not communicated at all. Why? Some of the reasons might have been: crewmembers, masters and officers might have been under strict orders not to communicate with coastal state authorities; communication equipment might have been out of order; poor seamanship, for example, masters or officers may have forgotten or been unaware of the obligation to keep radio communication contact with other ships and shore- based stations. Therefore, it is reasonable that responsible authorities in Denmark and Sweden should have the possibility to fully exercise the rights of the coastal state to prevent and intervene in the case of an environmental threat.

Today, about 150 years after the treaty was signed, safety and environmental matters are very much in focus. A new international conference will therefore have to be arranged, where those issues will be the starting points for a revised international treaty on Öresund waters.

8.1.10 A "plan B" for the risk consequences of a closedown of the Öresund link

We already know that the Öresund link will be closed down on certain occasions, for instance when the wind is very strong or when there has been an accident on the link. Hopefully, it will be closed just for a couple of hours. This will of course disturb the flow of traffic using the link, but it will probably not mean that people and goods will use alternative ways. But, if there were a closedown for more than a couple of hours[86], this would be the case. There could

[86] The Öresund link was for instance closed down for lighter vehicles for 30 hours between 30th and 31st of October 2000.

be a severe car accident, a lorry transporting oil products starting to burn in the channel part or an oil or chemical tanker in collision with the bridge that catches fire. The last case would suspend traffic not only on the bridge, but also under the bridge (the Flint channel will have to close), and it could take several weeks to return to normal operations.

A breakdown in the Öresund link that is longer than just a few hours would mean that the amount of goods and passengers that would have passed the link during that period will have to go somewhere else. To begin with, the excess capacity of existing ferries and ferry-lines will be used, but this will not be sufficient if there is an extended breakdown. New ferries will have to be brought in and perhaps it will even be necessary to start new ferry lines .

This raises a number of safety-related questions like: What are the consequences of a sudden, very intense use of the existing remaining capacity for crossing or passing through Öresund? What are the consequences of new ferries being put into use or new ferry lines being started? Vital questions in this context are, for instance, What is the safety level of those ferries that are free on the market and can be hired on short notice? How well are the harbours and the rest of the infrastructure prepared to adapt to those ferries and the increase in flows?

It is advisable to develop in advance a “plan B”, or rather a number of B plans, for different situations, including the closure of the Öresund link for a shorter or longer time period. This will affect the flows and thereby the risks in Öresund. Therefore, it is important to develop ready-made action plans and have them in place to handle any kind of situation.

8.1.11 An open ship register

Hägg (2000a) points out that a considerable number of substandard ships pass through Öresund every year. These ships are very often in bad condition and have a crew of low quality. The *substandard ships are a threat* to the crew, to other ships and to the marine environment. This is a problem that is also mentioned in several other Sundrisk reports. The “Freedom of the sea” gives the coast states very limited possibilities to take direct actions against ships that do not fulfil the level of standard that the coast state finds reasonable, at least not as long as there has not been an accident.

The work to improve safety at sea by means of stricter regulation has to go through international organisations like the IMO (International Maritime Organisation), and this normally takes a considerable amount of time. Effective implementation of the regulations is also often hard to execute. Hägg (2000a) discusses the possibility of working through stimulation of voluntary actions. He suggests starting an open ship register for mainly those shipping companies that have traffic in the Baltic and Öresund areas. In exchange for taking into consideration the shipping companies’ wishes when it comes to labour, risk capital and taxes, increased demands can be placed on the shipping companies as regards the implementation of sea safety standards and general safety at sea.

8.1.12 Mitigating oil spills - effective and efficient methods

A fast response is vital in minimising the effects of an oil spill. The time available to contain a spillage in Öresund is very limited. Because of the prevailing weather conditions (winds and currents) and the narrowness of the waters, it will take only a few hours, if not less, for a spill to reach the shore and spread to the entire area. The entire area is a "hot spot." No matter where in Öresund an oil spill has occurred, the entire area may be affected, in particular in the case of a "large" ("major") oil spill. Given the quantities and various types of oils carried through and near the area, more effective and efficient *methods* and means should be sought *for containing, collecting and cleaning-up oil spills* in Öresund.

In the collision event between two ships – the Baltic Carrier and the Tern (Chapter 7), the oil spills became thick and submergible due to the low temperature, which made it very difficult to deal with, i.e. to contain, collect and clean up. The event illustrates that there are occasions where it is not possible to collect the oil, at least not immediately. Since there are large concentrations of birds in the Öresund area exposed to threats from oil spills, *methods* and *means* should be found *to drive birds* and other inhabitants, if possible, *away* from the area immediately after a marine event, for example, grounding, collision, or fire/explosion which may lead to an oil spill.

8.1.13 Special efforts for tankers

Events involving tankers may be liable to major spills and fatalities. Measures should be taken to reduce groundings and collisions with tankers. Tanker ships carrying oil and oil products and chemical tankers were frequently (93% or 21/23) involved in grounding, collision and contact events. Every tenth collision involved a tanker ship. A collision between a tanker and a passenger ship has not been reported but is not unlikely to occur. Such a collision may cause a large number of fatalities and must therefore be avoided.

The safety measures may include *mandatory pilotage for tanker ships*. The size limits and types of cargoes could be determined. A preventive measure for avoiding collisions between tankers and other types of ships may also include *giving precedence to tankers*. Tankers, in particular large tankers, regardless of whether they are loaded or not, should be given precedence while passing or calling at ports in the area. Collision situations with tankers must be avoided, even by temporarily halting other kinds of traffic, in particular passenger traffic.

8.1.14 Introducing ATC systems for ships

The same technology that is used today for railways, called ATC (Automatic Train Control), can also be applied to ships in the future. The ATC system used on trains means that the engine driver is only in command of the train as long as he keeps to the rules. If, for example, he drives too fast or fails to stop where there is a “red light”, the ATC system, after having sent warnings to the driver automatically, takes control of the train if those warnings are neglected. The system may either stop, or more suitably, slow down the speed of the train. An automatic ship control system working by means of satellites may also play a similar role for ships. By continuously checking on the position and speed of each ship in the area, for example, and comparing that information with maps, the system may warn ships’ personnel of such dangers as shallow waters. This technology has turned out to be very efficient in reducing the number of accidents in railway transport. The same kind of technology applied to shipping may lead to a reduction of the number of collisions or groundings.

In a more advanced version, this technology could also be used to operate ships from land via satellite. No crew will then be needed on board the ship, which means that the crew will not be injured or killed.

8.1.15 Some other suggestions

1. When it comes to oil pollution, the focus is very much on oil tankers, but practically every ship passing or crossing the Öresund is carrying bunker oil. The consequences of an accident are less likely to be severe, but the probability that there will be an accident is higher. It is therefore important that we do not neglect the bunker oil problem. Consequently there is a need *to be aware of bunker oil* and bunker oil spills and to follow up those cases carefully by means of separate statistics.

2. Bad air quality constitutes a threat to human beings, and to people living at or near Öresund air emissions from the bunker oil of ships crossing or passing through Öresund constitute one important source of air pollution. The quality of the bunker oil affects the size of the pollution, and there is a wide range of bunker oil qualities. Pollution is also affected by the existence of a purifying system and how advanced it might be. *New regulations* and incentives must be introduced in order *to decrease air emissions from bunker oil.*

3. A new type of ship, high-speed ferries, often in the shape of catamarans, is coming into use. The catamaran Felix, which was used in the ferry service between Limhamn and Dragör, is such an example. We do not have much experience of these ships yet, but it seems that Felix has had many incidents reported. This could have been a temporary problem, but we do not know for certain. Another question is what the long-term environmental effects will be. There is a debate going on about the impact of high-speed ferries on the environment. Hence, for different reasons there is a need *to be aware of* those *high-speed ferries* and follow them up carefully by, for example, separate statistics.

4. Illegal oil spills, sometimes in large quantities, have occurred in Öresund. Identification of ships discharging oil has not often been possible, and probably will not be in the near future. Fixed or movable *devices that may sense chemical presence and changes in water* contents, biota and sediments could be installed in the Öresund area. Such devices will enable detecting deliberate discharges into the sea of any size of oil or chemical. In addition, they may provide an on-line assessment of the status of Öresund's marine environment.

5. Speed has been an important factor affecting the extent of damage sustained after a grounding, collision, or contact event. *Maintaining "manoeuvring" rather than "sea" speed* throughout the passage is important. In the case of grounding, the ship will land gently. In poor visibility the speed should be further reduced.

6. In order *to maintain and improve a ship's manoeuvrability*, the main engine should be switched from heavy fuel to diesel oil. A second, or even a third, auxiliary engine should be switched on. Case histories have shown that in a number of cases ships have experienced a total blackout. Many of them have subsequently grounded or contacted piers or other ships.

7. In order to cover environmental risk costs and restore environmental damages, *fines could be imposed* by the responsible authorities in the coastal states (Swedish and Danish) on ships involved in a marine accident or incident, regardless of whether this has resulted in marine

environmental pollution or not. The ship has to be found (or judged) liable for the event. The amount of money, expressing environmental damage in monetary terms, should be claimed from the liable party(ies) and invested annually for the prevention, reduction and mitigation of oil spills in Öresund.

8.2 BENEFITS AND COSTS

The safety-increasing measures discussed above involve costs. Consequently, the question that we have to consider is: Will the value of the rise in safety be higher than the cost of providing the action? A *cost/benefit analysis* has to be conducted for each action.

Several of the proposals will have effects outside the Öresund area. Transponders, for instance, are useful more or less all over the world, and not only in Öresund. The benefits of the action will be spread outside the Öresund area. Another aspect linked to some of the suggested actions is that they could speed up the introduction of new international standards. This is, for example, the case with transponders and a joint database. In those cases as well the benefits of the action are *spread outside the Öresund area.* This kind of effect must also be considered when comparing the costs for and benefits of each of the proposed measures to improve safety.

Öresund waters consist of Danish and Swedish waters and some small areas of international waters. It is not possible to pass through or call at a harbour in the Öresund area without using Swedish and/or Danish territorial waters. This means that the Danes and the Swedes can execute some kind of control of the Öresund region. In order to achieve the full effect of actions, they have to be agreed upon by both the Danish and the Swedish sides and preferably *be jointly executed.*

The above suggestions can be said to be based on new and advanced technological developments and standardisation. New technology, e.g. transponders, creates new opportunities for increased safety, but investments can be heavy and difficult to handle, especially for the owners of old and substandard ships. We know, however, that prices will normally go down as time goes by. Standardisation, i.e. agreeing on a common standard, increases the safety enhancing value of an investment progressively, because the more units such as ships, companies and authorities that use the same standard, the higher the safety enhancing effects. Successful standardisation also means mass production and therefore lower production costs and a lower price.

Other ways to distribute the proposed measures are those using negative incentives, like new compulsory laws and regulations, and positive incentives, like subsidies for investments in safety-enhancing new technology. Negative incentives usually take more time but can be very efficient if generally agreed upon. Positive incentives can yield safety-enhancing effects much faster, but the effect might be temporary and not very potent. Both ways are recommended, and they can be seen as complementary to each other.

Traffic is extremely heavy in Öresund waters, and many different types of ships, sizes of ships and flags are seen in the area. This creates a complex and risky situation. A large number of ships passing through Öresund do not sail under Danish or Swedish flags. This means that the possibilities for Danish and Swedish authorities to act are restricted, at least as long as there has not been an accident. The possibilities of proactive safety work and safety actions are limited, but, as can be seen from the above list of suggested measures, there are also *many actions that can be implemented.*

9 RESULTS AND FINAL REMARKS

9.1 DIFFICULTIES IN ANALYSING

In this study a number of data bases have been used. Risk-related data and information, consisting of numbers of data sets, were not be provided by a single source. One reason is that Öresund is the water between two individual countries and subsequently two countries are directly involved: Denmark and Sweden, each keeping their records. Since the data about oil spills in Öresund is limited we have also chosen to use additional data sets on a regional (Baltic Sea area) and world scale. These choices have created a number of methodological and practical problems.

A detail analysis of oil spills risks in Öresund required collection of data sets from a number of sources. The purpose of collecting and combining various data sets was to: a) fill the gap and b) extend data. Depending on the nature of data, data sets can be used separately (primary and secondary data sets) or as a single merged data set. The best alternative was to use all available data as a single merged set, but with the current sources merging data sets presented problems and limitations as the fit among sets was imperfect. Definitions, descriptions and units/values of data did not perfectly agree.

9.2 CONCLUSIONS

9.2.1 Marine oil spill events

Dangerous cargoes could be involved (spilt/released) along the course of marine events, if not involved in the initial event. All categories of events had a potential to cause an oil spill. However, the following categories of initial events were directly liable for oil spills in Öresund: grounding, collision, contact, hull/watertightness failure and listing/capsizing. In the later cases ships have foundered intact, assuming that a foundered ship might have caused an oil spill. There are many world-wide experiences where oil still leaks daily from ships sunk many years ago.

Oil spills may also result from operating activities in ports/terminals, such as loading, discharging, bunkering and other operations. Deliberate oil discharges are also a concern.

The oil spills in Öresund (1985-1999), their causes, contributing factors and consequences thereof, share similarities and differences with oil spill events that have occurred around the world. Categories of events which led to oil spill were generally similar, but with different frequencies of contribution. Thus, the grounding events contributed to 60% of oil spills in Öresund compared to 32% of world major oil spills. With reference to ITOPF world oil spill data 1974-2000 (see table 5.1, ITOPF, 2001), 50% and 83% of large oil spills - of the ranges 7-700 tonnes and 700 tonnes and above respectively, were due to marine events, where groundings and collisions were the largest contributors. Compared to world-wide events, "hull/watertight failure" and "foundering" events have occurred at a lower frequency in Öresund. Most of major oil spills events were followed by one or two subsequent events. The oil was often spilt after the initial event. For example, 4 out of 8 grounding events, which led to the world major oil spills, were followed by either fire (3 cases) or explosion (1 case). Ships had disintegrated and in one case foundered. None of the groundings in Öresund led to either fire or explosion.

9.2.2 Causes and contributing factors

Grounding, contact, collision, hull failure, machinery and listing/capsizing events were the main immediate causes of oil spills in Öresund. Groundings were the most frequent events causing oil spills. 60% of oil spills in Öresund were due to groundings. However, given certain circumstances, such as: the number and type of ships involved (e.g. tanker and ferry), forces exerted, positions of the impact, hazards released (e.g. fire/explosion), collisions are liable to cause larger oil spills and pose serious threats to human including people ashore and passengers and personnel aboard ferries, environment and properties.

Most of marine events were as the result of a combination of actions and circumstances, all of which contribute in varying degrees to the outcome. Causes and contributing factors of the above marine events were: human, technical, weather/sea and other related factors (such as vessel traffic), where the human related factor was dominant. Because of their sharing influences, it becomes very difficult to determine and allocate the amount of responsibility (influence) of each category of causes and contributing factors to marine events and oil spills.

Öresund is a very risky area for navigation mainly due to shallow and confined waters, poor visibility and the density of the vessel traffic. Generally, the pattern of the frequency of marine events matched the pattern of changes in the vessel traffic in Öresund. Any change in the vessel traffic may influence the frequency of marine events, which means: as the vessel traffic in Öresund increases, so does the number of marine events. This may subsequently affect the increase of oil spills. Therefore, preventive counter measures should be taken in order to reduce the frequency of marine events in Öresund, in particular groundings, collisions and contacts.

9.2.3 Claims

The cost of the worst oil spill scenario in Öresund is estimated to US$ 300 millions. The average risk cost of "large" oil spills each year in Öresund is estimated to US$ 223,500. However, this figure does not include "operational" oil spills resulting during loading, discharging, and other oil-related activities.

The figures should be treated with caution as they are based on the estimation of the amount (tonnes) of the oil spilled in Öresund in the past (1973-1991) and the claims estimated per one ton of the oil spilled in case of a major oil spill on a world-wide basis.

Because of prices and "social" inflation, claims have increased over the time. Higher claims are expected in the future. Given the particular characteristics of the Öresund area, in the case of a major oil spill, the extent of consequences may be severer and claims may be higher than suggested.

9.2.4 Safety-increasing actions

More than 20 suggestions for safety-increasing actions are presented and discussed in chapter 8.

The choice and implementation of different safety-increasing actions is done within risk management. One challenge in risk management is to see all the advantages and disadvantages in new technology. Another challenge is to get a holistic view of the different actions and not only judge one action at a time because there is very often links between them. A third challenge is to judge which actions that have political dimensions and which have not and adapt the arguments to that. A fourth challenge is to judge which actions that need collaboration across borders and finally a fifth challenge is to make a realistic valuing of how much money and effort the different parts including maritime authorities, harbours, coast guards, shipowners, carriers and politicians are prepared to spend on safety-increasing actions.

9.3 THE RESULTS RELEVANCE FOR OTHER DANGEROUS CARGOES THAN OIL

The Öresund area is not only exposed to hazards oil spills resulting from marine accidents and operational activities such loading, discharging or bunkering. The people, environment and properties in the area are is also exposed to hazards of a variety of types of dangerous cargoes and other activities than transport. The cross-table 4.1 (chapter 4) shows the types of ships involved and initial events. Based on their main groups and types, ships could be divided into: passenger, dry cargo, tankers, barge and other category. Although the current data has not shown any major event involving other dangerous cargoes than the oil, Öresund is also exposed to:

Liquid chemicals carried in bulk. 10 of 24 tanker ships were chemical carriers, where more than half of which were involved in grounding events. If spilt at sea, chemicals are very difficult, if not impossible, to contain and collect. Given their properties, chemicals may cause wide spread damage to marine biota and fauna even when they are spilt in small quantities.

Packaged dangerous goods (PDG). A large numbers and divers types of PDG are carried daily through Öresund waters by different types and sizes of ships. They are also handled and store in Öresund ports. At least, 1/3 of the total number of ships involved in marine events in Öresund (1985-1999) were cargo ships which might have carried dangerous goods in packaged form. Events involving PDG may cause or pose threats to:

Marine environment pollution due to:

- Losses of individual packages, such as containers and other types of packages lost overboard due to heavy rolling or listing, collision, contact. No such event has been reported in Öresund.

- Foundering of ships with PDG. According to SMA data, out of three ships (two fishing boats and one "other" ship) reported foundered during the period 1985-1999, only one (a small fishing vessel) was foundered within Öresund waters. Given the water depths, medium and large ships are unlikely to be foundered in Öresund.
- Water ingress into cargo spaces as a result of events such as grounding, listing/capsizing, hull/watertight breach or failure, collision, contact, and fire fighting water. This category of events is more likely to happen in Öresund.

Unless they are damaged, packages with dangerous goods lost at sea could be identify and recovered without causing any serious environmental damage. But, if damaged and the dangerous contents is lost at sea, given their hazard properties (as some of them fall in the category of severe marine pollutants), PDG will be liable for a "permanent" damage to a large area. Many substances and materials carried in packaged form cannot be contained and collected from the sea.

Human health and safety - fatalities and injuries due to:
- Fire and explosion associated with toxic fumes and gases.
- Inhalation of toxic fumes and gases released from damaged packages.
- Contacts, for example, with corrosive materials.

No fatality or injury has been reported due hazards of materials and substances carried in packaged form in Öresund. However, world experiences have shown that events such fire, explosion and release of toxic fumes may cause health and safety problems to the ship personnel and beyond, including passengers, stevedores and other people, damage to ships and properties in ports and a mass evacuation of the local community.

Causes and contributing factors. The main categories of causes and contributing factors of events involving PDG are:
- Marine events: e.g. grounding, collisions, contacts, hull failures, fire/explosions, listing capsizing.
- Technical: e.g. packaging design, material, construction failures.
- Operational: e.g. packing, handling, loading, unloading, stowing, caring.
- Weather/atmospheric hazards: e.g. water, temperature, or other atmospheric conditions.
- Hazard properties of dangerous goods: e.g. self-reactive, combustion, explosion, corrosion.

Given their hazard properties, dangerous goods carried in packaged form are liable to cause greater consequences to human, environment and properties compared to oil, oil products and chemicals carried in bulk. In addition, they are exposed to larger number of various hazards. But, these (hazards-consequences and exposure) are encountered by, inter alias, the limitation of quantities carried and different levels of insurance i.e. levels of packaging such as, for example, bottle-carton/box-pallet-container.

9.4 SUGGESTIONS FOR FURTHER RESEARCH

Many of the conclusions and recommendations provided in this reported are based on the empirical data i.e. case histories. Case histories represent a sample size rather than the entire population of events which have led or likely to lead in oil spills in Öresund. With some additional efforts, the analysis of risks of oil spills in Öresund that is based on "exhaustive" data (i.e. the entire population) is possible and desirable. Based on pooled data sets (Swedish and Danish data) a more thorough of risks analysis could be conduct.

Each of the suggested safety-increasing actions (chapter 8) need to be elaborated further and could be a new research project of its own.

Further studies may address the following questions suggested: a) How to determine risk criteria for the Öresund area? This should include the design of individual, societal, environmental risk criteria and a regional scrutiny level for the traffic of oil and oil products, including other dangerous materials and substances handled and carried through Öresund waters. b) How to measure environmental (pollution) risks? What variables should be design to measure these risks? c) How to improve or enhance marine events database(s)? d) How has the Öresund fixed link affected the maritime risks in Öresund? e) What are the risks of dangerous goods traffic on the Öresund link?

9.5. FINAL REMARKS

More than 40.000 ships are every year passing through the sound in the direction north-south or opposite. Other ships including ferries are frequently crossing the sound in the direction east-west or west-east. This makes Öresund one of the areas in the world with most ship movements. *Heavy traffic* increases of course the risk for marine events and for oil spills.

The ships are of different types, sizes and age and are travelling under different flags. The maintenance of the ships are changing considerably as well as the ambition concerning safety matters. The *complexity* of the situation increases the risks.

Öresund is also a quite narrow sound with a *difficult navigation situation*. This increases the risks for marine events and stresses the negative consequences of oil spills.

The Öresund area is also *a heavily populated area* with many people living at the sound or quite near it. It is also a *sensitive area* with sanctuaries for birds an other animals and many bathing places along the coasts. The consequences of an oil spills could easily become very serious.

In the 1991 assessment study *oil spill was regarded as the biggest risk* to Öresund waters and we think that this is still the case. Ships with thousands of tonnes of oil are regularly passing through the sound.

A number of *minor oil spills* are happening every year and there are fixed routines for its handling. The oil is normally taken care of by the Coast Guard and the environmental consequences are limited and local.

Some *larger oil spills* have happened during the years but any really big oil spill has, fortunately, not happened so far. But the possibility for a really big oil spill and a catastrophe to people, environment and property is constantly there. This was underlined by the Baltic carrier/Tern event which occurred on 29 March 2001 in the southern coast of Denmark (described in chapter 7). The oil slicks affected very seriously the Danish marine environment. It also posed threats to the Öresund area but because of luck with winds and currents never reach it.

If there is an oil spill catastrophe *huge claims* will have to be paid. For a worse case scenario we are talking about a hundred million dollars or more. On average it is a question of one hundred thousand dollars or more per year. And then only third-party claims are considered. If we include loss of or damage to the cargo and the ship the costs will rise.

The potential magnitude of the claims makes *insurance questions* of prime interest to all involved.

If we could *eliminate or diminishing the risk of oil spills* the cost of oil spills would go down. Those money could be spent on safety-increasing actions. Or rather the other way around. If we invest in *safety-increasing actions* the money saved on less oil spills as a result of those investments could be used to pay back the investment. In those cases where you cannot eliminate the risk of oil spills you could try to eliminate or diminish the negative consequences of an oil spill.

Oil spills do get much media attention today. With increasing number of ship movements in Öresund and a growing public interest in safety matters and environmental questions *focus on oil spills, oil spill consequences and oil spill prevention will become even bigger in the future.*

The building of the Öresund link has strengthen the possibilities and ambitions of integration and expansion in the Öresund region. A good infrastructure and fair prices/taxes is the base for any expanding region. The Öresund region has a quite good infrastructure. But to attract investors to invests in the region the *infrastructure* also *has to be reliable and safe*. So risk analysis, risk assessment and risk management issues are vital for the expansion in the region.

Oil spills in Öresund have occurred in the past and probably will occur in the future. A complete prevention i.e. zero oil spill may be prohibitively costly and practically impossible. But through risk analysis and risk assessment we could get more and better information about risks and their negative consequences but also of safety-increasing actions and their costs, information that can be used within risk management *to* at reasonable costs *create a safer Öresund.*

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APPENDIX

Appendix 1: Databases

This study is based on local, regional and world wide data and information. They are acquired from the sources described below.

1. Öresund and Baltic Sea Marine Event Case Histories

A large part of this study is based on empirical data (i.e. marine events case histories) collected from three databases. Marine events occurring in Öresund are recorded by both the Swedish and Danish authorities on each respective database. The databases are:

Databases
- Swedish Maritime Administration
- VTS Drogden - Denmark
- Baltic Sea Oil Spills

2. World Oil Spill Case Histories

World major oil spill case histories, including information/data concerning world oil spills in general, are collected from the sources available, such as; independent suppliers of maritime information services, shipping presses and other specialist publications, vessel owners, associations, insurers, safety and environment protection organisations/agencies - maritime administrations, coast guards. Generally, published sources provide information related to large spills resulting, for example, from collisions, groundings, fires and explosions, structural failures. Small operational spillages are in many cases not reported, as many of them go unrecorded. There are information variations among sources. Many early spills are not well documented.

Main sources of information/data were: ITOPF, Intertanko, USCG, Lloyd's Register, Lloyd's London Press (LLP), and others. A short description and the respective web site for each sources are provided. Information is acquired electrically (by means of internet) and in hard copies (magazines, news papers, reports).

International Tanker Owners Pollution Federation (ITOPF), which is a non-profit organisation funded by the majority of the world's shipowners, records most of ship-source related oil spills occurred world wide. ITOPF provides technical advice, expertise, assistance and information on effective response to pollution. Its technical advisers have attended on-site at over 400 spills in more than 70 countries.

Since 1974, the ITOPF has maintained a database of oil spills from tankers, combined carriers and barges. The database covers all accidental and incidental spillages except those resulting from acts of war. The database is amongst the most comprehensive oil spills database. The database contains nearly 10,000 incidents (as 2001).

The database contains information on: spills - amount, type of oil spilt, cause and location and the ship involved. The amount of oil reported spilt in an events includes all oil lost to the sea, burnt or remains in a sunken vessel. Spills are categorised in three size ranges: <7 tonnes, 7-700 tonnes and >700 tonnes. The amount of spill for each event is also recorded. The majority (85%) of spills is less than 7 tonnes.

Web site - http://www.itopf.com/

International Association of Independent Tanker Owners (INTERTANKO). It provides information concerning safety, environment and transport of oil and oil products by tankers. Information is collected from the members and other sources. INTERTANKO has some 260 (November 2000) members with 2,070 tankers totalling 162 million tons deadweight. Members represent about 76 per cent of the independently owned tanker fleet above 10,000 dwt. Their tanker fleet represent about 72 percents of the total tanker fleet. INTERTANKO also has around 300 associate members (companies).

Web site - http://www.intertanko.com/

The Lloyd's Register (LR) Group serves the marine, offshore and land-based industries. The group consists of numbers of subsidiary companies around the world. It provides classification, certification and verification services. It also provides expertise in many areas of the industry; analysis, investigations, assessments. The LR fleet covers all ship types, totalling over 100 million gross tonnage.

Web site - http://www.lr.org/

The Lloyd’s Register of Shipping (LR) database contain over 140,000 ship and 170,000 ship owner and manager entries, forming the world’s principal source of maritime information. The database provides information on marine casualties. It is also possible to view a casualty history for each ship. Extensive information is also available for: ships details (name, LR No., call sign or official number; ship type, size, age, tonnages etc), shipowners and managers, nationality, shipyards. The access to this database is limited.

World Casualty Statistics (Fairplay - Fairplay Publications Limited) is an annual summary listing ship losses and disposals during the year. It is compiled at the end of the calendar year from LR's maritime information databases. Information includes analysis of losses by registration, ship type and size, category and type of loss. It also includes individual ships with brief details of the casualty.

The Maritime Information Publishing Group of Lloyd's Register. The Group merged (July 1, 2001) with Fairplay Publications Limited, forming a new joint company, Lloyd's Register - Fairplay Limited. The company has a staff of over 130 and a worldwide customer base of over 15,000. Lloyd's Register - Fairplay has become the world's largest independent supplier of maritime information services.

Lloyd's Register - Fairplay maintain the largest and most comprehensive database of the world's merchant fleet comprising over 90,000 sea-going merchant ships, together with details of over 50,000 ships either totally lost or broken up. The company maintains, inter alias, extensive databases on marine casualties and other historical statistics.

Informa - Lloyd's London Press
Informa was created (1998) from the merger of the Lloyd's London Press (LLP) Group and another group (IBC Group). LLP Group was the publishing division of the Lloyds insurance market. Informa supplies information to major international markets using a range of media formats, both in traditional and electronic forms, such as: newspapers, magazines, newsletters, books, CD-ROM, internet and other electronic online services. Among the markets are: maritime, transport, and energy. Informa produces more than 1,500 publishing products delivered to 80,000 subscribers in 188 countries.

Lloyd's List. Lloyd's List (news paper) is published by Informa. It has a circulation of 11,000 in more than 109 countries. The Lloyd's List has a global network of journalists. Lloyd's List is also available in electronic format on the internet (Lloydslist.com) providing maritime news and information, including a *daily casualty report*. The daily casualty report provide, inter alias, worldwide information on marine casualties, including oil spill events. Exclusive information is received by the Informa's in-house Casualty Department. In addition, the Lloydslist.com provides a library service, including the "Lloydslist Casualty Library", by means of a searchable database of a full list of recent casualties and all casualties dating back to 1991. The latter is accessible by subscription/ registration only.

Web site - http://www.lloydslist.com

Casualty Department. The department receives information from various sources throughout the world including the worldwide network of Lloyd's agents, coast guards, port authorities, shipowners, press agents etc. The information received is edited and verified. Detail information such as; ship's voyage (departure/destination), flag, gross tonnage, dwt, classification society and ownership, is also added. Casualty data is produced daily in Lloyd's Casualty Report and weekly in Lloyd's Casualty Week.

United States Coast Guard (USCG) - Pollution Statistics
US Coast Guard's Marine Casualty and Pollution database. Statistical data related to pollution events in and around U.S. waters are found in the U.S.C.G. Spill / Release Compendium. The database contains commutative and annual data for oil spills occurred during the period 1969-1999. The database is maintained by the Office of Investigations and Analysis of the U.S. Coast Guard, Department of Transportation.

Web site - http://www.uscg.mil/hq/g%2dm/nmc/response/stats/aa.htm

Oil Spills Case Histories Database. The database contains summaries of significant US and international spills from 1967-1991.[87] Case histories are collected and developed with funding and consultation from the USCG Research and Development Center. Information for the case histories are collected from U.S. Coast Guard OSC Reports and Pollution Reports, file reports of the International Tanker Owners Pollution Federation Ltd., NOAA (National Oceanic and Atmospheric Administration) Scientific Support Coordination (SSC) Branch spill reports, newsletters, state agency, industry and scientific reports.

[87] Oil spills case histories 1967-1991. Summary of significant U.S. and international oil spills. September 1992, Report HMRAD 92-11. NOAA/Hazardous Materials Response and Assessment Division.

The case histories include all spills that: exceeded 100,000 barrels internationally, exceeded 10,000 barrels in U.S. waters, involved the use of dispersants, involved bioremediation, involved severe environmental impacts: more than 500 birds killed, more than 100 mammals killed, smothering of over a mile of inter-tidal zone, closure of fisheries.

Each case history contains information such as: spill - location, product, size; weather conditions and events leading up to the spill; consequences - shoreline types affected, losses of organisms; description of the behaviour of the oil including movement, evaporation, mousse formation, and dispersion; countermeasures and mitigation - use of dispersants.

Web site - http://response.restoration.noaa.gov/oilaids/spilldb.pdf

Environmental Technology Centre, Emergencies Science Division, Canada

Worldwide Tanker Spill Database. There are (March, 2000) 742 tanker spills in this database. The database contains spills which meet the followings: the source of the spill must be a vessel, generally a tanker or barge, could be cargo or fuel for the ship; size - at least 1,000 barrels in size (42,000 gallons, 136 metric tons); the spill must be accidental/incidental, not acts of war.

Spill events include the following details: vessel - type, flag, size, deadweight, year when was built; the spill - volume of spill, type of oil, location; consequences - number of fatalities, habitat & coast, other biological losses.

Web site - http://www.etcentre.org/main/e/db/db,html

3. Other sources

Some other sources of information were: pollution/spill reports, commercial newsletters in the public domain, state agency reports, industry reports, published scientific reports, and many more. For example, the International Salvage Union web site (http://www.marine-salvage.com/index.htm) has been used to collect information. Some well known oil spill cases are also available in the internet. Examples of sites: Exxon Valdez oil spill

Appendix 2

Database over "World major oil spills: Hazardous events and causes 1967-1996"

The accident case histories cover a period of 30 years (1967-1996). They are of a world-wide character and include major oil pollution events from 1967 until March 1996[88],[89],[90]. Cases were selected on the basis of the extent of consequences in followings terms; large numbers fatalities/injuries, extensive damages to environment, large amounts of oil spilled/released, liability claims involved. The database was put together by Arben Mullai. In appendix 1 it is number 10.

[88] International Tanker Owners Pollution Federation Ltd (ITOPF)2000.
[89] Lloyd's of London Press, UK 1999
[90] Drewry Shipping Consultant, UK - http://www.drewry.co.uk/drewry/ 2000

	Ship's name	Year	Location	Event	DWT ,000	Oil Spilt/ Released	Clean up and other costs In millions	Environmental	Human	Damages - Local community
1	Torrey Canyon	1967	Scilly Isles, UK	Grounded/ Explosion	120	119,000	16	Grave		
2	Wafra	1971	Off C. Aqulhas, South Africa	Machinery/ Grounded/ Foundered	40	40,000		Serious		
3	Metula	1974	Magellan Strait, Chile	Grounded/	210	50,000		1000 miles square		
4	Jacob Maersk	1975	Oporto, Portugal	Grounded/Fire	90	88,000		20 miles beaches	6	Smoke affected local
5	Urquiola	1976	La Coruna, Spain	Grounded/ Fire/ Explosion	108	100,000	62	Wide spread		Explosion/ smoke
6	Hawaiia Patriot	1977	Honolulu (300 m)	Hull/ Fire/ Explosion	99	95,000			1	
7	Amoco Cadiz	1978	Off Brittany, France	Machinery/ Grounded	232	223,000	380	Oil trace on beaches in 1989		
8	Andros Patris	1978	Spain	Hull/ Fire/ Explosion		50,000			30	
9	Betelguese	1979	Ireland	Explosion			120	Heavy pollution	50	Damage terminal
10	Atlantic Empress	1979	West India	Collision/Fire	287	287,000			29	
11	Burmah Agate	1979	Texas, USA	Collision/Fire/ Explosion		35,000			32	
12	Independenta	1979	Bosphorus Turkey	Collision/Fire/ Explosion	95	95,000		Great ecological threats	42	Explosion/ smoke
13	Assimi	1983	Oman	Machinery/Fire	53	53,000				
14	Castillo de Bellver	1983	Off Saldanha Bay, South Africa	Fire/Explosion	252	252,000			3	Black oily rain – crops and sheep
15	Nova	1985	Iran	Foundered	70	70,000				
16	Odyssey	1988	Nova Scotia (700 miles), Canada	Foundered	132	132,000				
17	Exxon Valdez	1989	Prince W. Sound, Alaska, USA	Grounded	37	37,000 (108)	1 b up to 10 b	Grave		
18	World Prodigy	1989	Newport, USA	Grounded		1,400		Threats		
19	Khark 5	1989	120m off Atlantic coast, NW Africa	Explosion	248	80,000				

20	ABT Summer	1991	700 miles off Angola	Foundered	260	260,000				
21	Agip Abruzzo (Moby Prince)	1991	Italy	Collision/Fire/ Explosion	80	80,000	50	Moderate	143	
22	Haven	1991	Genoa, Italy	Fire/Explosion	144	144,000	728			
23	Aegean Sea	1992	La Coruna, Spain	Grounded/fire/ foundered	74	74,000	152	Wide damages		3,000 fishermen affected
24	Braer	1993	Shetland Islands, UK	Machinery/ grounded	85	85,000	75 + 100	Wide spread		Oil spray-contaminated farm land
25	Sea Express	1996	Milford Haven, UK	Grounded	72	72,000	75 + 100	Grave damages – sensitive area		
						2,495,400	5,658		336	