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GENERAL CARGO SHIP SAFETY

IACS FSA study – Step 2 (Risk analysis)

Submitted by International Association of Classification Societies (IACS)

SUMMARY	
Executive summary:	This document provides in the annex the report of the Risk Analysis (FSA Step 2) from the FSA study that has been conducted by IACS regarding General Cargo Ship Safety
Strategic direction:	5.2 and 12.1
High-level action:	5.2.1 and 12.1.2
Planned output:	12.1.2.2
Action to be taken:	Paragraph 3
Related documents:	MSC 77/25/4; MSC 85/19/1; MSC 86/INF.4 and MSC 87/20/1

1 At MSC 77, the issue of General Cargo Ship Safety was brought before the Committee by RINA (MSC 77/25/4). IACS has been carrying out an FSA study on General Cargo Ships. The results of step 1 (Evaluation of Historical Data) were submitted to IMO (MSC 85/19/1 and MSC 86/INF.4) and have recently been updated to include two additional years of historical data so that it now represents the period 1 December 1997 to 31 December 2008 (MSC 87/INF.3).

2 As reported in MSC 87/20/1, subsequent to undertaking this step 1, the casualty records for general cargo ships have been investigated by IACS and the risk model developed for ships with a gross tonnage of 500 or above and built after 1982. This risk model (step 2 of an FSA) is reported in detail in the annex.

Action requested of the Committee

3 The Committee is invited to note the report as set out in the annex and take it into account, as appropriate, in its further consideration of this issue.

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ANNEX

FSA General Cargo Ship

Step 2: Risk Analysis

Version 1/2010-01-07

Contents

1 Introduction

The issue of general cargo ship safety was noted at IMO in 2006 in the submission by Russia (MSC 82/21/19, 2006). This submission highlights the disparity between the fraction of general cargo ships of the world fleet (17 % in number of ships) and the share of this ship type of all total losses (42 %) and of all fatalities (27 %) for the period 1999 to 2004. At MSC 83 several additional papers that focus on general cargo ship safety were submitted. In these submissions the safety with respect to other ship types (MSC 83/20/1, 2007; MSC 83/20/5, 2007), the causes of total losses of general cargo ships and the causes of fatalities on general cargo ships (MSC 83/20/3, 2007) are further highlighted. According to the cited submissions, occupational risk contributes with 63 % (MSC 83/20/3, 2007) of the total risk.
The importance of general cargo ship safety was also highlighted by the EMSA *Maritime Accident Review 2008* (EMSA, 2009).
To bring forward the discussion of general cargo ship safety, IACS started a project on the statistical analysis of general cargo ship safety and submitted the results of the preparatory step (FSA step 1) to IMO (MSC 86/INF.4). That report summarises the results of the initial review of accident data and fleet data which provide the basis for further analyses within a FSA.
For this analysis the LRF PC-ship register of 2007 and the LRF casualty database of 2007 are used. Meanwhile, this statistical investigation was updated and now considers the historical data until 2008-12-31 REF
The first analyses give strong indications of underreporting for ships of non IACS societies. Consequently, to minimize the effect of under-reporting for this analysis only the data for IACS ships are considered to be representative for general cargo ships. For ships larger than 20,000 GT this assumption has no or limited effects as nearly 100 % of these ships are classified by IACS member societies. The results of the first analyses led to the following definition of scope for the updated analysis REF:

- Ships “due or delivered” after 1981-12-31 and before 2009-01-01 (corresponding to a maximum ship age of 27 at the end of the investigation period);
- A gross tonnage greater than 499;
- Classed by IACS society (based on the assignment in LRF 2009);
- Casualty reports for IACS classed ships and classified as “severe” accident.

The statistical data in terms of accident frequency are produced for:

- the size categories:
  - $500 \leq GT < 1{,}000$;
  - $1{,}000 \leq GT < 20{,}000$;
  - $20{,}000 \leq GT$.
- the accident categories:
  - All severe;
  - Total loss;
  - Killed and missing.

In this report the developments of the risk models for *General Cargo Ships* are summarised. This is the second step of a Formal Safety Assessment (FSA) for this ship type (MSC 83/INF.2). The objectives of this report are the specification of the high-level generic risk models and the values

used within. The risk model covers the accident categories collision, contact, fire & explosion, foundering, hull, machinery as well as wrecked/stranded. The development of the risk model is based on the sample specified above.
The purpose of the risk analysis in step 2 is a detailed investigation of the frequencies and consequences of the identified accident scenarios. This can be achieved by the use of suitable techniques that model the risk. This allows attention to be focused upon high risk areas and to identify and evaluate the factors which influence the level of risk. Different types of risk (i.e. risks to people, the environment or property) are addressed and the following measures of risk are considered:

- Potential Loss of Life (PLL): Average risk, in terms of fatalities, experienced by a whole group of people (e.g. crew) exposed to an accident scenario
- Environmental risk: Amount of (bunker) oil released in the environment.
- Property risk: Financial loss in monetary terms taking into account the days out of service.

The construction and quantification of fault trees and event trees are standard risk assessment techniques that can be used to build a risk model.
A fault tree is a logic diagram showing the causal relationship between events which singly or in combination occur to cause the occurrence of a higher level event. A fault tree is used to determine the frequency of a top event, which may be a type of accident or unintended hazardous outcome. The development of a fault tree is a top-down approach, systematically considering the causes or events at levels below the top level. If two or more lower events need to occur to cause the next higher event, this is shown by a logic "and" gate. If any one of two or more lower events can cause the next higher event, this is shown by a logic "or" gate. The logic gates determine the addition or multiplication of probabilities (assuming independence) to obtain the values for the top event.
An event tree is a logic diagram used to analyse the effects of an accident, a failure or an unintended event. The diagram shows the probability or frequency of the accident linked to those safeguard actions required to be taken after occurrence of the event to mitigate or prevent escalation. The probabilities of success or failure of these actions are analysed. The success and failure paths lead to various consequences of differing severity or magnitude. Multiplying the likelihood of the accident by the probabilities of failure or success in each path gives the likelihood of each consequence.
The generic methodology that is applied during risk analysis is consisted of linking the fault tree with the event tree in order to represent a full accident scenario. An accident scenario is a sequence of events starting with a departure from the normal course of events, which is called "basic event" or "top event". This departure will trigger a response from the vessel systems and/or crew in an effort to bring the vessel back to a normal state. These responses are associated with the "causes" ("root causes" might be difficult to be determined accurately) in the accident sequences. Therefore, controls need to be applied in order to mitigate the consequences and prevent the event sequence from escalating (FSA Step 3). Finally, each sequence will end with a certain level of damage (from no damage to total vessel loss, for example). These consequences are called "end states". The combination of the fault tree and event tree techniques is symbolised as a bow tie, where the accident scenario is represented as a complete path from the initiating event to the end event.

The report is structured as follows: Section 2 gives a summary in a table format of the statistical analysis of the examined casualty records and a brief description of the accident scenarios is provided at Section 3. Notes from the examined records are included in Section 4 and the results from the risk analysis are outlined at section 5. Finally, some comments are made with respect to the recorded fatalities in Section 6 and the conclusions are drawn at section 7.

2 Accident statistics

Based on the LRF (2009) database for general cargo ships, the frequency of occurrence of the different accident categories is derived for IACS classed ships. Table 0-1 summarises the number of casualties, the frequency of casualties, and consequences in terms of fatalities (10 injuries = 1 equivalent fatality) per accident category.

Table 0-1: Casualty statistics and accident frequencies for general cargo ships (1997-01-01 ~ 2008-12-31)

Accident category	Casualty Nr.	Ship years	Frequency	Consequences				
				Fatalities	Fatalities per ship year	Pollution events	Days out of service	General Cargo Ship losses
Collision	238	43,222	5.5 E-03	99.7	2.3E-03	2	1~45	22
Contact	99	43,222	2.3 E-03	12.1	2.8E-04	2		2
Foundering	64	43,222	1.5 E-03	220	5.1E-03	1	--	59
Fire/explosion	116	43,222	2.7 E-03	20.2	4.7 E-04	1	1~10	11
Hull damage	86	43,222	2.0 E-03	12.2	2.8 E-04	0	1~14	1
Wreck/Stranding	326	43,222	7.5 E-03	61	1.4E-03	9	2~168	22
Machinery damage	533	43,222	1.2 E-02	13.1	3.0 E-04	1	1~21	1
TOTAL	**1,462**			**438.3**				

3 Accident scenarios

Based on a balanced consideration of the provided records, the following accident scenarios have been selected:

Collision

Collision scenarios represent about 16 % of all identified accident categories. This accident category is mostly observed in harbours, rivers/canals and coastal waters. There was not sufficient information in the casualty reports to determine differences between struck and striking ship. The consequences of the collision scenarios vary between slight damage to the ship structure only and total loss of the ship and fatalities. The frequency of a collision accident with fatalities is 6.3 % and the number of fatalities in a single accident varies between one and 16. The total number of fatalities reported in the records is 99 and 7 severe injured crew. With respect to safety collisions are the second important risk contributor.

Contact
Contact scenarios represent about 7 % of all identified accident categories. These accidents mostly occur in harbour and on river or canals. Especially in harbour the contact accident involve an interaction between a ship and the fixed harbour installations like berth, bridge or crane. The consequences vary. However, contact accidents mostly lead to small damages to the ship structure and have a relatively low impact on crew safety.

Grounding (wreck/stranding)
Grounding scenarios represent about 22 % of all identified accident categories. These accidents are observed in harbour, on river or canal and in coastal waters. Grounding accidents are observed as powered grounding caused by human error or technical error (steering failure), or as drift grounding following a blackout, loss of propulsion etc. Drift grounding mostly took place in combination with bad weather like hurricane or heavy swell. In the records 61 fatalities were reported for this accident category. With respect to crew safety the impact of grounding is significantly smaller than that for foundering and even smaller than collision. Nearly 15 % of all fatalities are caused by this accident category.

Fire/Explosion
Fire and explosion scenarios represent 7.94% of all identified accident categories. Engine-room and accommodation fires are considered to be common for all cargo ship types. Cargo hold fires can be considered similar to bulk or break bulk carrier fires, whilst when fire or explosions occurred to containerised cargoes (liquid, dry, bulk) the provisions of the FSA on containerships (MSC 83/INF.8, MSC 87/INF.2) apply. However, it should be noted that this is a high level generic FSA and an additional study should be required for a cargo specific FSA if deemed necessary. Explosions in engine room are associated with main engine (crankcase) and boiler, whereas explosions in cargo holds are related to lack of knowledge or exact documentation and which precautions should be taken for the transported cargo. Fire-fighting by onboard means was successful for 63.8% of the cases.

Machinery damage
Machinery damage scenarios account for 36.46% of all identified accident categories, 2 out of the 533 resulted into striking an object, whilst 13 drifted. Breakdown of propulsion equipment dominates with 88.18%, steering/rudder failures represent 8.63% and the remaining 3.19% are associated with electrical/electronic failures. Within the current analysis, an indication will be drawn on the causes of navigation related accidents (collision, contact and grounding) due to machinery failure.

Hull damage
Hull damage scenarios represent 16.14% and are associated with heavy weather damage, structural degradation and listing most probably due to cargo shift. From this scenario, it will be attempted to identify the causes for Foundering (including Missing) scenarios.

Foundering
Foundering scenarios represent about 4 % of all identified accident categories. Typically, foundering occurs in open sea or coastal waters (92). Typical causes for foundering in these operational states are cargo shift and water ingress. Seldom are foundering accidents in harbour or on river/canal (8 %). Accidents in this operational state are mainly caused by loading errors. With respect to crew safety foundering is the biggest risk contributor. Nearly 50 % of all fatalities reported for IACS classified general cargo ships between 1996 and 2008 are related to this accident category (220). Characteristic basic events for foundering accidents are cargo shift and water ingress as well as a combination of both.

4 Evaluation of the Casualty Reports

The data basis for this FSA was described in (REF). All frequencies for the basic events whether for the fault trees or the event trees are calculated on basis of the ship years (43,222) determined for IACS classified ships and for the period 1997-01-01 to 2008-12-31. As mentioned in this report only casualty reports for ships belonging to an IACS class at the date of incident were taken into consideration. The information in the LRF reports was checked by means of the public available GISIS reports and amended respectively. This check is based on the IMO numbers given in the LRF casualty reports. Hence, only accidents listed in LRF are checked by the GISIS data. The LRF reports are not amended by additional GISIS reports. In case of deviating information in LRF and GISIS, the GISIS information are regarded as correct and the casualty reports used for the development of the risk models are updated accordingly.
In approximately 31 % of the requests, GISIS contains a record for this accident. In detail these figures are:

- Collision: 33 %
- Contact: 20 %
- Fire/Explosion: 35 %
- Foundering: 76 %
- Hull: 22 %
- Machinery: 25 %
- Wrecked/Stranded: 33 %

However, in GISIS public access, only 37 % of the records contain a description of the accident details.
For evaluation purpose classes are defined with respect to damage extent, damage location in the ship, cause of incident/accident as well as the final outcome. These classes are specified in the respective sections of the risk model. Furthermore, the operational state (operation area) and the loading conditions are taken into consideration. The following operational states are specified:

- Open sea;
- Coastal waters: all waters outside harbour, river, canal and with a maximum distance of 12 sea miles to shore;
- Harbour: all wasters in harbour;
- River/Canal: all waters of rivers and canals including locks;
- Ice.

With respect to the loading conditions the following classes are specified:

- Loaded;
- Empty;
- Ballast;
- Loading;
- Discharging;

- Unknown.

The risk model for the general cargo ships is developed on basis of the casualty reports. Although, as mentioned in the report for the step 1 of the FSA, strong indications for underreporting exist, the existing database is regarded as a sound basis. Where necessary the historical data are adjusted by expert judgement.

5 Risk Model

In this section the development of the risk model is described in detail. The risk model is developed by means of event trees. An event tree is developed for each of the following accident categories:

- Collision;
- Contact;
- Fire/Explosion;
- Foundering;
- Hull;
- Machinery;
- Wrecked/Stranding.

The risk model considers the consequences with respect to safety, environment and property. Because the property consequences are required for the cost-benefit analysis in step 4 of the FSA, the present risk model contains no specifications with respect to monetary losses. Property consequences are specified qualitatively.
The generic high-level risk model is enlarged by a fault tree summarising the basic events for the accident as provided by the casualty reports.
A high percentage of the casualty reports do not provide sufficient information to be classed into one or more of the categories specified for the event tree. To consider the consequences of these reports in the risk model, these consequences are distributed into the specified classes. Details with respect of this distribution are explained in the respective sections of this report.

5.1 Collision

The collision risk model is developed on basis of 238 casualty reports. The frequency of the initiating event for the event tree for collision is determined to 5.5 E-03. 8 % of the casualty reports contain information with respect to the accident cause. The causes are human failure (6 reports; 32 % of causes), mooring failure (3; 16 %), steering failure (5; 26 %), anchor failure (3; 16 %) and engine/machinery failure (2; 10 %). These causes (basic events) are considered in a fault tree leading to the accident category collision (Figure 0-1). Regarding these causes as characteristic for collision the following initial frequencies are calculated (Table 0-1).

Table 0-1: Frequencies for initiating events of collision accidents

Cause	Frequency
Anchor	8.69 E-04
Engine/machinery	5.80 E-04
Human	1.74 E-04
Mooring	8.69 E-04
Steering	1.45 E-04

Total	5.51 E-03

Following the investigation of the casualty reports and expert judgement the consequences of collision accidents are influenced by the part the ship is playing (struck or striking), the operational state (in restricted areas the rescue of the crew and ship is easier than in open sea or coastal waters) and the loading conditions (property loss: damage to ship and cargo).
The high-level event tree is plotted in Figure 0-1. This figure shows also a fault tree summarising the causes leading to collision mentioned in the in the list above.
The event tree for foundering is shown in Annex A.1 (pp.45)

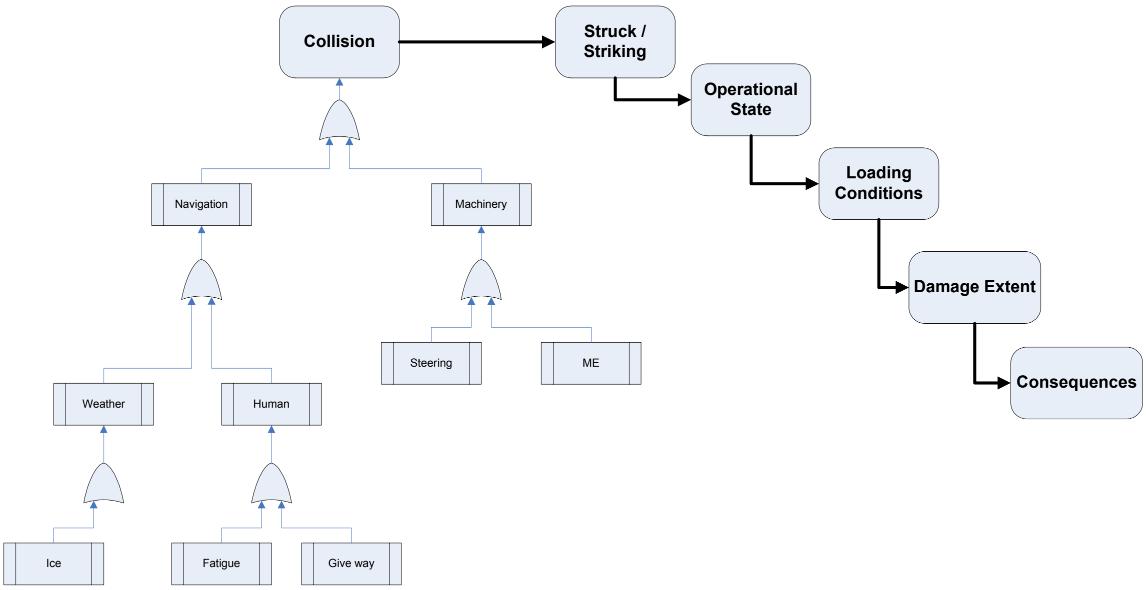


Figure 0-1: High-level generic scenario for Collision.

5.7.1 Struck/Striking

The casualty reports do not contain sufficient data to perform statistical investigations. However, this step remains in the event tree and 50 % for each branch is used.

5.7.2 Operational State

In 97 % of all reports an operational state was specified. Accordingly, the majority of accidents were reported for “River/Canal” (31 %), followed by “Harbour” (26 %), “Coastal Waters” (24 %) and “Open Sea” (18 %). Only 1 % of the accidents took place in ice.

5.7.3 Loading Conditions

The database is analysed with respect to the loading conditions of the ships. For 50 % of the collision accidents (118 of 239), the database contains information about the loading condition of the ship. Of these, the vast majority of ships being involved in an accident are loaded (81 %). The

rest of the accidents were reported for “Empty” and “Ballast” 13 %, and “Loading/Discharging” 6 %.
The main cause to consider the loading condition is the impact of cargo to the loss of property. Both, empty ships and ships under ballast are without cargo. Hence, for the matter of simplification it is deemed to be satisfactory to merge these classes “Empty” and “Ballast” to a class named “Empty”. Additionally, the classes “Loading” and “Discharging” are merged to “Load/Dis”.
The relation between operational status and loading conditions is analysed (Figure 0-2). It is observed that the relative distribution of “Loaded” and “Empty” varies with the operational state. The biggest percentage of “Empty” ships is determined for ships in “Coastal Waters” (23 %). For “Open Sea” and “River/Canal” 9 % and 6 % of the ships are categorised as “Empty”. In “Harbour” most of the ships are loaded. For this operational state the class “Load/Dis” appear which is only possible for this class.
For the operational state ”Ice” only three accidents were reported of which two reports provide no characterisation of the loading conditions. Hence, this operational status is not considered in Figure 0-2.
Based on this result, the values for the event tree are determined and are summarised in Table 0-2. Due to relatively low number of accidents in the different classes the uncertainty is expected to be high. Hence, the relative probabilities are rounded. For “Ice” the number of reports is too low to make any statistical evaluation. However, outside arctic sea areas ice conditions are more likely for coastal waters than for open sea. Hence, it is deemed to be adequate to use the probabilities of “Coastal Waters”.

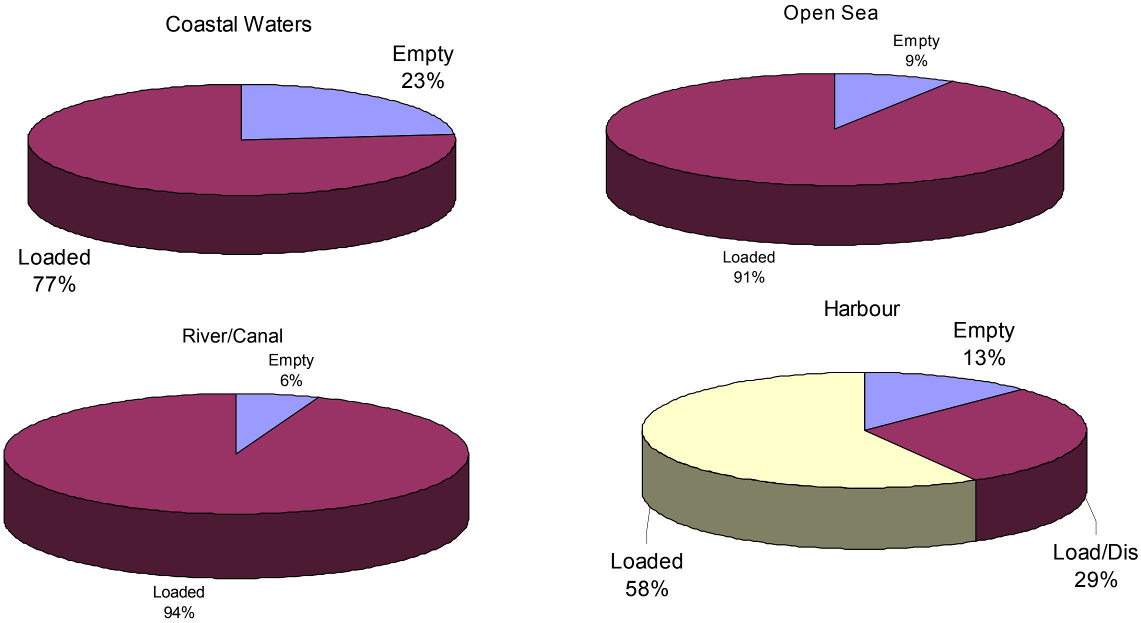


Figure 0-2: Relative probabilities for loading conditions in different operational states

Table 0-2: Relative probabilities for loading conditions in different operational states.			
Operational status	**Loaded (%)**	**Empty (%)**	**Load/Dis (%)**
Open Sea	90	10	--
Coastal Waters	80	20	--
River/Canal	90	10	--
Harbour	60	10	30
Ice	80	20	--

5.7.4 Consequences

The casualty reports are evaluated with respect to the consequences. As mentioned above the three risk categories safety, environment and property are taken into consideration. Based on the damage description the following damage categories are specified:

- Small: a ship involved in an accident leading to small consequences either has no damage or damages like scratches or dents were reported, but no water ingress. The ship returns to service after inspection, or repair work is required due to damages with descriptions like dents, small holes also no water ingress (holes above waterline).

  Typical descriptions are:

  - 700 X 200 mm hole;
  - Rupture to port side shell plating;
  - 15 inch gash;
  - 7 m gash in hull;
  - Dent approximately 3 by 10 metres;

- Severe: LRF contains classification like sustained severe, heavy damage or significant structural damage with or without water ingress. Typical descriptions:

  - Water ingress;
  - Requires docking;
  - Port side hull holed. Sustained damage to port anchor, bow and forecastle railing;
  - Hull holed. Gear compartment and accommodation area flooded;
  - Steering gear and engine room were both holed and one cabin in accommodation was crushed;
  - 32 metres length bulwark, No.1 hatch cover and forecastle.

- Loss: total loss of the ship. This may either be due to sinking, broken up or a insurance total loss (repair costs supersede the actual value of the ship).

These categories relate to the ship structure and do not consider the follow up consequences like loss of income. The investigation for these categories with respect to fatalities show that the frequency of fatalities increases with the accident severity. So for the accident category *small* three fatalities were reported in total. Nine fatalities were reported for *severe* accidents (3) and 85 fatalities were reported for the accident category *loss*. However, each damage category contains also accidents without any fatality.
The relation between damage extent and year of construction of the vessel are analysed to check if a correlation between construction regulations and damage extent exists (Figure 0-3). The accident frequencies are plotted versus the construction year are shown in Figure 5-3 and are broken down into the damage extent categories *small*, *severe* and *loss*. For total loss the highest frequencies are observed for ships constructed in the period 1982 to 1985. Afterwards, only single events of total loss are reported. For the damage extent classes no trends are identified.
The results for *loss* show small differences between ships built before 1986 and afterwards. As far as known, this observation relates not to a change in the regulations and, hence, this is not considered in the risk model.

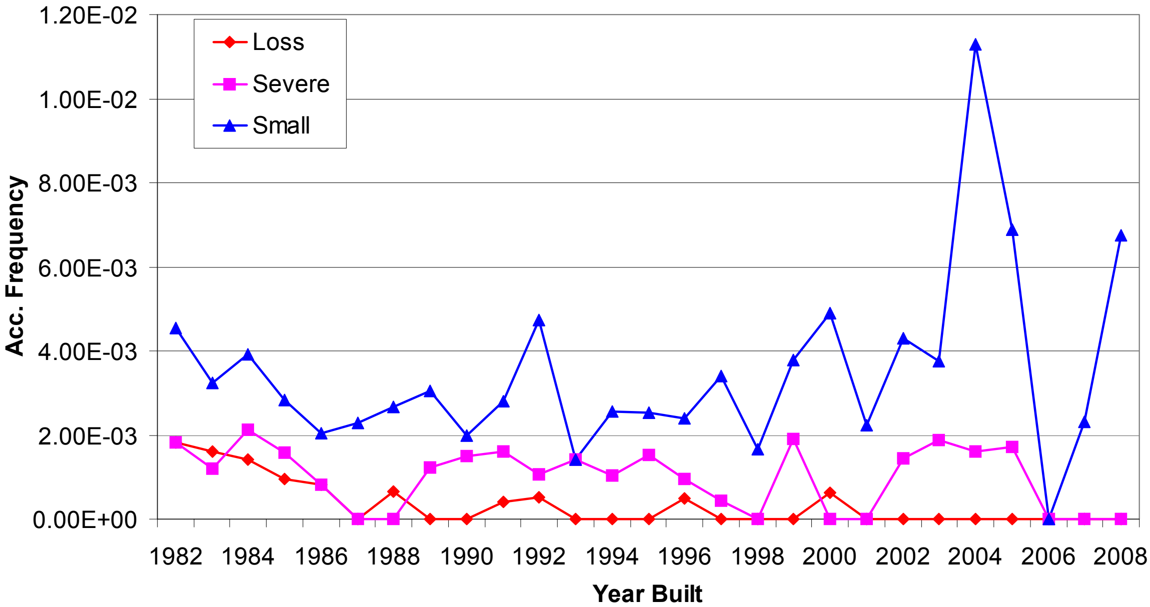


Figure 0-3: Accident frequency over year of construction broken down into damage extent categories.

5.1.4.1 Safety

The final safety related consequences depend on several other parameters, for instance, the operational state influences possible life saving actions. Additionally, it is observed that the number of fatalities is related to the damage extent. The frequency of fatalities is increased with the accident severity. So, for the accident category *small,* three fatalities were reported in total for 141 accidents. Nine fatalities were reported for *severe* accidents (3 accidents) and 85 fatalities were reported for the accident category *loss* (22 accidents). For the accident with a total loss of the ship the highest PLL (Potential Loss of Life) is observed, whereas for the accident with minor damage to the ship mostly no fatalities were reported. However, even if very small, for all damage categories the probability of one or more fatalities is greater than zero and, hence, cannot be neglected in the risk model.
The probability of each branch is determined based on the historical data taking into consideration all previous steps of the ET, i.e. “Struck/Striking”, “Operational State” and “Loading Condition”. All accidents with “Unknown” loading condition are distributed on the

loading conditions “Empty” and “Loaded” corresponding to the relative distribution of accidents for both loading conditions (Table 0-3).

Table 0-3: Relative probabilities for safety related consequences taking into account operational state and loading condition determined on basis of the database.					
Operational State	**Loading Condition**	**Damage Extent**	**Probability (%)**	**No. of accidents with fatalities**	**Total number of fatalities reported for all accidents**
Open Sea	Loaded	Small	44	1	3
		Severe	38	2	6
		Loss	17	3	39
	Empty	Small	72	0	
		Severe	0	0	
		Loss	28	0	
Coastal Waters	Loaded	Small	48	0	
		Severe	21	0	2.4
		Loss	32	4	31
	Empty	Small	89	0	
		Severe	11	0	0.6
		Loss	0	0	
River/Canal	Loaded	Small	67	0	
		Severe	28	0	
		Loss	5	2	14
	Empty	Small	100	0	
		Severe	0	0	
		Loss	0	0	
Harbour	Loaded	Small	73	0	
		Severe	23	0	
		Loss	4	1	1
	Empty	Small	100	0	
		Severe	0	0	
		Loss	0	0	
	Load/Dis	Small	44	0	
		Severe	56	0	

In Table 0-4 the values of the event tree are summarised. The probability of fatalities and the number of fatalities are adjusted to meet the statistical data as well as to cover potential risks. For instance, even for accidents with the damage extent *small* a low probability of fatalities and a small number of fatalities is considered in the event tree.

Table 0-4: Relative probabilities of the event tree for safety related consequences.							
Operational State	**Load. Cond.**	**Damage Extent**	**Probability[1]**	**Remarks**	**Fatalities**		**Remarks**
			%		%[2]	No.[3]	
Open Sea	Loaded	Small	40	All values rounded.	5	2	
		Severe	40		15	3	
		Loss	20		50	12	
	Empty	Small	70	Severe accidents are possible. Hence, 10 % probability for severe and other classes reduced by 5 %	5	2	No reports. Same values like loaded.
		Severe	10		15	3	
		Loss	20		30	12	
Coastal Waters	Loaded	Small	50	All values rounded.	2	1	
		Severe	20		10	3	
		Loss	30		35	7	
	Empty	Small	88	Loss accidents are possible. Hence, 5 % probability for loss and other classes reduced	2	1	
		Severe	10		10	3	
		Loss	2		30	7	
River/Canal	Loaded	Small	70	All values rounded.	2	1	
		Severe	25		10	2	
		Loss	5		60	6	
	Empty	Small	90	Severe and loss accidents are possible. Hence, small probability for loss and severe, other classes reduced	2	1	
		Severe	9		10	2	
		Loss	1		50	6	
Harbour	Loaded	Small	74		2	1	
		Severe	25		10	1	
		Loss	3		40	1	
	Empty	Small	90	Severe and loss accidents are possible. Hence, small probability for loss and severe, small reduced	2	1	
		Severe	9		5	1	
		Loss	1		20	1	
	Load/Dis	Small	40	All values rounded.	2	1	
		Severe	60		10	1	
Ice	Same like Coastal Waters						

5.1.4.2 Environment

For 13 of 238 accidents the release of oil was reported. Of these only two contain a specification of the spill size (2737 tonnes, 11 tonnes). The probability of an oil release in a collision accident

[1] Probabilities used in the risk model. Values adjusted on basis of historical data.

[2] Probability of fatalities

[3] Characteristic number of fatalities for this scenario (characteristic number of fatalities for an accident following this scenario)

is calculated to 5.4 %. On basis of the two accidents with a specified spill size the average spill size is calculated to 1374 tonnes. The vast majority of the oil spills were reported for the damage categories *loss* (8). The remaining three accidents are of the damage categories *severe* (3) and *small* (2). In case of a loss of ship the probability of an oil spill is about 36 %. The respective value for the category *severe* is 6 % and for *small* 1 %.
The bunker oil capacity of a general cargo ship with 5,000 GT is something between 250 tonnes and 340 tonnes. Hence, an oil spill of more than 500 tonnes seems possible only for large general cargo ships.
On basis of the discussion above the following oil spill sizes are specified for the different damage extent classes:

- Loss: possibility of a significant oil spill of one bunker tank with a capacity of 120 tonnes;
- Severe: a spill of one small bunker oil tank, the average ship size is about 5,000 GT. For this average ship the capacity of the small bunker oil tanks is about 50 tonnes;
- Small: no oil spill because no damage to the hull with water ingress.

These spill sizes are linked with an estimated probability of an oil spill for the damage classes *severe* (5 %) and *loss* (20 %). Due to missing statistical data both values are defined on basis of the data for wrecked/stranded. On basis of these probabilities an average spill size for all accidents in the classes *severe* (2.5 tonnes) and *loss* (24 tonnes) are calculated.

5.1.4.3 Property

The casualty reports are investigated with respect to the damage to the ship and all follow up costs. The descriptions of damage to ship itself are used to determine the following damage categories:

- Small
- Severe
- Loss

The relative probabilities are summarised in Table 0-3. In the present state of development of the risk model the damage to ship and cargo as well as additional monetary losses are not quantified. The quantification of property related consequences will be taken into account in the cost-benefit analysis (FSA Step 4).

5.7.5 Risk Model Collision

The event tree is shown in Annex A.1 (pp.45). With this risk model a PLL of 2.43 E-03 is calculated which is regarded to be in good agreement with the historical value of 2.30 E-03. The probability of spilling a tonne of bunker oil is calculated to 1.8 E-02. This is equivalent to 766 tonnes spilt in the period 1997 to 2008. This is lower than the reported 2748 tonnes. However, as explained above, the tank capacity of the representative cargo vessel is significantly lower than the one spill of 2727 tonnes and, hence, the tank capacity of the average vessel is considered in the risk model. The probability of a loss of ship is calculated to 5.8 E-04. That yields 25 losses for the 12 year period which is 13 % higher than the reported losses.

5.2 Contact

The contact risk model is developed on the basis of 97 casualty reports of LRF. The frequency of the initiating event for the event tree is determined on basis of these reports to 2.2 E-03. Compared to collision the frequency of contact accidents is less than 50 % of collision accidents. In 27 % of the casualty reports information are provided that allow an identification of the accident causes. Following this information the main causes (basic events) for a contact accident are human failure (48 %), often in combination with heavy weather conditions like ice, and technical problems (48 %), e.g. steering failures (Figure 0-4). Assuming that these basic events are representative for contact accidents the frequencies per ship year for these basic events are calculated to 1.1 E-03. Compared to the accident categories foundering, collision and wrecked/stranded the impact on crew safety is smaller with 12.1 fatalities reported for the period 1997 to 2008.
The investigation shows that contact is an accident typical for narrow areas like harbour (54 %), river and canal (together 30 %). Due to the fact that ships operate in these areas with reduced velocity the kinetic energy of the ship is expected to be smaller compared to collision accidents in open sea or coastal waters and, hence, the damage to the ship is expected to be smaller. With respect to the consequence *loss* this expectation is confirmed, only 4 % of contact accidents cause a loss of ship (collision 11 %). However, for damage categories *severe* and *small* comparable figures are observed for contact and collision:

- *small*: contact 66 % - collision 65 %.
- *severe*: contact 23 % - collision 31 %

Furthermore, the investigation shows that 80 % of the ships are loaded. Whether loading condition influences the probability of an accident or ships normally operate loaded and, hence, the probability of loaded ships being involved in a contact accident cannot be confirmed on basis of the available data. However, the loading condition influences the possible property damage and, hence, is considered in the high-level event tree.
The high-level event tree for contact accidents is shown in Figure 0-4. Following the investigation summarised above and in the following the consequences depend of the operational state (harbour, river/canal, open sea, coastal waters) and the loading conditions (property damage).

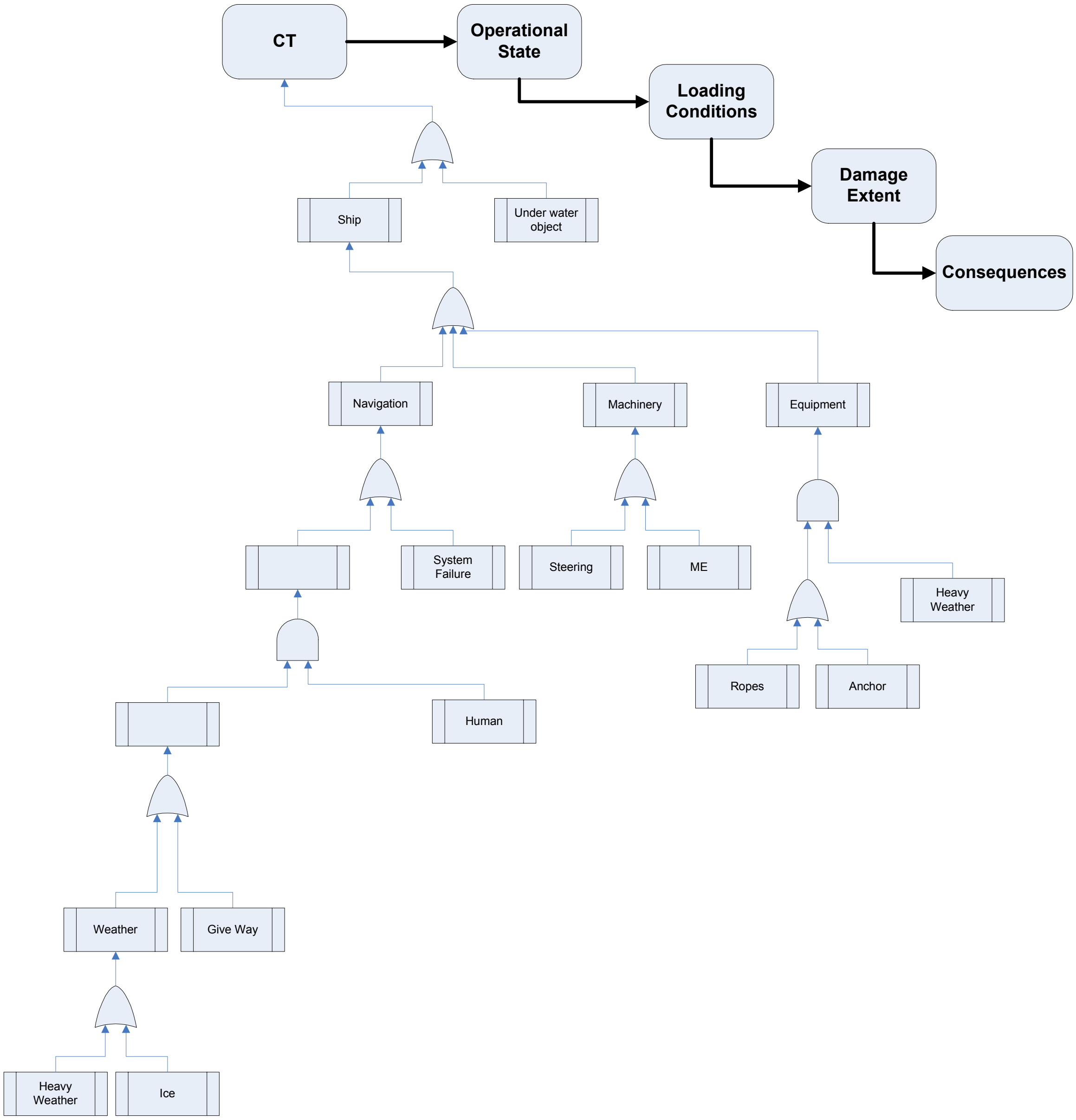


Figure 0-4: High-level generic scenario for contact accidents.

Figure 0-4 contains also a generic fault tree summarising the basic events (accident causes) provided by the casualty reports. Contact accidents mainly are caused by:

- Human related navigation failures often in combination with bad weather conditions like storm or ice, or interaction with other objects (wrong consideration of environmental conditions): 44 %;

- System failures:

    - Navigation (autopilot): 4 %;
    - Machinery (thrusters, ME, steering): 36 %;

- Equipment failures:
    - Ropes: 4 %;
    - Anchor: 4 %.

The event tree for foundering is shown in Annex A.2 (pp. 56)

5.7.1 Operational State

As mentioned above four different operational states are distinguished. The relative distributions with respect to the operational state are summarised in Table 0-5 considering 97 accidents. As shown contact accidents mostly happen in harbour and on river/canal.

Table 0-5: No. of accidents and relative probabilities with respect to operational state.

Operational state	No. accidents	Rel. (%)
Coastal Waters	8	8
Harbour	53	55
Open sea	6	6
River/Canal	30	31

5.7.2 Loading Conditions

For about 33 % of the accidents information with respect to the loading conditions are available (33 of 98). Similar to other accident categories most of the ship involved in accidents operate in loading conditions (75 %). Empty ships were involved in 19 % of the accidents and 6 % took place during loading or discharging.
The relative probabilities for the loading conditions with respect to the operational state are summarised in Table 0-6.

Table 0-6: Relative probabilities with respect to loading condition broken down into operational state.

Operational state	Loading condition		
	Empty (%)	Loaded (%)	Load/Dis (%)
Coastal Waters	34	66	--
Harbour	12.5	75	12.5
Open sea	50	50	--
River/Canal	22	78	--

5.7.3 Consequences

The reports of the database are evaluated with respect to the consequences safety, environment and property. 85 % of all reports contain information that allows an estimation of the damage extent. Similar to the accident category collision the following classes are specified:

- Small: a ship involved in an accident leading to small consequences either has no damage or damages like scratches or dents were reported, but no water ingress. The ship returns to service after inspection, or repair work is required due to damages with descriptions like dents, small holes also no water ingress (holes above waterline).

  Typical descriptions are:

  - 75 cm gash in forward hull two metres above water line;
  - Sustained damage above the bulbous bow;
  - Sustained damage to bow approximately 33 by 64 cm;
  - Sustained damage to propeller required emergency dry docking;
  - Sustained plate and frame damage to lower stern on port side, 2.7.m above water line;
  - Rudder struck seabed with force which fractures rudder stock causing loss of rudder.

- Severe: LRF contains classification like sustained severe, heavy damage or significant structural damage with or without water ingress. Typical descriptions:

  - Stem crushed and overhanging the quay, damage being 30 cm above the water line. The forecastle and forepeak tanks are damaged;
  - Sustained damage from bow on starboard side to outer shell plate at stern;
  - Sustained fracture damage to port bow with subsequent ingress of water to holds;
  - Sustained damage and leaked fuel oil;
  - Sustained heavy damage to accommodation area, bridge, funnel and cranes;
  - Port bow severely set in and breached from 0.5 metres below forecastle deck to bottom shell on port side of the bulbous bow. Length of gash in forepeak tank top level is app. 5 metres and 8-9 metres in bottom shell level;
  - Causing several metres of indenting damage to the ship's bow opening a fairly large howl;
  - Sustained damage to the starboard bulwark and some hull gashes. Reported water ingress;
  - Sustained denting to hull 2.5 metres high starboard aft 4 metres above water line;
  - Severe damage to a ship borne crane;
  - Damage to the propeller, a hole in the hull reported water ingress.

- Loss: total loss of the ship. This may either be due to sinking, broken up or a insurance total loss (repair costs supersede the actual value of the ship).

Consequences with respect to safety, environment and property are related to these damage categories.

5.2.3.1 Safety

In total 12 fatalities and one severe injured crew were reported. The maximum number of fatalities is 7, and was caused by a loss of ship after dragging anchor in heavy weather. The average number of fatalities per contact accident is 0.122. Following the accident reports a risk

for loss of life exists for all damage categories. Considering the reports as representative for the safety related consequences the number of fatalities in a contact accident leading to total loss is significantly higher.
Based of these observations the average number of fatalities for each damage extent category is defined (Table 0-7).

Table 0-7: Probability of fatalities and average number of fatalities per damage extent category.		
Damage extent	**Probability of fatalities**	**Av. no. of fatalities**
	%	
Small	2	1
Severe	4	1
Loss	50	7

5.2.3.2 Environment

For only one of the accidents an oil spill was reported with a size of 180 tonnes (loss). Due to the fact that more than 80 % of the accidents took place in harbour or on river/canal the probability of underreporting should be lower than for other accident categories. However, the probability of an oil spill is regarded as realistic for the damage categories *severe* and *loss*. To consider this risk, an oil spill of 60 tonnes (smaller bunker tank of an average general cargo ship of 5,000 GT) is considered for the scenario severe and of 120 tonnes (larger bunker tank of an average general cargo ship of 5,000 GT) for loss respectively.
These spill sizes are linked with an estimated probability of an oil spill for the damage classes *severe* (5 %) and *loss* (20 %). Due to missing statistical data the both values are defined on basis of the data for wrecked/stranded. On basis of these probabilities an average spill size for all accidents in the classes *severe* (2.5 tonnes) and *loss* (24 tonnes) are calculated.

5.2.3.3 Property

The damage extent to ship is summarised in Table 0-8. In the present state of development of the risk model the damage to ship and cargo as well as additional monetary losses are not quantified. The quantification of property related consequences will be carried out in the cost-benefit analysis (Step 4 of FSA).

Table 0-8: Probabilities for different damage classes related to operational state and loading condition.				
Operational state	Loading condition	Damage extent	Probability	Remarks
			%	
Open Sea	Loaded	Small	60	Six accidents in open sea. Most of them with unknown damage extent. No information with respect to loading conditions. Estimated that most of accidents with small damage extent. Percentages for *severe* and *lost* specified respectively.
		Severe	30	
		Loss	10	
	Empty	Small	60	
		Severe	30	
		Loss	10	
Coastal Waters	Loaded	Small	30	Eight accidents in coastal waters. Six

		Severe	60	records with loading condition. Two *empty* (all *severe*) and four *loaded* (2 *severe*, 2 *small*). For all records: two third with severe damage extent. The risk model considers the possibility of loss.
		Loss	10	
	Empty	Small	30	
		Severe	60	
		Loss	10	
River/Canal	Loaded	Small	70	30 reports of which 21 without loading conditions. All accidents with small (22) or severe (4) damage. Same probabilities for both loading conditions. Low probability for loss
		Severe	28	
		Loss	2	
	Empty	Small	70	
		Severe	28	
		Loss	2	
Harbour	Loaded	Small	60	51 reports of which 31 without loading conditions. Accidents with small (25), severe (16) and loss (2) damage. Same probabilities for both loading conditions.
		Severe	37	
		Loss	3	
	Empty	Small	60	
		Severe	37	
		Loss	3	
	Load/Dis	Small	60	
		Severe	37	
		Loss	3	

5.7.4 Risk Model Contact

The event tree is shown in Annex A.2 (pp.56). With this risk model a PLL of 3.41 E-04 is calculated which is higher than the historical value of 2.80 E-04. However, it should be taken into consideration that the PLL is relatively small and, hence, the consideration of possible fatalities in the accident scenarios (damage extent *small*) has a relatively high impact. The probability of spilling a tonne of bunker oil is calculated to 3.9 E-03. This is equivalent to 168 tonnes spilt in the period 1997 to 2008, and, hence nearly equivalent to the reported value of 170 tonnes. The probability of a loss of ship is calculated to 8.1 E-05. That yields 3.5 losses for the 12 year period which is 17 % higher than the three losses reported.

5.3 Foundering

After the critical review of the reports the number of accidents is reduced by 2 so that 64 casualty reports for “Foundering” remain. The frequency of the initiating event (Event Tree) is determined to 1.5 E-03. In 60 % of the casualty reports information with respect to the accident cause are provided which are

- Capsize: 8 % or 6.9 E-05 per ship year;
- Loading error: 5 % or 4.6 E-05 per ship year
- Cargo shift (including listing): 45 % or 3.9 E-04 per ship year;
- Water ingress (also due to structural failure): 42 % or 3.7 E-04 per ship year.

About 50 % of all foundering accidents are reported to happen in heavy weather conditions like hurricane, strong winds or heavy swell.

The majority of accidents were reported for ships built before 1990 (47 of 64). The relation between number of accidents of ships built in one specific year and the number of ship years for this year is investigated. As shown in Figure 0-5 the frequency for ships built after 1991 is lower than for the ships built before. The average frequency for ships built between 1981 and 1992 is about five times higher than for the ships built between 1991 and 2009. Additionally, Figure 0-5 contains the 95 % confidence interval for each year. These intervals increase after the year 2001 due to the decreasing number of ship years for younger ships. This decrease in the accident frequency could be the result of new SOLAS regulations for ships longer than 100 m coming into force after 1991 that require a damage stability calculation and double bottom. The later one is required also for ships below 80 m.

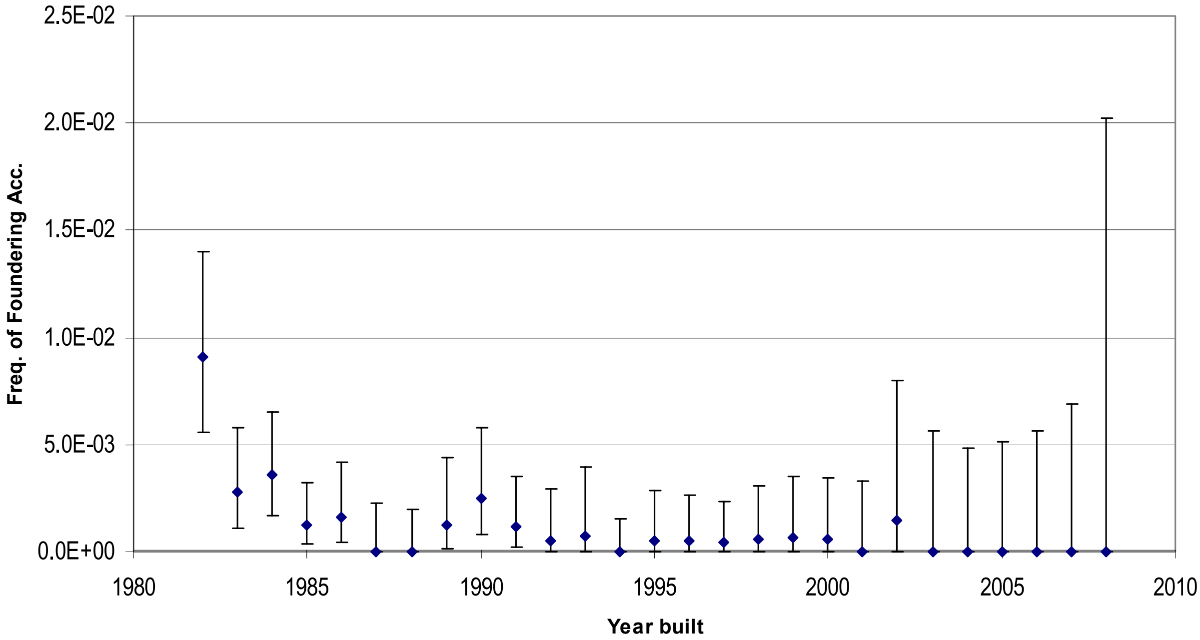


Figure 0-5: Accident frequency per year built

Following the investigation of the casualty reports the consequences of foundering accidents are influenced by the loading conditions (property loss, loaded ship sinks faster than un-loaded ship), the operational area (in restricted areas the rescue of the crew is easier than in open sea) and whether the foundered ship can be re-floated. The year of built is not considered in the event tree scenarios but it could be taken into consideration via different accident frequencies (2.5 E-03 for 1982 to 1991; 4.3 E-03 for 1992 to 2008). The high-level event tree is plotted in Figure 0-6. This figure shows also a fault tree summarising the causes leading to foundering mentioned in the list above.

The event tree for foundering is shown in Annex A.4 (pp. 66)

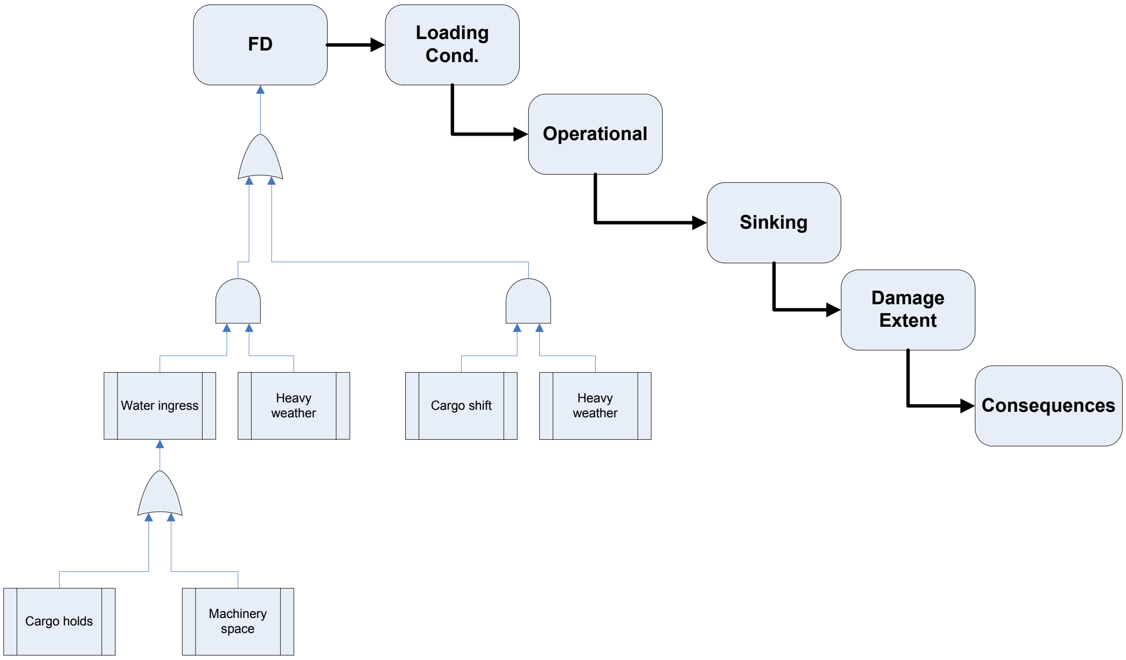


Figure 0-6: High-level generic scenario for Foundering.

5.7.1 Loading Conditions

The distribution of loading conditions is shown in Figure 0-7. In 72 % of the records (46 of 64) the database contains information with respect to the loading condition of the ship. Of these 98 % are loaded ships. This agrees well with the main accident causes identified, cargo shift and water ingress, mostly in combination with heavy weather conditions. A loaded ship provides less safety margin than an empty ship, especially in heavy weather conditions.

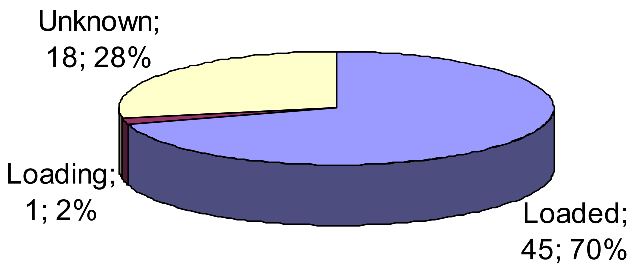


Figure 0-7: Distribution of loading condition for foundering (all records considered).

5.7.2 Operational State

In 95 % of the records the operational state is specified (Figure 0-8). Of these, most of the foundering accidents took place in “Open Sea” (73 %) followed by “Coastal Waters” (14 %), “Harbour” (6 %), “Unknown” (5 %) and “River/Canal” (2 %). Following the accidents reports the foundering accidents in harbour are related to cargo handling failures which lead to capsizing of the vessel.

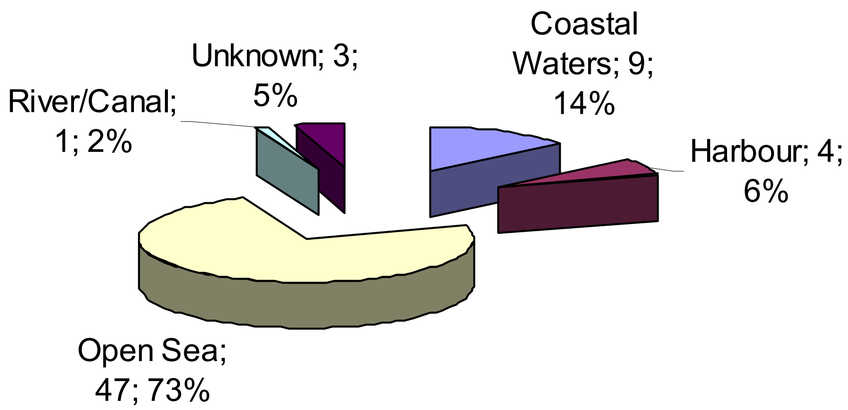


Figure 0-8: Distribution of operational state for foundering (all records considered).

5.7.3 Consequences

The LRF reports and the additional information provided by GISIS are evaluated with respect to the consequences. The three risk categories safety, environment and property are taken into consideration. Like above damage categories are defined on basis of the LRF reports. In contrast to the other accident categories Foundering does not contain accidents with "small" damage because ships sank and only in a few cases were re-floated. Hence only two damage categories are specified:

- Loss: total loss of the ship
- Re-floated: ship sank but was re-floated and returned to service.

The casualty reports are investigated with respect to these damage categories and fatalities, environmental impact and property loss are assigned to them.

5.3.3.1 Safety

In total 220 fatalities were reported for the accident category Foundering. The distribution of these accidents with respect to the operational status is shown in Figure 0-9. The maximum number of fatalities in a single accident was 25. 56 % of the foundering accidents are without fatalities. 73 % of all foundering accidents took place in open sea contributing 72 % (159) of all fatalities (Figure 0-10). The safety related consequences depend on several parameters, for instance, operational state which has an influence on the possible life saving actions and to the damage extent.

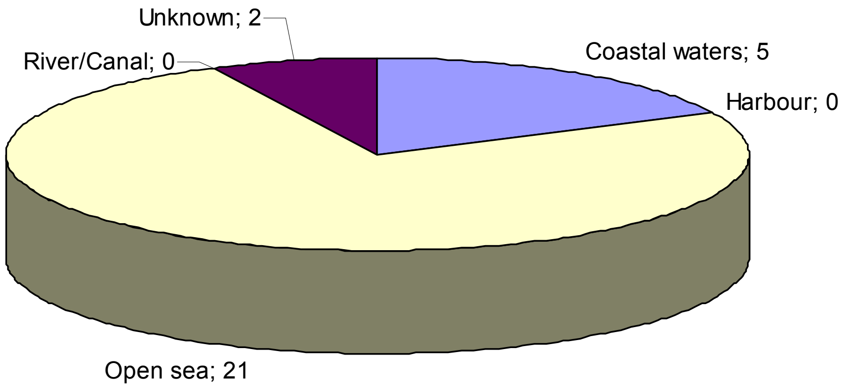


Figure 0-9: Distribution with respect to operational status of accidents with fatalities (with number of accidents)

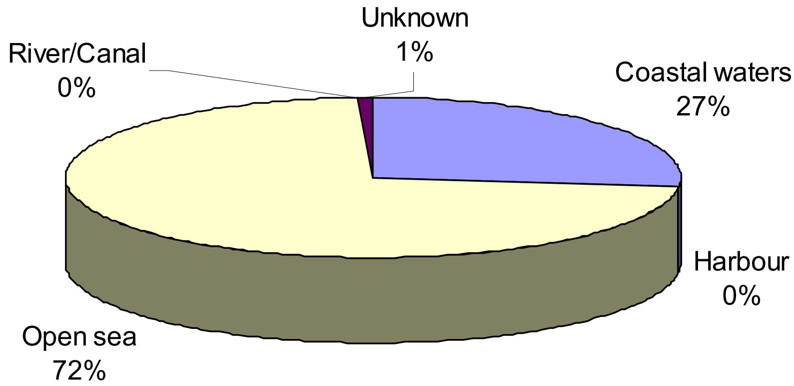


Figure 0-10: Distribution of fatalities with respect to operational status.

Following the historical data the probability of having fatalities in a foundering accident taking into account the operational state is:

- Open sea: 45 % of all accidents in open sea have fatalities
- Coastal waters: 56 % of all accidents in coastal waters have fatalities
- Harbour: 0 %
- River/Canal: 0 %.

The average number of fatalities per foundering accident was calculated to

- Open sea: 3.38
- Coastal waters: 6.44
- Harbour: 0
- River/Canal: 0.

On basis of this data the values for the ET are determined (Table 0-9). To determine these numbers it is assumed that also for accidents a small percentage of accidents should lead to fatalities.

Table 0-9: Relative probabilities for safety related consequences taking into account operational state and damage extent.

Category		**%**	**Remarks**	**%-Acc. w. Fat.**	**Fat/Accident w. Fatalities**	**Remarks**
Operational state	Damage extent					
Open sea	Loss	98	Only 1 of 47 accidents ship was re-floated	45	7.5	Adjusted to meet roughly the historical data (+6%)
	Re-floated	2		10	7.5	
Coastal waters	Loss	90	Only 1 of 9 accidents ship was re-floated	60	12	Adjusted to meet roughly the historical data (+0.6%)
	Re-floated	10		10	12	
Harbour	Loss	25	1 of 4 lost.	2	1	A small probability for fatalities exist even if no accident were reported
	Re-floated	75		2	1	
River/Canal	Loss	50	Only one accident. Between harbour and coastal waters	2	1	A small probability for fatalities exist even if no accident were reported
	Re-floated	50		2	1	

5.3.3.2 Environment

The casualty reports contain no information with respect to the spill of oil. However, the risk model should cover not only historical but also potential risk. The authors are convinced that the oil of the bunker tanks will be released to the environment. Not always at the day of accidents but at the latest when the bunker oil tank collapsed due to corrosion. To cover this risk it is assumed that the content of one full bunker oil tank is released. The average size of a general cargo ship is determined to 5000 GT. For such a ship two different tank arrangements are identified

- Two pairs of tanks (one pair with 130 m^3 each, one pair with 60 m^3 each)
- One centre tank with 140 m^3 and one pair with 60 m^3 each.

For the risk model the bunker oil tank volume is defined to 130 m^3 which is equivalent to 120 tonnes HFO. It is assumed that this amount of oil is spilled in case of a total loss of the ship in open sea or coastal area independent of other consequences. In case of an accident where the ship is re-floated or the accident took place in Harbour or on River/Canal the oil spill is only assumed for the scenarios leading to fatalities.

5.3.3.3 Property

In case of foundering accidents nearly 90 % lead to a total loss of the ship. In 10 % or the accidents the ship is re-floated. However, these ships were foundered and hence should be heavily damaged by the water.

5.7.4 Risk Model Foundering

The event tree is shown in Annex A.4 (pp.66). With this risk model a PLL of 5.22 E-03 is calculated which is about 2 % higher than the historical value of 5.1 E-03. The probability of spilling a tonne of bunker oil is calculated to 1.6 E-01. This is equivalent to 6810 tonnes spilt in the period 1997 to 2008. The casualty reports contain no information with respect to oil spill. However, long term observations show that the bunker oil is released to the environment, if not directly I during the accident then later due to corrosion. The probability of a loss of ship is calculated to 1.4 E-03. That yields 61 losses for the 12 year period which is 5 % lower than the 64 losses reported (of these 7 were re-floated).

5.4 Hull

The hull damage risk model is developed on basis of the 86 casualty reports. In this scenario, accidents resulting from weather damage and cargo shift are included. For the first one, weather was responsible for 25.6% of the cases leading to water ingress due to structural degradation (corrosion, cracks) minor, major or severe damage to the hull due to ship motions or slamming. For the latter, listing and capsizing happened for the 47.7% resulting from cargo shift (improper cargo stowage). The remaining 26.7% is associated with structural failure which does not lead to a sinking. Concerning this scenario, only one loss (capsizing) was recorded. The frequency of the initiating event (first circumstance on the event tree) has been estimated as 2.8 E-04. High level causes could be: wrong heading and speed either by operational failure or loss of steering/propulsion, design failure, lack of compliance with procedures (for example maintenance). Noted causes are corrosion (20%), fatigue (7%), cargo shift related to human error (26%), cargo shift related to weather (22%), damage resulted from weather (23%) and damage from cargo (2%). These causes are considered in a fault tree and they can be assumed as the most probable root causes for the accident category “hull damage”. Hence, the following frequencies of root causes can be estimated:

- Corrosion: 3.9 E-04
- Fatigue: 1.4 E-04
- Cargo shift related to human error: 5.1 E-04
- Cargo shift related to weather: 4.4 E-04
- Damage resulted from weather: 4.6 E-04
- Damage from cargo: 4.6 E-05

The high level risk model (event and fault tree) is shown at Figure 5-10.

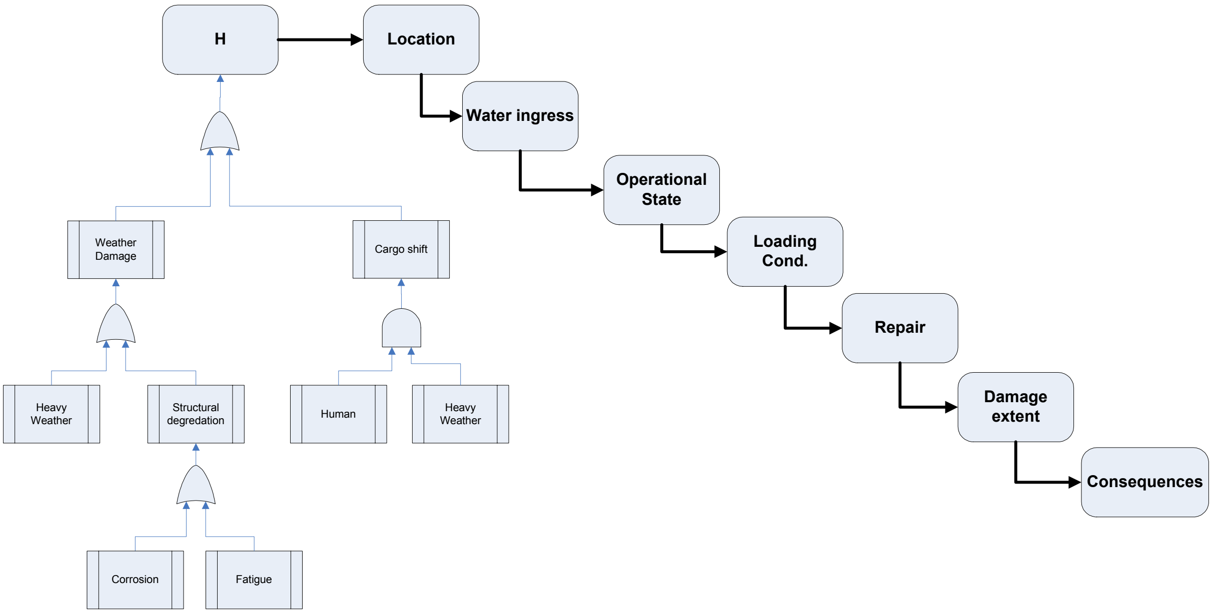


Figure 0-11: High level generic risk model for hull damage accident scenario.

5.7.1 Location

The location characterises the part of the ship where the damage occurred. In 76% of the records the fore part was damaged, whilst the remaining 24% had recorded damage at the aft part.

5.7.2 Water ingress

In 41% of the cases, water ingress was observed after the damage, meaning that water entered the compartment without leading to sinking. The remaining 59% of the reports were recorded without water ingress.

5.7.3 Operational State

The operational state characterises the geographical location where the accident happened. The majority of accidents were reported at "open sea" (57%), followed by "coastal waters" (28%) and "harbour" (15%).

5.7.4 Loading Conditions

For 30% of the accident reports the loading condition was unknown. Again, the classification merging performed previously is applied in the "hull damage" accident scenario. The rest 70% is distributed as follows:

Table 0-10: Relative probabilities for loading conditions taking into account operational state

Location	Loaded	Empty
Open sea	100%	--
Coastal waters	88%	12%
River/Canal	--	--
Harbour	100%	--

5.7.5 Repair

Repair was required for 86% of the cases whilst the remaining 14% need not be repaired.

5.7.6 Consequences

The LRF reports and the additional information found at GISIS are evaluated with respect to the consequences and three risk categories are taken into consideration (safety, environment and property). Based on the damage description the following damage categories are specified:

- Small (including minor): damages to equipment and no water ingress
- Severe: water enters a compartment and heavy weather damage
- Loss: total loss of the ship either due to sinking or an insurance total loss

Table 0-11: Summarised consequences in terms of PLL and relative frequencies for property damage

Location	**Human**	**Property**		
	PLL	**Small**	**Severe**	**Loss**
Aft		5.4E-07	2.7E-06	
Fore	2.8E-04	4.8E-06	7.8E-06	2.7E-07
TOTAL	**2.8E-04**	**5.4E-06**	**1.1E-05**	**2.7E-07**

5.4.6.1 Safety

The classes defined previously are used, with regard to the damage extent:

- Maximum number of fatalities is 2 (small)
- Maximum number of fatalities is 7 (severe)
- Maximum number of fatalities is 20 (loss)

Table 0-12: Relative probabilities for safety related consequences

Location	**Damage extent**	**Accidents**	**Fatalities**	**Fatality/Accident**
Aft	Small	19%	--	--
	Severe	81%	--	--
	Loss	--	--	--
Fore	Small	40%	--	--
	Severe	58%	100%	0.316
	Loss	2%	--	--

As shown from the above table, 12 fatalities were the result of 2 severe accidents.

5.4.6.2 Environment

No pollution events where recorded for this accident scenario. However, for the one loss it could be assumed that there could be a release of oil around 130 t.

5.4.6.3 Property

In the present state of development of the risk model the damage to ship and cargo as well as additional monetary losses are not quantified. The quantification of property related consequences will be taken into account in the cost-benefit analysis (FSA Step 4).

5.5 Fire/Explosion

The fire/explosion risk model (Figure 5-11) is developed on basis of the 116 casualty reports. The majority of fire/explosion accidents occurred in the engine room (61.2%), some happened at accommodation spaces (12.07%) whilst the remaining 26.73% at the cargo area. Explosions after fire (6%) as well as explosions (7%) occurred in engine room and cargo spaces. The frequency of the initiating event (first circumstance on the event tree) has been estimated as 2.7 E-03. Noted causes are oil leakage (38%), crankcase explosion (8%), overheating (6%), cable failure (14%), switchboard malfunction (9%), cargo operation/handling (12%) and cargo properties (13%). These causes are considered in a fault tree and they can be assumed as the most probable root causes for the accident category "fire/explosion". Hence, the following frequencies of root causes can be estimated:

- Oil leakage: 1.0 E-03
- Crankcase explosion: 2.1 E-04
- Overheating: 1.6 E-04
- Cable failure: 3.7 E-04
- Switchboard malfunction: 2.3 E-04
- Cargo operation/handling: 3.5 E-04
- Cargo properties: 3.7 E-04

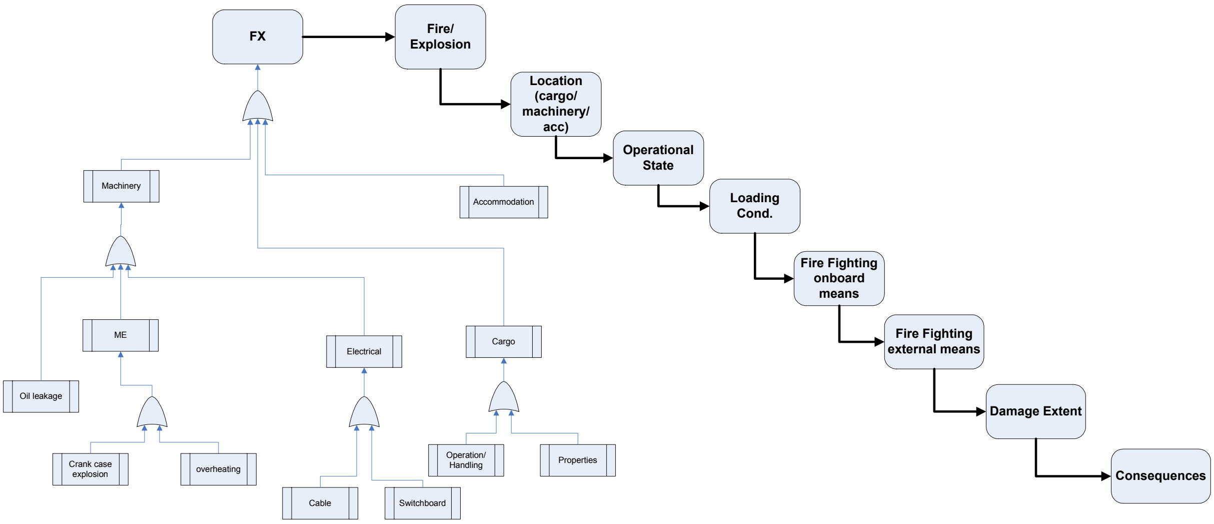


Figure 0-12: Generic high level risk model for the fire/explosion accident scenario

5.7.1 Fire/Explosion

This branch characterises whether there was explosion after fire (6%), fire only (87%) or only explosion (7%).

5.7.2 Location

The location characterises the part of the ship where the accident occurred. So, 12% of the cases happened at accommodation spaces, 61% occurred in engine room, whilst the remaining 27% had fire/explosion at the cargo area.

5.7.3 Operational state

The operational state characterises the geographical location where the accident happened. The majority of accidents was reported at "harbour" (38%), followed by "open sea" (35%), "coastal waters" (22%) and "river/canal" (4%).

5.7.4 Loading Conditions

For 33% of the accident reports the loading condition was unknown. Again, the classification merging performed previously is applied in the "fire/explosion" accident scenario. The rest 67% is distributed as follows:

Table 0-13: Relative probabilities for loading conditions taking into account operational state

Location	Loaded	Empty
Open sea	93%	7%
Coastal waters	94%	6%
River/Canal	100%	--
Harbour	72%	28%

It is shown that there is a correlation between the accident and the loading condition.

5.7.5 Fire-fighting

This branch characterises whether the accident was suppressed by on-board means (64%), or external assistance was needed (36%). The distribution is as follows:

Table 0-14: Relative probabilities for fire-fighting taking into account operational state and damaged location in the ship

Fire-fighting	Operational state	Location	
External means (42)	Open sea: 31%	Accommodation	15%
		Cargo area	46%
		Engine room	39%

	Coastal waters: 14%	Accommodation	17%
		Cargo area	50%
		Engine room	33%
	River/canal: 2%	Accommodation	--
		Cargo area	100%
		Engine room	--
	Harbour: 53%	Accommodation	23%
		Cargo area	45%
		Engine room	32%
On-board means (74)	Open sea: 38%	Accommodation	4%
		Cargo area	4%
		Engine room	92%
	Coastal waters: 27%	Accommodation	10%
		Cargo area	5%
		Engine room	85%
	River/canal: 5%	Accommodation	25%
		Cargo area	--
		Engine room	75%
	Harbour: 30%	Accommodation	10%
		Cargo area	40%
		Engine room	50%

External assistance was needed more for fire/explosion accidents in the cargo spaces and when the ship was at harbour, whilst most of the engine room fire/explosion accidents were suppressed by on-board means.

5.7.6 Consequences

The LRF reports and the additional information found at GISIS are evaluated with respect to the consequences and three risk categories are taken into consideration (safety, environment and property). Based on the damage description the following damage categories are specified:

- Small (including minor): fire brought under control in a couple of hours
- Severe: crew abandoned vessel and fire was burning for a couple of days
- Loss: total loss of the ship either due to sinking or an insurance total loss

Table 0-15: Summarised consequences in terms of PLL and relative frequencies for property damage

Event type /Location	**Human**	**Property**		
	PLL	Small	Severe	Loss
Explosion after fire				
Engine room	2.3E-05	4.0E-07		4.0E-07
Cargo area	5.3E-05	2.0E-07	2.0E-07	2.0E-07
Fire				
Accommodation	6.9E-05	1.2E-06	8.0E-07	
Engine room	2.6E-04	4.4E-06	1.2E-06	1.2E-06
Cargo area		3.4E-06	1.0E-06	2.05E-07
Explosion				

Engine room	2.8E-05	8.0E-07		
Cargo area	3.7E-05	2.0E-07		2.0E-07
TOTAL	**4.7E-04**	**1.1E-05**	**3.2E-06**	**2.2E-06**

5.5.6.1 Safety

The classes defined previously are used, with regard to the damage extent (parenthesis):

- Maximum number of fatalities is 2 (small)
- Maximum number of fatalities is 7 (severe)
- Maximum number of fatalities is 20 (loss)

Table 0-16: Relative probabilities for safety related consequences				
Location	**Damage extent**	**Accidents**	**Fatalities**	**Fatality/Accident**
Explosion after fire				
Accommodation	Small	--	--	--
	Severe	--	--	--
	Loss	--	--	--
Cargo area	Small	33%	--	--
	Severe	34%	100%	3.0
	Loss	33%	--	--
Engine room	Small	50%	50%	0.5
	Severe	--	--	--
	Loss	50%	50%	1.0
Fire				
Accommodation	Small	57%	44%	1.7
	Severe	43%	56%	2.0
	Loss	--	--	--
Cargo area	Small	73%	--	--
	Severe	19%	--	--
	Loss	8%	--	--
Engine room	Small	75%	21%	1.5
	Severe	13%	79%	5.5
	Loss	12%	--	--
Explosion				
Accommodation	Small	--	--	--
	Severe	--	--	--
	Loss	--	--	--
Cargo area	Small	50%	100%	1.5
	Severe		--	--
	Loss	50%	--	--
Engine room	Small	100%	100%	1.5
	Severe	--	--	--
	Loss	--	--	--

5.5.6.2 Environment

One incident was characterised with unknown quantity of oil spilled. Hence this is assumed to be equal to 120 t (one tank).

5.5.6.3 Property

In the present state of development of the risk model the damage to ship and cargo as well as additional monetary losses are not quantified. The quantification of property related consequences will be taken into account in the cost-benefit analysis (FSA Step 4).

5.6 Machinery damage

The machinery risk model (shown at Figure 5-12) is developed on basis of the 533 casualty reports. Damages to equipment (propulsion, steering/rudder, electrical equipment) are included in this scenario, accounting for 8.63%, 88.18% and 3.19% of the cases respectively. The frequency of the initiating event (first circumstance on the event tree) has been estimated as 1.2 E-02. Most probable causes could be attributed to the wear out phase of the equipment, maintenance procedures not being carried out properly, as well as failure of gauging equipment. Noted causes are steering/rudder equipment failure (8%), inadequate maintenance of steering/rudder (0.4%), failure of propulsion equipment (78%), inadequate maintenance of propulsion equipment (7.3%), failed gauging of propulsion equipment (3%), failure of electrical equipment (1.5%) and inadequate maintenance of electrical equipment (1.8%). These causes are considered in a fault tree and they can be assumed as the most probable root causes for the accident category “machinery damage”. Hence, the following frequencies of root causes can be estimated:

- Steering/rudder equipment failure: 1.0 E-03
- Inadequate maintenance of steering/rudder: 4.6 E-05
- Failure of propulsion equipment: 9.6 E-03
- Inadequate maintenance of propulsion equipment: 9.0 E-04
- Failed gauging of propulsion equipment: 3.7 E-04
- Failure of electrical equipment: 1.9 E-04
- Inadequate maintenance of electrical equipment: 2.1 E-04

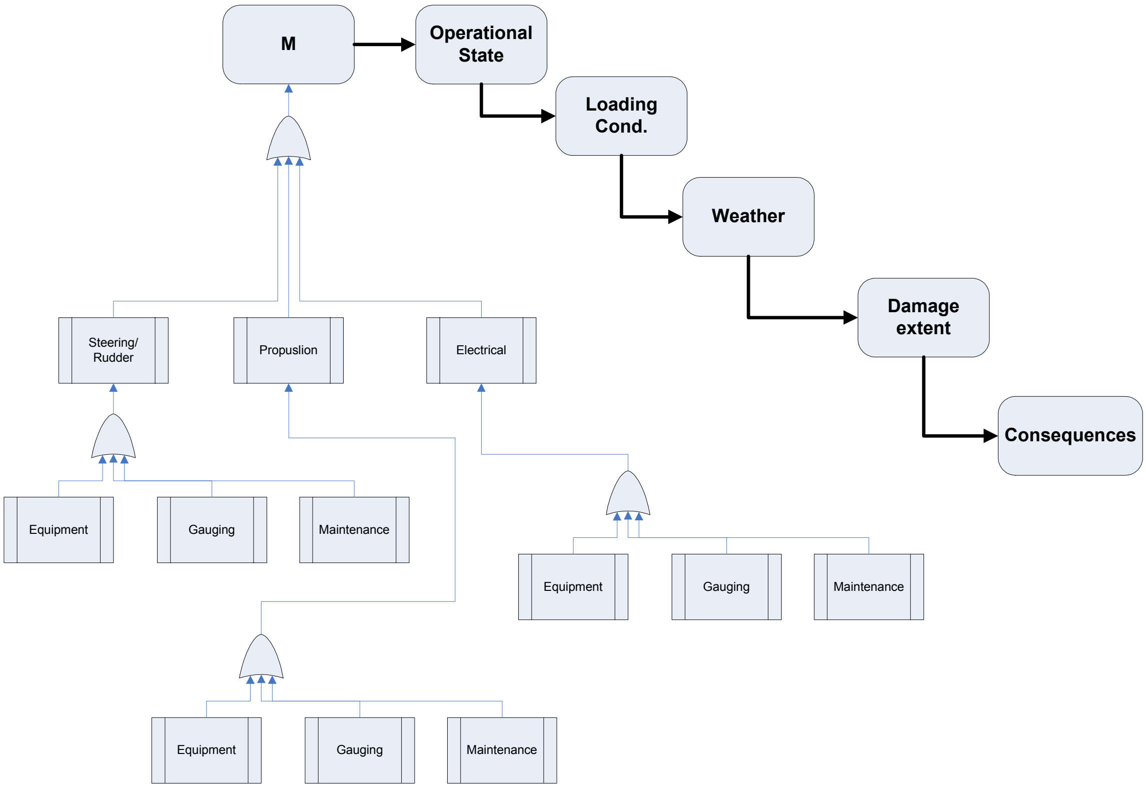


Figure 0-13: Generic high level risk model for the machinery damage accident scenario

5.7.1 Operational State

The operational state characterises the geographical location where the accident happened. The majority of accidents was reported at "open sea" (56%), followed by "coastal waters" (30%), "river/canal" (9%) and "harbour" (5%).

5.7.2 Loading Conditions

For 51% of the accident reports the loading condition was unknown. Again, the classification merging performed previously is applied in the "machinery damage" accident scenario. The remaining 49% is distributed as follows:

Table 0-17: Relative probabilities for loading conditions taking into account operational state

Location	Loaded	Empty
Open sea	90%	10%
Coastal waters	74%	26%
River/Canal	75%	25%
Harbour	75%	25%

5.7.3 Weather

The weather conditions are described in this branch. For 70% of the casualty records the weather was unknown or not reported. For the remaining 30%, the weather is distributed as follows:

Table 0-18: Relative probabilities for weather conditions taking into account operational state

Location	Good weather	Heavy/bad weather	Hurricane/storm
Open sea	34%	60%	6%
Coastal waters	35%	60%	5%
River/Canal	48%	50%	2%
Harbour	40%	60%	--

It can be observed that the majority of machinery damage scenarios are associated with bad weather.

5.7.4 Consequences

The LRF reports and the additional information found at GISIS are evaluated with respect to the consequences and three risk categories are taken into consideration (safety, environment and property). Based on the damage description the following damage categories are specified:

- Small (including minor): repair effected by crew only
- Severe: equipment lost, severe damage and major replacement was needed, salvage was employed;
- Loss: total loss of the ship either due to sinking or an insurance total loss

Table 0-19: Summarised consequences in terms of PLL and relative frequencies for property damage

Weather	Human	Property		
	PLL	**Small**	**Severe**	**Loss**
Good	4.6 E-05	1.5 E-06	2.2 E-07	
Heavy/Bad	2.6 E-04	2.3 E-06	4.3 E-07	4.3 E-08
Hurricane/Storm		1.3 E-07		
TOTAL	**3.0 E-04**	**4.0 E-06**	**6.5 E-07**	**4.3 E-08**

5.6.4.1 Safety

The classes defined previously are used, with regard to the damage extent (parenthesis):

- Maximum number of fatalities is 2 (small)
- Maximum number of fatalities is 7 (severe)
- Maximum number of fatalities is 20 (loss)

Table 0-20: Relative probabilities for safety related consequences

Weather	Damage extent	Accidents	Fatalities	Fatality/Accident
Good	Small	79%	100%	0.118

	Severe	21%	--	--
	Loss	--	--	--
Heavy/bad	Small	82%	82%	0.25
	Severe	17%	--	--
	Loss	1%	18%	2.0
Hurricane/storm	Small	100%	--	--
	Severe	--	--	--
	Loss	--	--	--

All fatalities occurred during accidents falling into the “small” machinery damage category.

5.6.4.2 Environment

One accident was recorded with the release of 515 t of fuel oil.

5.6.4.3 Property

In the present state of development of the risk model the damage to ship and cargo as well as additional monetary losses are not quantified. The quantification of property related consequences will be taken into account in the cost-benefit analysis (FSA Step 4).

5.7 Wrecked/Stranded

The wrecked/stranded risk model is developed on basis of the 238 casualty reports. The frequency of the initiating event (Event Tree) is determined on the basis of the casualty reports identified by means of LRF and GISIS databases to 5.5 E-03. In only 8 % of the casualty reports information with respect to the accident cause are provided. Noted causes are human failure (6; 32 %), mooring failure (3; 16 %), steering failure (5; 26 %), anchor failure (3; 16 %) and engine/machinery failure (2; 10 %). These causes (basic events) are considered in a fault tree leading to the accident category wrecked/stranded. The risk contribution tree (combination of event tree and fault tree) is shown in Figure 0-14.
Assuming that these causes are characteristic for wrecked/stranded the following initial frequencies are calculated (the unknown accidents are distributed onto these basic events):

- Anchor: 3.68E-04
- Engine/machinery: 2.30E-04
- Human: 7.36E-04
- Mooring: 3.68E-04
- Steering: 5.98E-04

The investigation shows further that the basic event *Anchor*, *Machinery*, *Steering* and *Mooring* often occur in combination with bad weather condition like strong wind or swell. These basic events are also typical for so-called drift grounding accidents. In this context it is investigated if the two grounding categories drift grounding and powered grounding lead to different consequences. 26 % of the accidents can be classified into these categories. Of these 57 % are drift groundings, 41 % are powered groundings and 2 % are emergency grounding performed to avoid capsizing or foundering. The combination of grounding category and damage extent is shown in Table 5-21. These results provide no clear trend with respect to the consequences and, hence, this is not taken into consideration in the event tree.

Table 0-21: Relation between grounding category and damage extent.

Grounding category	Damage extent		
	Loss	Severe	Small
	%	%	%
Drift	16	14	70
Powered	10	35	55

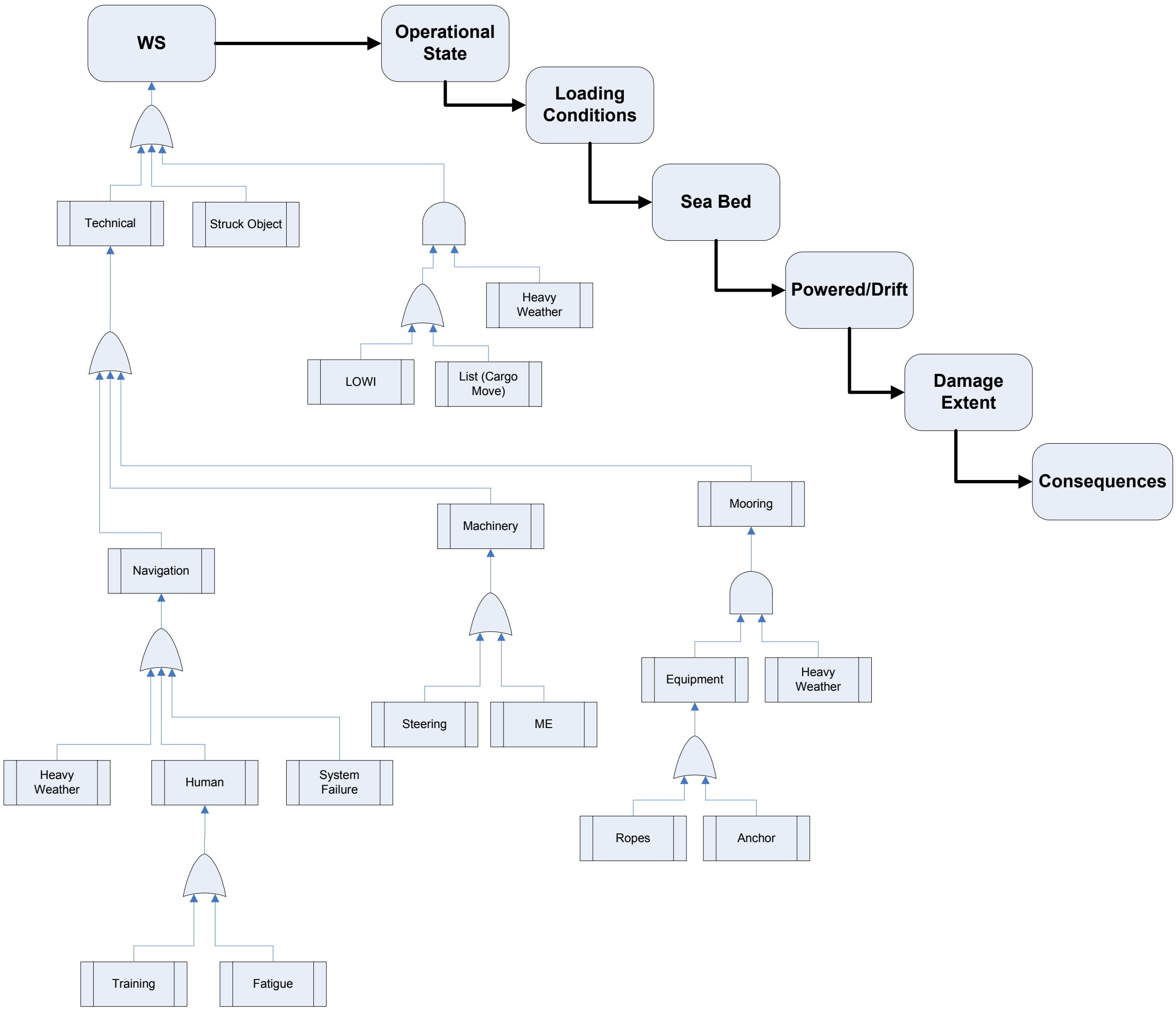


Figure 0-14: High-level generic accident scenario for Wrecked/Stranded

The event tree for wrecked/stranded is shown in Annex A.7 (pp. 76)

5.7.1 Operational State

In 99 % of all reports an operational state was specified. Accordingly, the majority of accidents were reported for “Coastal Waters” (67 %), followed by “River/Canal” (23 %), “Harbour” (9 %) and “Open Sea” (1 %).

5.7.2 Loading Conditions

For 66 % of the wrecked/stranded accidents (215 of 325), the records contain information with respect to the loading conditions of the ship. Accordingly, 84 % of the ships with known loading conditions were loaded. The investigation of the reports showed no relation between loading condition and the damage to the ship hull. However, the loading condition has impact on the economic loss, and hence the loading condition is considered in the event tree.
For the risk model wrecked/stranded the classes “Empty”, “Ballast” and “Partial Loaded” are merged to one group assigned “Empty”. The following table summarises the relation between the two loading condition categories and the operational condition, and which are used in the event tree.

Table 0-22: Relation between operational status and loading condition.

Operational Condition	Loaded	Empty	Load/Dis	Remarks
	%	%		
Open Sea	90	10	--	Only small number of reports. Hence, same values like collision event tree.
Coastal Waters	80	20	--	151 reports. Results are similar to the event tree collision.
River/Canal	90	10	--	47 reports. Results are similar to the event tree collision.
Harbour	80	20	--	16 reports. Portion of loaded ships higher than in collision accidents.

5.7.3 Seabed

It is expected that the seabed conditions have an impact on the damage extent, for instance, the damage to hull for a grounding accident on a sandy seabed is less severe than for a similar accident on a reef. Hence, the casualty reports are investigated with respect to information for seabed and damage extent. No information with respect to seabed is found in 88 % of all LRF reports. For the remaining group 63 % of the stranding took place on rocky seabed. Of these, 78 % lead to severe damage to the ship. In the opposite case, stranding on sand, only small damage is reported.

Table 0-23: Relation seabed condition and damage extent.			
Seabed	**Small**	**Severe**	**Loss**
	%	%	%
Sand	100	--	--
Rock (reef)	22	48	30
Other objects (e.g. wreck)	--	100	--
Unknown	69	25	6

The relation between seabed and operational status is investigated. For River/Canal all accidents were reported for sandy seabed. In harbour one third of the accidents took place on rock. 82 % of the accidents in coastal waters are on rocky seabed, 14 % on sandy seabed and 4 % are other objects like a wreck. The probabilities used in the event tree for both sub-branches "Empty" and "Loaded" are summarised in Table 5-24. Except for other objects, similar values are used for coastal waters and open sea. For open sea, the probability for a stranding on a wreck is set to zero and the probabilities for sand and rock are increased accordingly. For wrecked/stranded on River/Canal the possibility of rocky seabed is taken into consideration, for instance spur dyke. The number of accidents reported for open sea allows no statistical evaluation and, hence, except for other objects similar values are used for coastal waters and open sea. For open sea the probability for a stranding on a wreck is set to zero and the probabilities for *sand* and *rock* are increased accordingly. For wrecked/stranding on River/Canal the possibility of rocky seabed is taken into consideration, for instance, spur dyke.

Table 0-24: Relation operational status and seabed condition.				
Operational status	**Sand**	**Rock**	**Other objects**	**Remarks**
	%	**%**	**%**	
Open Sea	18	82	0	Only one report contains information, values for coastal waters used.
Coastal Waters	16	80	4	
River/Canal	98	2	0	Consideration of rocky seabed.
Harbour	67	33	0	

5.7.4 Consequences

The LRF reports and the additional information provided by GISIS are evaluated with respect to the consequences. The three risk categories safety, environment and property are taken into consideration. Based on the damage description the following damage categories are specified:

- Small: ship is re-floated and returns to service after inspection, not valuable repair or repair work required, damage descriptions like dents, small holes. No water ingress (holes above waterline).
- Severe: Sustained severe. Indication severe or significant structural damage leading to water ingress and/or requires docking for repair. In the following some typical damage descriptions taken from the records are summarised:

- Reported ingress of water to Nos. 3 and 4 ballast tanks;
- 10 metres hole from stern to astern was torn. Bow propeller room flooded. No. 1 starboard tank holed;
- Sustained 40 metres tear in hull with damage to three bunker tanks;
- Ballast tanks 6, 8 and 10 were flooded with water. After diving inspection the external shell plating was found to be torn in two places approximately 20 metres in length;
- Fracture 7 m * 0.7 m to bunker tank and further severe damage to hull bottom;

- Loss: total loss of the ship. In lack of information loss or insurance loss is not distinguished.

The specification of these categories relates to the ship structure and do not consider the follow up consequences like loss of income.
In total 61 fatalities were reported for five wrecked/stranding accidents. 98 % of all wrecked/stranded accidents are without fatalities. The majority of fatalities were reported for the loss of a loaded ship operating in coastal waters (80 %). This consequence to safety is higher than the percentage of accidents in coastal waters (67 %). The fatality rate per accident for all wrecked/stranded accidents is 0.19, increasing with the damage extent. In case of loss of ship the fatality rate per accident is 2.65.
The further development of the event tree with respect to safety, environment and property is explained below.

5.7.4.1 Safety

In total 61 fatalities are reported. The final safety related consequences depend on several other parameters. For instance, the operational state influences the access and reaction time for means of rescue. Additionally, the statistical investigation shows that the number of fatalities relates to the damage extent (ref. discussion above). For the accident with a total loss of the ship the highest PLL (Potential Loss of Life) is observed, whereas for the accident with minor damage to the ship mostly no fatalities were reported. However, even if very small, for all damage categories a PLL can be estimated.
The probability of fatalities is determined for each branch based on the historical data taking into consideration the previous steps of the event tree “Operational State”, “Seabed” and damage extent. All accident consequences are considered by distributing the consequences with respect to safety of the group *Unknown* on the other categories according to the relative distribution of the *Known* classes[4]. The basic data are summarised in Table 5-25.

Table 0-25: Relation operational status, seabed, damage extent and fatalities based on LRF data.

Operational State	Seabed	Damage Extent	Accidents	Fat	Remarks

[4] Example: N fatalities reported for coastal waters and seabed *Unknown*. The relative distribution for seabed in coastal waters is 16:80:4, hence the ten fatalities are distributed into these categories: 1.6:8:0.4 and added to the fatalities of these categories.

			No	%		
Open Sea						Only one accident.
Coastal Waters	Rock	Small	5	23	0	
		Severe	11	50	0	
		Loss	4	27	1	
	Sand	Small	4	100	0	
		Severe	0	--	--	
		Loss	0	--	--	
	Other object	Small	0	--	--	
		Severe	1	100	0	
		Loss	0	--	--	
	Unknown	Small	114	65	0	
		Severe	49	28	0	
		Loss	12	7	38	
River/Canal	Rock	Small	0	--	--	
		Severe	0	--	--	
		Loss	0	--	--	
	Sand	Small	7	100	0	
		Severe	0	--	--	
		Loss	0	--	--	
	Unknown	Small	51	80	0	
		Severe	12	19	0	
		Loss	1	1	22	
Harbour	Rock	Small	0	--	--	Only one accident.
		Severe	0	--	--	
		Loss	1	100	0	
	Sand	Small	2	100	0	
		Severe	0	--	--	
		Loss	0	--	--	
	Unknown	Small	18	78	0	
		Severe	4	17	0	
		Loss	1	5	0	

These data are used to specify the probabilities for the different scenarios of the event tree which considers also event not reported yet.

Table 0-26: Relative probabilities for fatalities in relation to operational status, seabed and damage extent category.					
Operational State	**Seabed**	**Damage Extent**	**Probability of fatalities(%)**	**Fat**	Remarks
Open Sea	Rock	Small	2	1	Same values as coastal waters
		Severe	5	2	
		Loss	20	12	
	Sand	Small	2	1	
		Severe	5	2	
		Loss	20	12	
Coastal Waters	Rock	Small	2	1	Even if no fatalities reported, small probability of one fatality considered.
		Severe	5	2	Even if no fatalities reported, small probability of two fatalities considered.
		Loss	20	12	Number of fatalities and probability

					adjusted to meet statistical values.
	Sand	Small	2	1	Same like rock.
		Severe	5	2	
		Loss	20	12	
	Other object	Small	2	1	Same like rock.
		Severe	5	2	
		Loss	20	12	
River/Canal	Rock	Small	2	1	Even if no fatalities reported, small probability of one fatality considered.
		Severe	10	7	Even if no fatalities reported, small probability for fatalities considered. Probability and number of fatalities adjusted.
		Loss	40	18	Only one accident. All fatalities reported for this accident. However, not every loss should lead to such a high number of fatalities. Hence, probability for fatalities reduced to 40 %. Number of fatalities adjusted to meet statistics.
	Sand	Small	2	1	Same like rock.
		Severe	10	7	
		Loss	40	18	
Harbour	Rock	Small	2	1	No fatalities reported. However, fatalities could not be excluded. Hence, 2 % probability for fatalities considered. Due to lower velocity number of fatalities expected to be smaller than for other scenarios.
		Severe	2	2	
		Loss	2	5	
	Sand	Small	2	1	
		Severe	2	2	
		Loss	2	5	

5.7.4.2 Environmental Consequences

The environmental impact of an accident could be caused by the spill of the fuel as well as by the cargo. Seldom, the casualty reports contain pollution details. In total 17 accidents caused environmental pollution (5 % of all wrecked/stranded), and of these 94 % were an oil release. In only 50 % of the oil related accidents the spill size was specified. For the accident causing pollution by cargo release the type of cargo is not known.
The present information with respect to environmental impact of wrecked/stranding accident is characterised by limited information mostly focused on oil release. The release of environment polluting cargo does not occur or is not reported. Even if more information is available the evaluation of the release of such substance would be difficulty because of missing information with respect to the environmental impact. Hence, the developed model considers only the spill of oil.
All accidents with specified spill size took place in coastal waters. The vast majority of these spills are linked to the damage category *loss* (four of eight). Four spills were reported for the damage category *severe*. For only three spills the seabed condition was specified. In all of them the seabed was rock. For the remaining accidents with oil spill no information with respect to the seabed are available.

The oil outflow is investigated with respect to the specified damage extent categories (*small, severe, loss*). No oil outflow was reported for the damage category *small*. For the damage categories *severe* and *loss* accidents with oil outflow were reported. . The comparison with respect to the oil outflow shows that the dependent probability for the category *loss* is significantly higher than for the category *severe* (probability of oil outflow in case of *loss* 20 %; *severe* 5 %).
The different probabilities of the seabed related damage extent are already taken into consideration under the heading "Seabed". However, in case of total loss of the ship it is expected that the seabed has an additional influence on the oil outflow caused by the different damage characteristics. In case of a stranding on rocks the hull is more likely to be damaged as for stranding on sandy seabed. Hence, in such a scenario the oil outflow should be more likely than for stranding on sand.
The historical data show that the oil spills size for *loss* varies between 6 tonnes and 160 tonnes, whereas for *severe* the spill size varies between 0.5 tonnes and 100 tonnes. For the damage category *loss* the average spill size is determined to 86.3 tonnes and for *severe* to 36.4 tonnes. The average spill size is in good agreement with the tank capacity (As mentioned above a general cargo ship with 5000 GT has two different tank arrangements each consisting of two tank sizes, large: 140 m^3 or 130 m^3 and small 60 m^3.).
To avoid another event in the scenarios the environmental consequences are not considered separately, but an average spill size is specified for all accidents in one damage category. Furthermore, as mentioned above the probability of an oil spill on rocky seabed is expected to be more likely than on sand. This is considered by a reduced spill size for the *sand* scenarios (statistical data using the same approach as for safety, i.e. accidents with unknown seabed specification and loading conditions are distributed according the relative distribution of the reports with respective information. The probabilities used in the event tree are summarised in Table 0-28.

Table 0-27: Average spill sizes.

		Av. spill size (tonnes)
Sand	Small	0
	Severe	2
	Loss	4
Rock	Small	0
	Severe	4
	Loss	15

These spill sizes consider the reported oil spills (potential spill of one tonne of oil: 8.3 E-03) as well as possible spills (potential spill of one tonne of oil: 1.56 E-03).

5.7.4.3 Property Hull Damage

As mentioned above the damage extent categories are specified on basis of the reports. The probabilities for the scenarios of the event tree are determined on basis of the statistical data using the same approach as for safety, i.e. accidents with unknown seabed specification and loading conditions are distributed according the relative distribution of the reports with respective information. The probabilities used in the event tree are summarised in Table 5-28.

Table 0-28: Relative probabilities for damage extent in relation to operational status, loading condition and seabed.

Operational State	Loading condition	Seabed	Damage Extent	Probability of damage extent	Remarks
				%	
Open Sea	Same for loaded and empty	Rock	Small	60	
			Severe	31	
			Loss	9	
	Same for loaded and empty	Sand	Small	70	
			Severe	25	
			Loss	5	
Coastal Waters	Same for loaded and empty	Rock	Small	60	
			Severe	31	
			Loss	9	
	Loaded	Sand	Small	57	
			Severe	37	
			Loss	6	
	Empty		Small	70	
			Severe	25	
			Loss	5	
	Same for loaded and empty	Other object	Small	60	
			Severe	31	
			Loss	9	
River/Canal	Same for loaded and empty	Rock	Small	80	
			Severe	18	
			Loss	2	
		Sand	Small	80	
			Severe	18	
			Loss	2	
Harbour	Same for loaded and empty	Rock	Small	70	
			Severe	16	
			Loss	14	
		Sand	Small	80	
			Severe	16	
			Loss	4	

5.7.5 Risk Model Wrecked/stranded

The event tree is shown in Annex A.7 (pp.76). With this risk model a PLL of 1.4 E-03 is calculated which is equivalent to the historical value. The probability of spilling a tonne of bunker oil is calculated to 1.4 E-02. This is equivalent to 581 tonnes spilt in the period 1997 to 2008 which is about 18 % higher to cover expected underreporting. The probability of a loss of ship is calculated to 5.2 E-04. That yields 22 losses for the 12 year period which is 5 % higher than the 21 losses reported.

6 F-N curve for historical data and risk model

The F-N curve for the IACS fleet between the historical data and the consequences from the risk model concerning safety (loss of life) is provided for verification purposes. It is observed that the two curves coincide well. However, the small drift to the right can be explained by the under-reporting of the fatalities in the casualty database (see discussion).

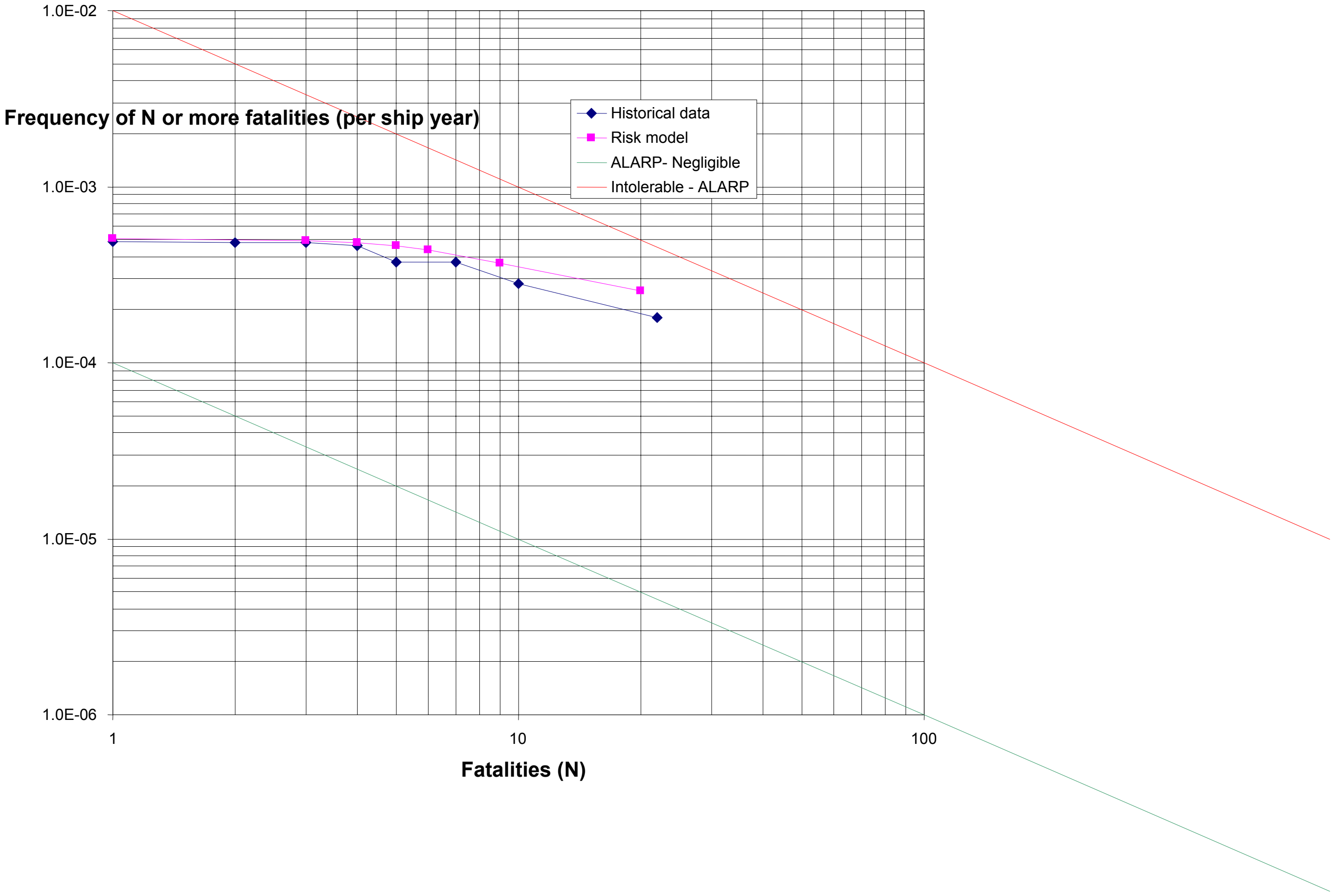


Figure 5-14. F-N curve for historical data and loss of life from the risk model

7 Discussion

Reference is made to MSC 82/21/19 submission by Russian Federation. In that document, all ships were included and thus explaining the increased number in fatalities which shown a bad picture of the general cargo fleet. However, in this report, the low PLL represents the IACS classed fleet where more information is available and a better monitoring is obtained.
There is a tendency in LRFP to underestimate the number of fatalities in known and reported ship accidents. For those records that are both in LRFP and GISIS, the numbers of fatalities are recorded in Table 6-1 (10 injuries = 1 equivalent fatality).

Table 6-1: Comparison between fatalities in LRF and GISIS

Accident category	LRF fatalities	GISIS fatalities	Difference (%)
Collision			
Contact			
Foundering			
Fire/explosion	17	19.1	12.4%
Hull damage	8	9	12.5%

Wreck/Stranding			
Machinery damage	13	13	--

8 Conclusions

This report summarises the results of a risk analysis concerning the safety of general cargo ships. During the process the following accident scenarios have been considered together with the most significant findings:

- Collision: Collision scenarios represent about 16 % of all identified accidents. This accident category is mostly observed in harbours, rivers/canals and coastal waters. There was not sufficient information in the casualty reports to determine differences between struck and striking ship and, hence, for the risk model a 50 % probability is used for both. The consequences of the collision scenarios vary between slight damage to the ship structure only and total loss of the ship and fatalities. On average the frequency of a collision accident with fatalities is 6.3 %. The number of fatalities in a single accident varies between one and 16. Additionally, it is observed that the number of fatalities relates to the damage extent. The frequency of fatalities increases with the accident severity. For 13 of 238 accidents the release of oil was reported. Of these only two contain a specification of the spill size (2737 tonnes, 11 tonnes). The probability of an oil release in a collision accident is calculated to be 5.4 %. The high-level risk model is developed on basis of an investigation of the casualty records with respect to the consequences (safety, environment) and the relation with respect to loading condition, operational state (location) and the damage extent. The probabilities in the risk model are not only based on the historical data, but take into account consequences not yet reported. This lead to an increase of the risk to crew of less than 2 %. The environmental risk is beneath the historical data because the historical data are dominated by a single event.
- Contact: Contact scenarios represent about 7 % of all identified accidents. These accidents mostly occur in harbour and on river or canals. Especially in harbour the contact accident is an interaction between a ship and the fixed harbour installations like berth, bridge or crane. The consequences vary, however, a contact accident mostly lead to small damages to the ship structure and have a relatively low importance for crew safety. In total 12 fatalities and one severe injured crew were reported. The maximum number of fatalities is 7 caused by a loss of ship after dragging anchor in heavy weather. The average number of fatalities per contact accident is 0.122. Following the accident reports a risk for loss of life exists for all damage categories. Regarding the reports as representative for the safety related consequences the number of fatalities in a contact accident leading to total loss is significantly higher. For only one of the accidents an oil spill was reported with a size of 180 tonnes (loss). Due to the fact that more than 80 % of the accidents took place in harbour or on river/canal the probability of underreporting should be lower than for other accident categories. Similar to the risk model for collision, historical data form the basis for the probabilities used in the scenarios. These values are adjusted to cover also potential scenarios. Due to the small absolute numbers the effect on the risk for contact of this consideration is relatively high. However, the effect on the relation to the other risk categories is regarded as small.

- Foundering: Foundering scenarios represent about 4 % of all identified accidents. Typically, foundering occurs in open sea or coastal waters. Seldom are foundering accidents occurring in harbour or on river/canal. With respect to crew safety foundering is the biggest risk contributor. Nearly 50 % of all fatalities reported for IACS classified general cargo ships between 1996 and 2008 are related to this accident category (220) with an average number of fatalities per accident as 5.4. Characteristic basic events for foundering accidents are cargo shift and water ingress as well as a combination of both. Like the other risk models potential scenarios are considered. Especially, the release of bunker oil is considered by postulating spill sizes with respect to the capacity of bunker tanks determined for an average vessel with 5000 GT.
- Hull damage: Hull damage scenarios represent 16.14% and are associated with heavy weather damage, structural degradation and listing most probably due to cargo shift. Repair was required for 86% of the cases whilst the remaining 14% need not be repaired. The average number of fatalities per accident has been calculated as 0.3. One total loss was recorded where it can be assumed that the release of oil is equal to the amount included in one tank (120 t).
- Fire/Explosion: Fire and explosion scenarios represent 7.94% of all identified accidents. Engine-room and accommodation fires are considered to be common for all cargo ship types. Explosions in engine room are associated with main engine (crankcase) and boiler, whereas explosions in cargo holds are related to lack of knowledge or exact documentation and which precautions should be taken into account for the transported cargo. Fire-fighting by onboard means was successful for 63.8% of the cases. It can be observed that for the losses, the consequences to life are small (max 2 fatalities), whilst more fatalities occur for the small and severe extents of damage. The average number of fatalities per accident has been calculated as 2.1. One incident was recorded with unknown spill quantity where it is assumed that the release of oil could be equal to the amount of oil in one tank (120 t).
- Machinery damage: Machinery damage scenarios account for 36.46% of all identified accidents, 2 out of the 533 resulted into striking an object, whilst 13 resulted in drifting. Most probable causes could be attributed to the wear out phase of equipment (88%) maintenance procedures not being carried out properly (10%) and failure of gauging equipment (2%). The average number of fatalities per accident has been calculated as 0.8 and only one incident has been recorded with the release of oil (515 t).
- Wrecked/Stranded: Grounding scenarios represent about 22 % of all identified accidents. These accidents are observed in harbour, on river or canal and in coastal waters. Grounding accidents are observed as powered grounding caused by human error or technical error (steering failure), or as drift grounding followed a blackout, loss of propulsion etc. Drift grounding mostly took place in combination with bad weather like hurricane or heavy swell. With respect to crew safety the impact of grounding is significantly smaller than that of foundering. Nearly 15 % of all fatalities are caused by this accident category. In 12 % the information in the records allow conclusions with respect to the seabed. According to that, 78 % of the accidents on a rocky seabed lead to severe damage to the ship. In the opposite case, stranding on sand, only small damage is reported. 98 % of all wrecked/stranded accidents are without fatalities. However, in total 61 fatalities were reported for five wrecked/stranding accidents. The majority of fatalities were reported for the loss of a loaded ship operating in coastal waters (80 %). The fatality rate per accident for all wrecked/stranded accidents is 0.19, increasing with the damage extent. In case for loss of ship the fatality rate per accident is 2.65. The environmental impact of an accident could be caused by the spill of the fuel as well as by the cargo. In total 17 accidents cause an environmental pollution, 5 % of all reported accidents, and of these 94 % caused an oil release. In only 50 % of the oil related

accidents the spill size was specified. The developed risk model agrees with the historical data. Again, the consideration of possible environmental related scenarios yields an increase of the probability of an oil spill.

It is interesting to note that 1 out of 3 LRF casualty reports have been identified within GISIS, whereas for hull damage and fire/explosion scenarios GISIS contained more accurate numbers (12%) with respect to the number of fatalities.

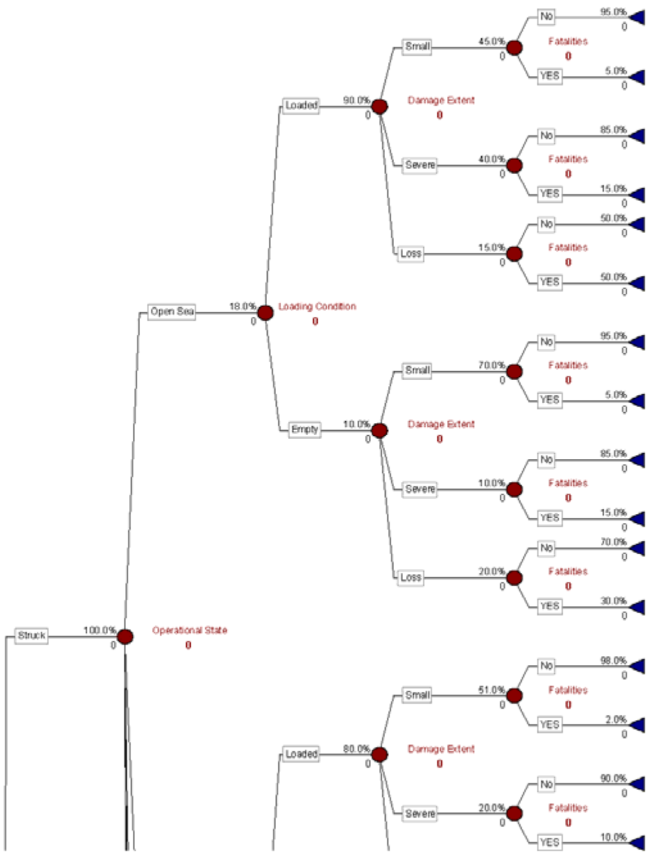
9 References

EMSA, 2009: Maritime Accident Review 2008. European Maritime Safety Agency.

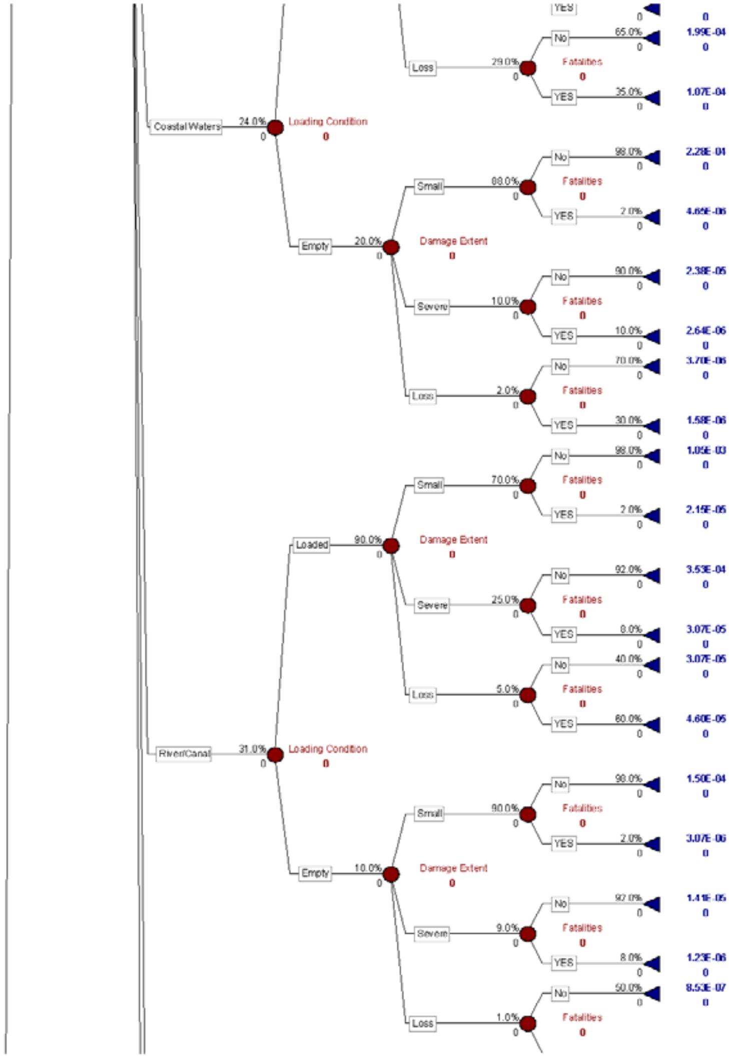
Annex A

Event Trees

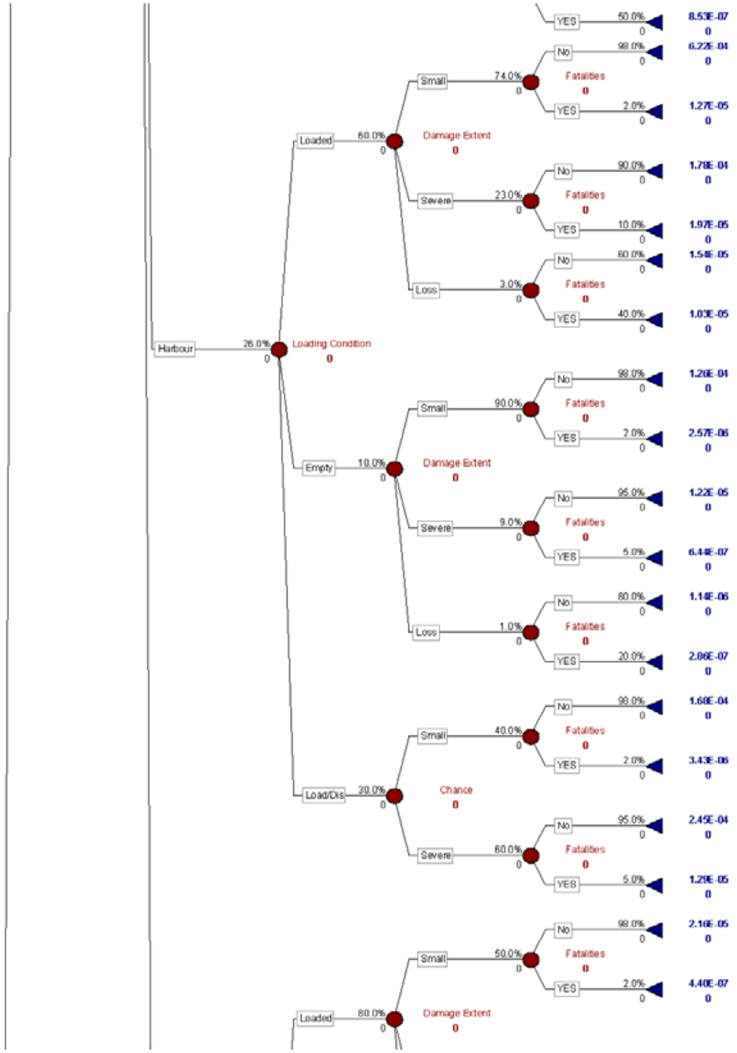
Collision



				Consequences				Cumultative risk contribution			
Probability of scenario (absolute)		*No Accidents per ship year*	*Sequence No*	Human fatalities crew	Environment Oil leakage [tonnes]	Ship damage [€]	Loss	PLL Potential Loss of Life per ship year Crew	Bunker spill tonnes per ship year	Property [€/ship year]	PLS Potential Loss of Ship per ship year
0.55%	1	0.0055						2.43E-03	0.017726005	0	0.00058432
3.81E-04 0		3.81E-04	*1*	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.00E-05 0		2.00E-05	*2*	2	0			4.01E-05	0.00E+00	0.00E+00	0.00E+00
3.03E-04 0		3.03E-04	*3*	0	2.5			0.00E+00	7.57E-04	0.00E+00	0.00E+00
5.35E-05 0		5.35E-05	*4*	3	2.5			1.60E-04	1.34E-04	0.00E+00	0.00E+00
6.68E-05 0		6.68E-05	*5*	0	24		1	0.00E+00	1.60E-03	0.00E+00	6.68E-05
6.68E-05 0		6.68E-05	*6*	12	24		1	8.02E-04	1.60E-03	0.00E+00	6.68E-05
6.58E-05 0		6.58E-05	*7*	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.47E-06 0		3.47E-06	*8*	2	0			6.93E-06	0.00E+00	0.00E+00	0.00E+00
8.42E-06 0		8.42E-06	*9*	0	2.5			0.00E+00	2.10E-05	0.00E+00	0.00E+00
1.49E-06 0		1.49E-06	*10*	3	2.5			4.46E-06	3.71E-06	0.00E+00	0.00E+00
1.39E-05 0		1.39E-05	*11*	0	24		1	0.00E+00	3.33E-04	0.00E+00	1.39E-05
5.94E-06 0		5.94E-06	*12*	12	24		1	7.13E-05	1.43E-04	0.00E+00	5.94E-06
5.28E-04 0		5.28E-04	*13*	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.08E-05 0		1.08E-05	*14*	1	0			1.08E-05	0.00E+00	0.00E+00	0.00E+00
1.90E-04 0		1.90E-04	*15*	0	2.5			0.00E+00	4.75E-04	0.00E+00	0.00E+00
2.11E-05		2.11E-05	*16*	3	2.5			6.34E-05	5.28E-05	0.00E+00	0.00E+00



1.99E-04	17	0	24		1	0.00E+00	4.78E-03	0.00E+00	1.99E-04
1.07E-04	18	7	24		1	7.50E-04	2.57E-03	0.00E+00	1.07E-04
2.28E-04	19	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.65E-06	20	1	0			4.65E-06	0.00E+00	0.00E+00	0.00E+00
2.38E-05	21	0	2.5			0.00E+00	5.94E-05	0.00E+00	0.00E+00
2.64E-06	22	3	2.5			7.92E-06	6.60E-06	0.00E+00	0.00E+00
3.70E-06	23	0	24		1	0.00E+00	8.87E-05	0.00E+00	3.70E-06
1.58E-06	24	7	24		1	1.11E-05	3.80E-05	0.00E+00	1.58E-06
1.05E-03	25	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.15E-05	26	1	0			2.15E-05	0.00E+00	0.00E+00	0.00E+00
3.53E-04	27	0	2.5			0.00E+00	8.82E-04	0.00E+00	0.00E+00
3.07E-05	28	2	2.5			6.14E-05	7.67E-05	0.00E+00	0.00E+00
3.07E-05	29	0	24		1	0.00E+00	7.37E-04	0.00E+00	3.07E-05
4.60E-05	30	6	24		1	2.76E-04	1.10E-03	0.00E+00	4.60E-05
1.50E-04	31	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.07E-06	32	1	0			3.07E-06	0.00E+00	0.00E+00	0.00E+00
1.41E-05	33	0	2.5			0.00E+00	3.53E-05	0.00E+00	0.00E+00
1.23E-06	34	2	2.5			2.46E-06	3.07E-06	0.00E+00	0.00E+00
8.53E-07	35	0	24		1	0.00E+00	2.05E-05	0.00E+00	8.53E-07



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6.22E-04	37	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.27E-05	38	1	0			1.27E-05	0.00E+00	0.00E+00	0.00E+00
1.78E-04	39	0	2.5			0.00E+00	4.44E-04	0.00E+00	0.00E+00
1.97E-05	40	1	2.5			1.97E-05	4.93E-05	0.00E+00	0.00E+00
1.54E-05	41	0	24		1	0.00E+00	3.71E-04	0.00E+00	1.54E-05
1.03E-05	42	1	24		1	1.03E-05	2.47E-04	0.00E+00	1.03E-05
1.26E-04	43	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
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1.22E-05	45	0	2.5			0.00E+00	3.06E-05	0.00E+00	0.00E+00
6.44E-07	46	1	2.5			6.44E-07	1.61E-06	0.00E+00	0.00E+00
1.14E-06	47	0	24		1	0.00E+00	2.75E-05	0.00E+00	1.14E-06
2.86E-07	48	1	24		1	2.86E-07	6.86E-06	0.00E+00	2.86E-07
1.68E-04	49	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.43E-06	50	1	0			3.43E-06	0.00E+00	0.00E+00	0.00E+00
2.45E-04	51	0	2.5			0.00E+00	6.11E-04	0.00E+00	0.00E+00
1.29E-05	52	1	2.5			1.29E-05	3.22E-05	0.00E+00	0.00E+00
2.16E-05	53	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
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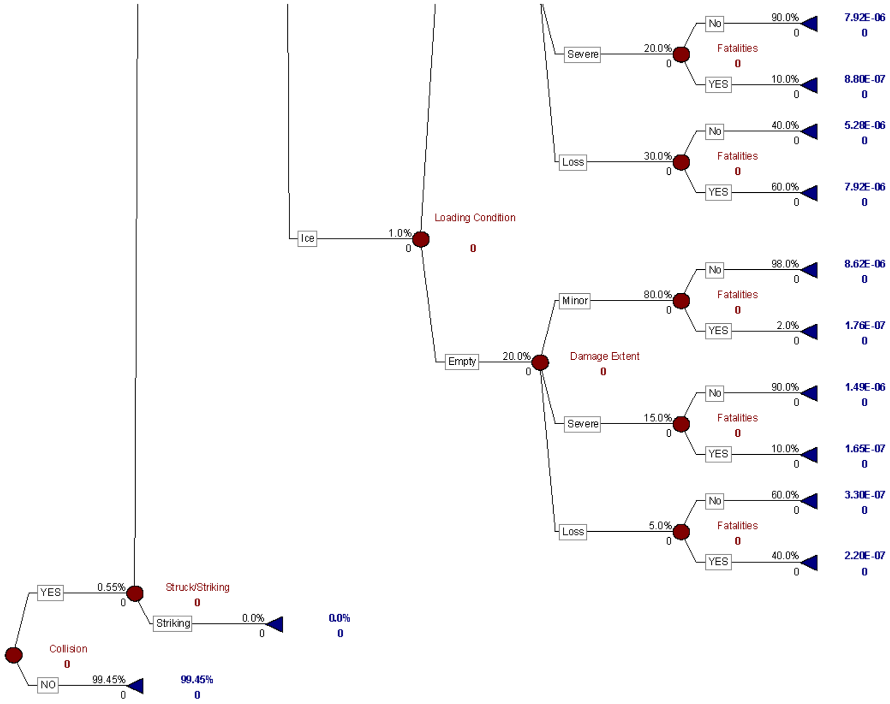

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5.28E-06	57	0	24		1	0.00E+00	1.27E-04	0.00E+00	5.28E-06
7.92E-06	58	7	24		1	5.54E-05	1.90E-04	0.00E+00	7.92E-06
8.62E-06	59	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.76E-07	60	1	0			1.76E-07	0.00E+00	0.00E+00	0.00E+00
1.49E-06	61	0	2.5			0.00E+00	3.71E-06	0.00E+00	0.00E+00
1.65E-07	62	3	2.5			4.95E-07	4.13E-07	0.00E+00	0.00E+00
3.30E-07	63	0	24		1	0.00E+00	7.92E-06	0.00E+00	3.30E-07
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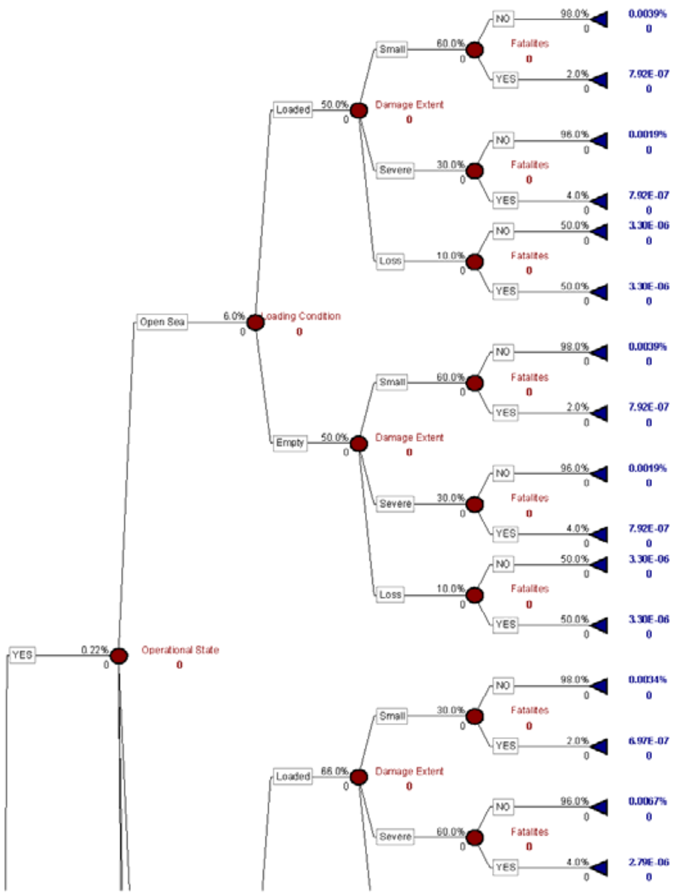
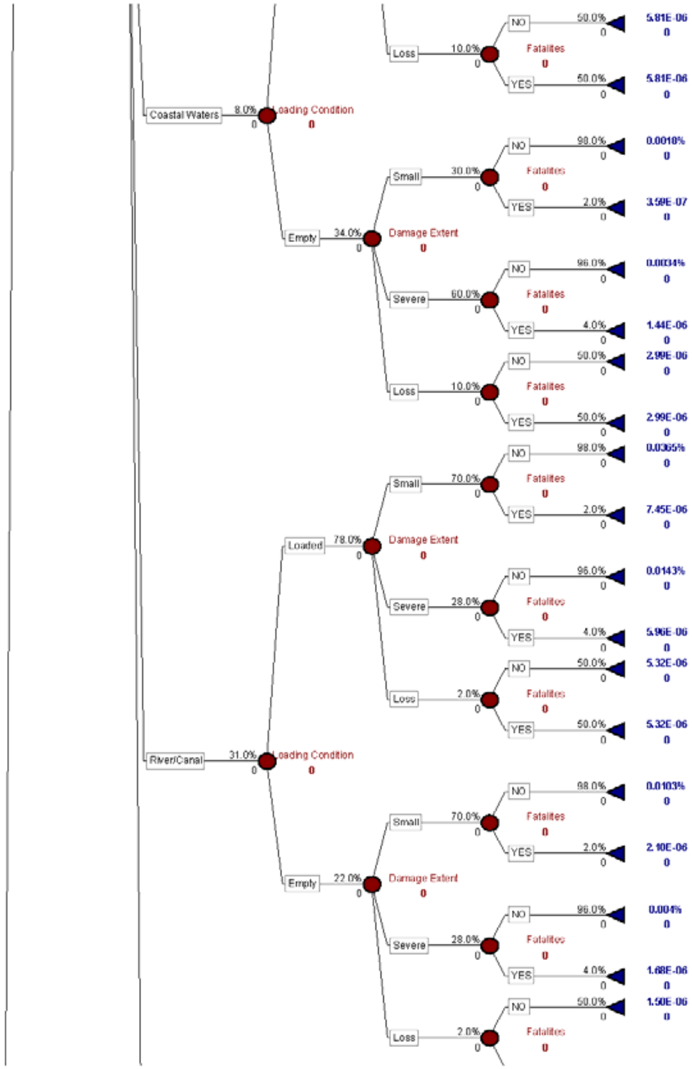
Contact



Probability of scenario (absolute)		No Accidents per ship year	Sequence No	Consequences: Human fatalities crew	Consequences: Environment Oil leakage [tonnes]	Consequences: Ship damage [€]	Consequences: Loss	Cumultative risk contribution: PLL Potential Loss of Life per ship year Crew	Cumultative risk contribution: Bunker spill tonnes per ship year	Cumultative risk contribution: Property [€/ship year]	Cumultative risk contribution: PLS Potential Loss of Ship per ship year
0.22%	1	0.0022						3.41E-04	0.00389741	0	8.092E-05
		3.88E-05	1					0.00E+00	0.00E+00	0.00E+00	0.00E+00
		7.92E-07	2	1				7.92E-07	0.00E+00	0.00E+00	0.00E+00
		1.90E-05	3		2.5			0.00E+00	4.75E-05	0.00E+00	0.00E+00
		7.92E-07	4	1	2.5			7.92E-07	1.98E-06	0.00E+00	0.00E+00
		3.30E-06	5	0	24		1	0.00E+00	7.92E-05	0.00E+00	3.30E-06
		3.30E-06	6	7	24		1	2.31E-05	7.92E-05	0.00E+00	3.30E-06
		3.88E-05	7					0.00E+00	0.00E+00	0.00E+00	0.00E+00
		7.92E-07	8	1				7.92E-07	0.00E+00	0.00E+00	0.00E+00
		1.90E-05	9		2.5			0.00E+00	4.75E-05	0.00E+00	0.00E+00
		7.92E-07	10	1	2.5			7.92E-07	1.98E-06	0.00E+00	0.00E+00
		3.30E-06	11		24		1	0.00E+00	7.92E-05	0.00E+00	3.30E-06
		3.30E-06	12	7	24		1	2.31E-05	7.92E-05	0.00E+00	3.30E-06
		3.42E-05	13					0.00E+00	0.00E+00	0.00E+00	0.00E+00
		6.97E-07	14	1				6.97E-07	0.00E+00	0.00E+00	0.00E+00
		6.69E-05	15		2.5			0.00E+00	1.67E-04	0.00E+00	0.00E+00
		2.79E-06	16	1	2.5			2.79E-06	6.97E-06	0.00E+00	0.00E+00



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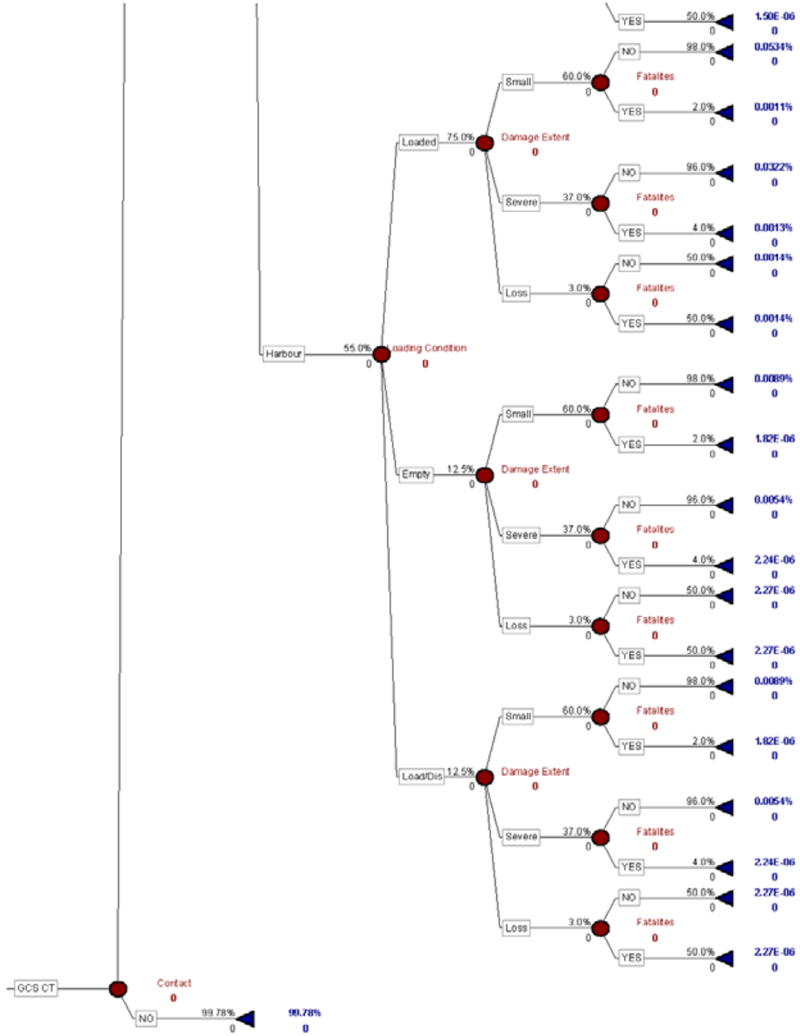
5.81E-06	18	7	24		1	4.07E-05	1.39E-04	0.00E+00	5.81E-06
1.76E-05	19					0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.59E-07	20	1				3.59E-07	0.00E+00	0.00E+00	0.00E+00
3.45E-05	21		2.5			0.00E+00	8.62E-05	0.00E+00	0.00E+00
1.44E-06	22	1	2.5		0	1.44E-06	3.59E-06	0.00E+00	0.00E+00
2.99E-06	23		24		1	0.00E+00	7.18E-05	0.00E+00	2.99E-06
2.99E-06	24	7	24		1	2.09E-05	7.18E-05	0.00E+00	2.99E-06
3.65E-04	25					0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.45E-06	26	1				7.45E-06	0.00E+00	0.00E+00	0.00E+00
1.43E-04	27		2.5			0.00E+00	3.57E-04	0.00E+00	0.00E+00
5.96E-06	28	1	2.5			5.96E-06	1.49E-05	0.00E+00	0.00E+00
5.32E-06	29		24		1	0.00E+00	1.28E-04	0.00E+00	5.32E-06
5.32E-06	30	7	24		1	3.72E-05	1.28E-04	0.00E+00	5.32E-06
1.03E-04	31					0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.10E-06	32	1				2.10E-06	0.00E+00	0.00E+00	0.00E+00
4.03E-05	33		2.5			0.00E+00	1.01E-04	0.00E+00	0.00E+00
1.68E-06	34	1	2.5		1	1.68E-06	4.20E-06	0.00E+00	1.68E-06
1.50E-06	35		24			0.00E+00	3.60E-05	0.00E+00	0.00E+00



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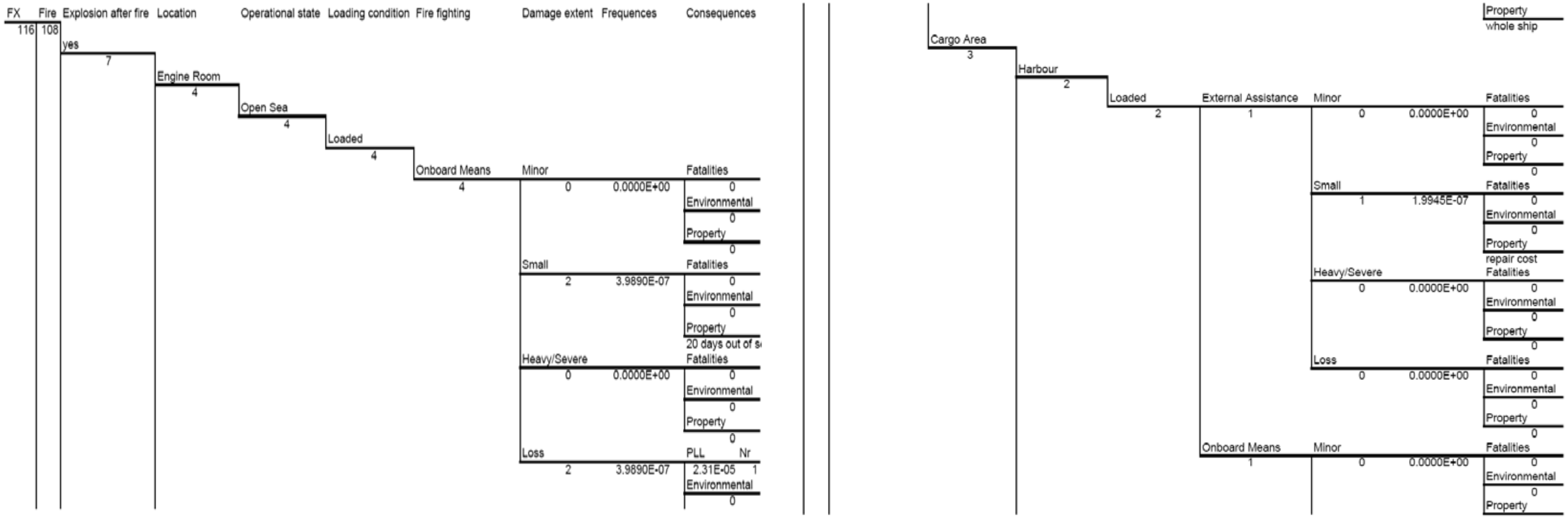
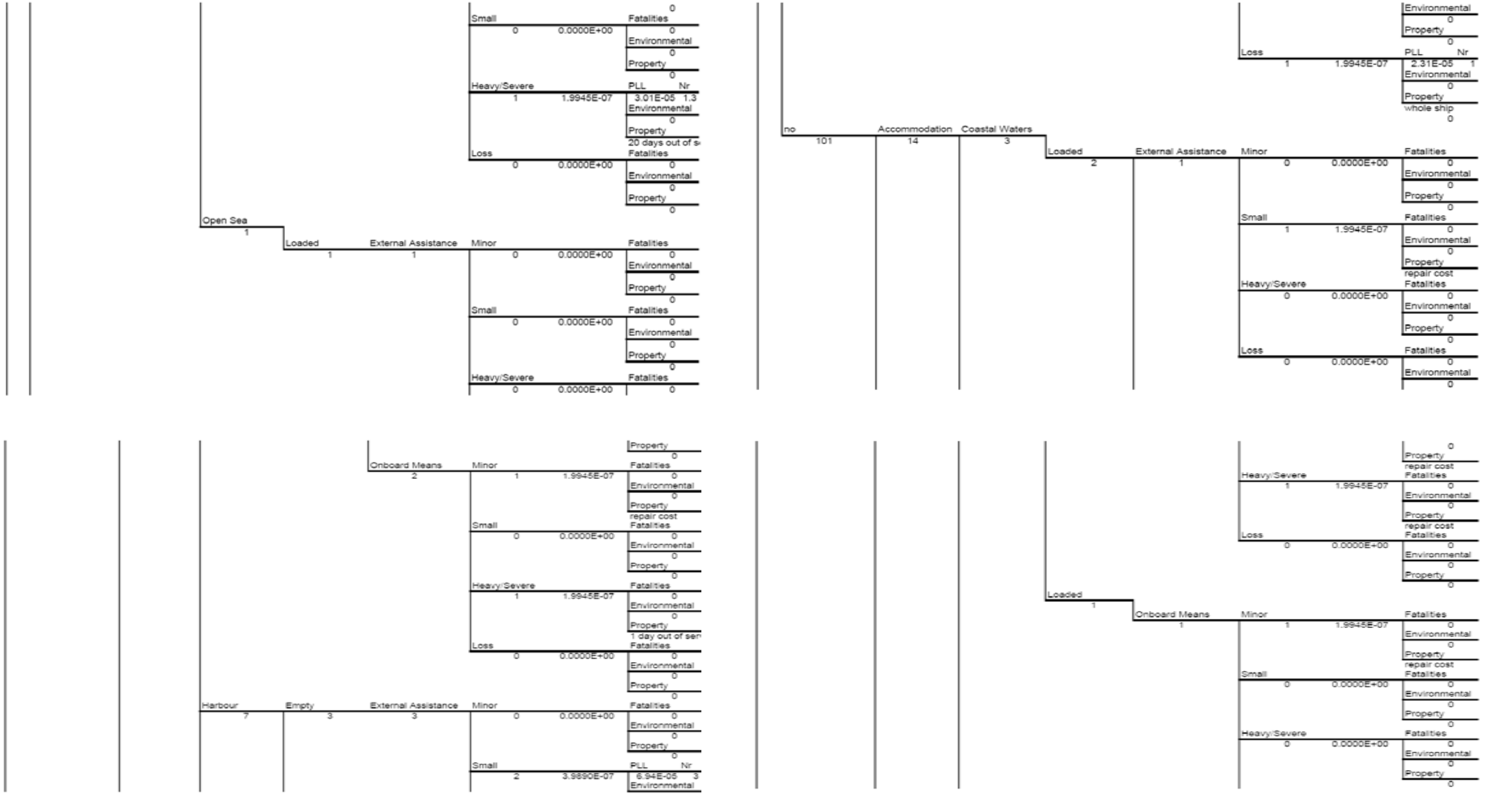
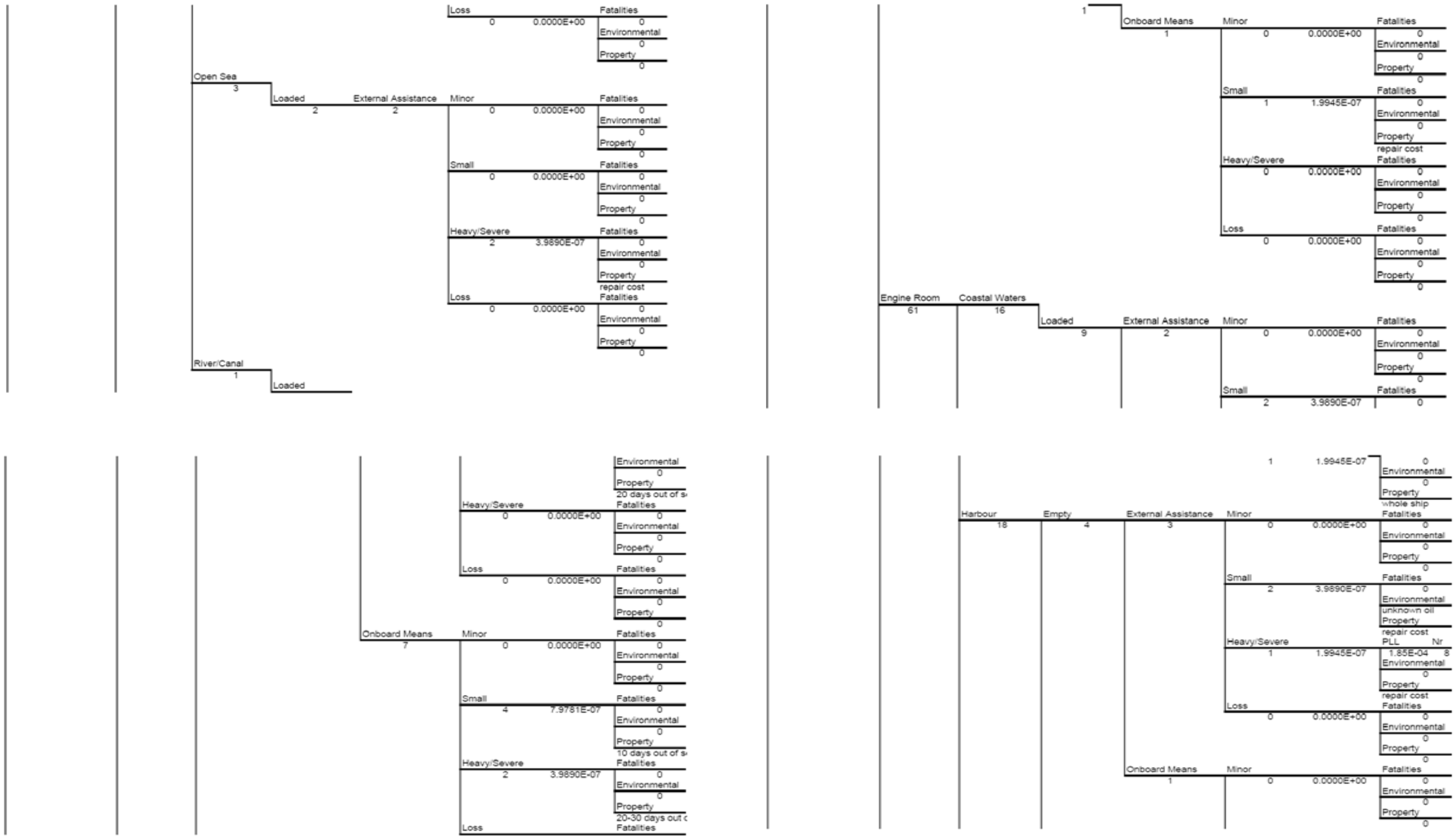
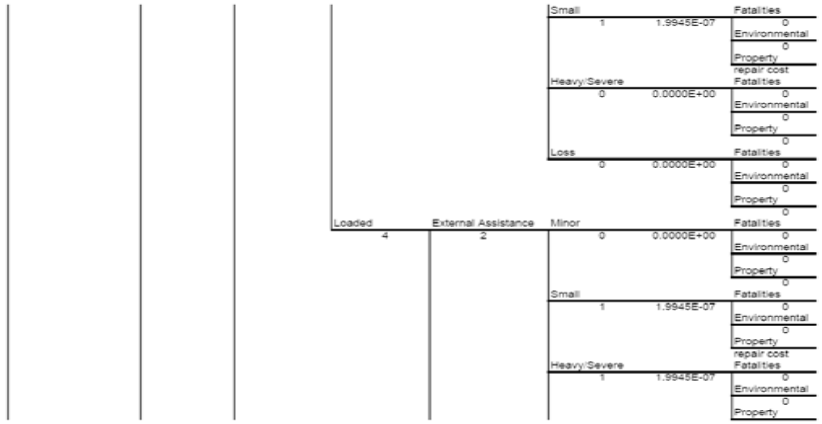
1.09E-05	38	1				1.09E-05	0.00E+00	0.00E+00	0.00E+00
3.22E-04	39		2.5			0.00E+00	8.06E-04	0.00E+00	0.00E+00
1.34E-05	40	1	2.5			1.34E-05	3.36E-05	0.00E+00	0.00E+00
1.36E-05	41		24		1	0.00E+00	3.27E-04	0.00E+00	1.36E-05
1.36E-05	42	7	24		1	9.53E-05	3.27E-04	0.00E+00	1.36E-05
8.89E-05	43					0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.82E-06	44	1				1.82E-06	0.00E+00	0.00E+00	0.00E+00
5.37E-05	45		2.5			0.00E+00	1.34E-04	0.00E+00	0.00E+00
2.24E-06	46	1	2.5			2.24E-06	5.60E-06	0.00E+00	0.00E+00
2.27E-06	47		24		1	0.00E+00	5.45E-05	0.00E+00	2.27E-06
2.27E-06	48	7	24		1	1.59E-05	5.45E-05	0.00E+00	2.27E-06
8.89E-05	49					0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.82E-06	50	1				1.82E-06	0.00E+00	0.00E+00	0.00E+00
5.37E-05	51		2.5			0.00E+00	1.34E-04	0.00E+00	0.00E+00
2.24E-06	52	1	2.5			2.24E-06	5.60E-06	0.00E+00	0.00E+00
2.27E-06	53	0	24		1	0.00E+00	5.45E-05	0.00E+00	2.27E-06
2.27E-06	54	7	24		1	1.59E-05	5.45E-05	0.00E+00	2.27E-06

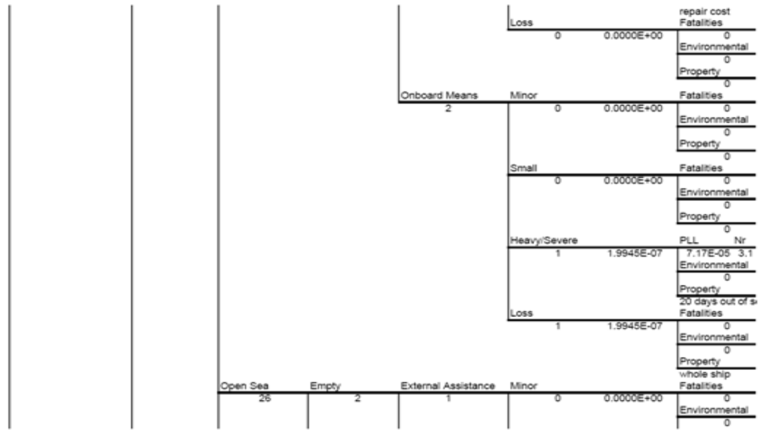
Fire and Explosion

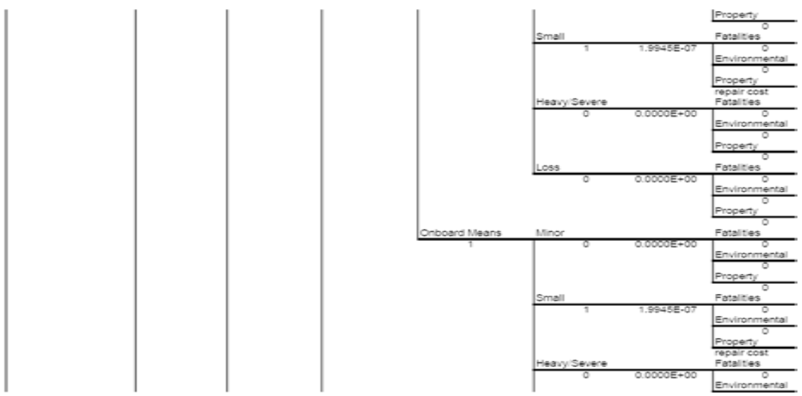


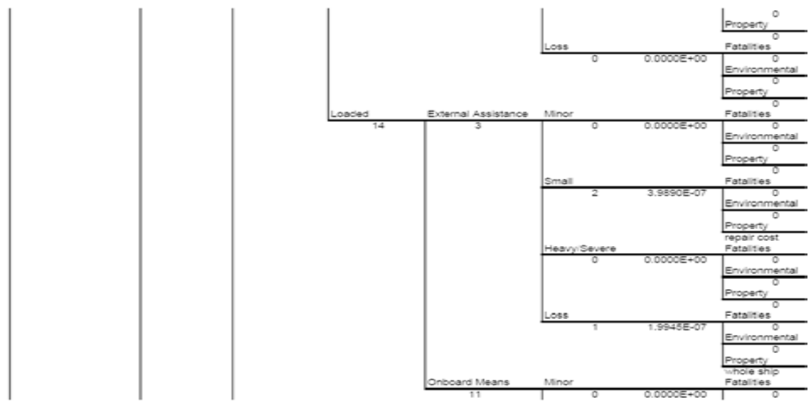

0
Small
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Heavy/Severe
PLL Nr
1 1.9945E-07
3.01E-05 1.3
Environmental
0
Property
20 days out of s
Loss
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Open Sea
1
Loaded
External Assistance
Minor
Fatalities
1 1 0 0.0000E+00
0
Environmental
0
Property
0
Small
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Heavy/Severe
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Loss
PLL Nr
1 1.9945E-07
2.31E-05 1
Environmental
0
Property
whole ship
0
no
Accommodation
Coastal Waters
101 14 3
Loaded
External Assistance
Minor
Fatalities
2 1 0 0.0000E+00
0
Environmental
0
Property
0
Small
Fatalities
1 1.9945E-07
0
Environmental
0
Property
repair cost
Heavy/Severe
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Loss
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Onboard Means
Minor
Fatalities
2 1 1.9945E-07
0
Environmental
0
Property
repair cost
Small
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Heavy/Severe
Fatalities
1 1.9945E-07
0
Environmental
0
Property
1 day out of ser
Loss
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Harbour
Empty
External Assistance
Minor
Fatalities
7 3 3 0 0.0000E+00
0
Environmental
0
Property
0
Small
PLL Nr
2 3.9890E-07
6.94E-06 3
Environmental
0
Property
repair cost
Heavy/Severe
Fatalities
1 1.9945E-07
0
Environmental
0
Property
repair cost
Loss
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Loaded
1
Onboard Means
1
Minor
Fatalities
1 1.9945E-07
0
Environmental
0
Property
repair cost
Small
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0
Heavy/Severe
Fatalities
0 0.0000E+00
0
Environmental
0
Property
0

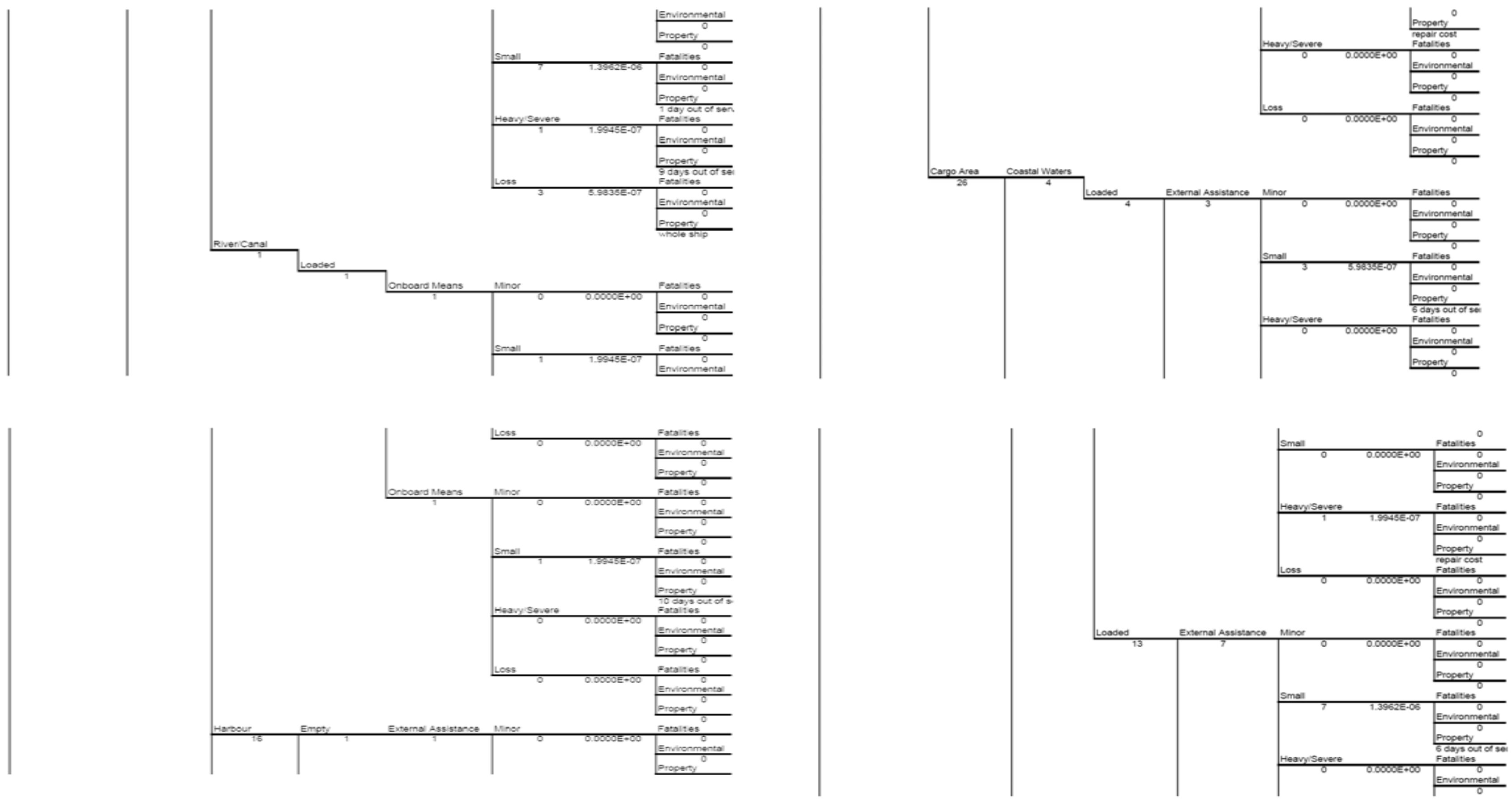


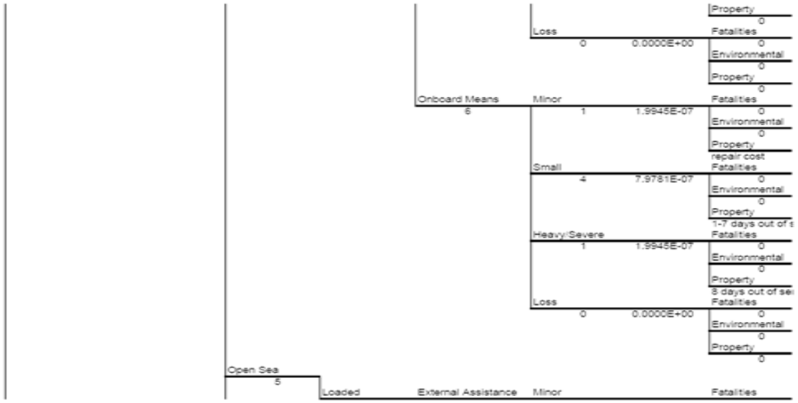




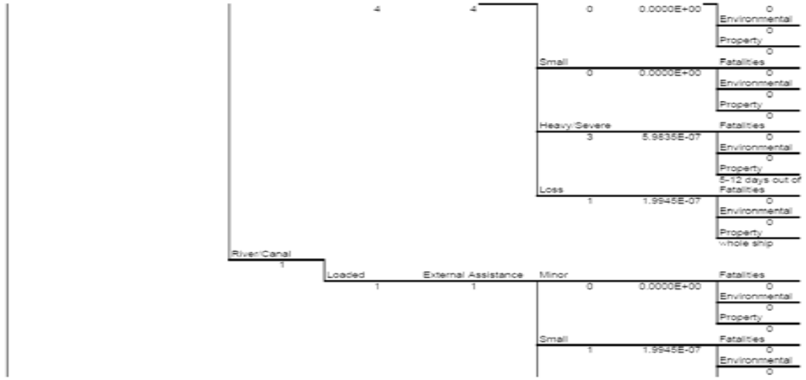




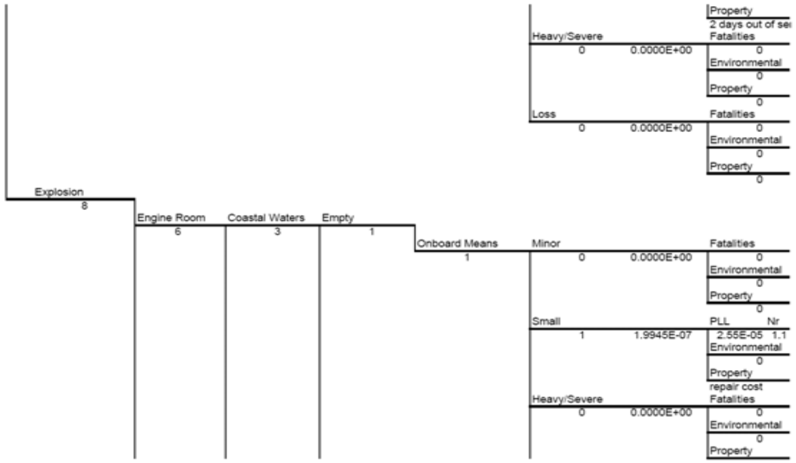




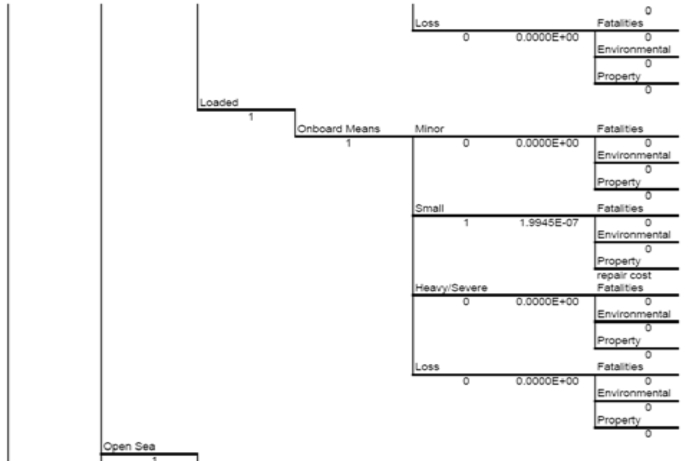
Property
0
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Onboard Means
6
Minor
1 1.9945E-07
Fatalities
0
Environmental
0
Property
repair cost
Small
4 7.9781E-07
Fatalities
0
Environmental
0
Property
1-7 days out of s
Heavy/Severe
1 1.9945E-07
Fatalities
0
Environmental
0
Property
8 days out of se
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Open Sea
5
Loaded
External Assistance
Minor
Fatalities



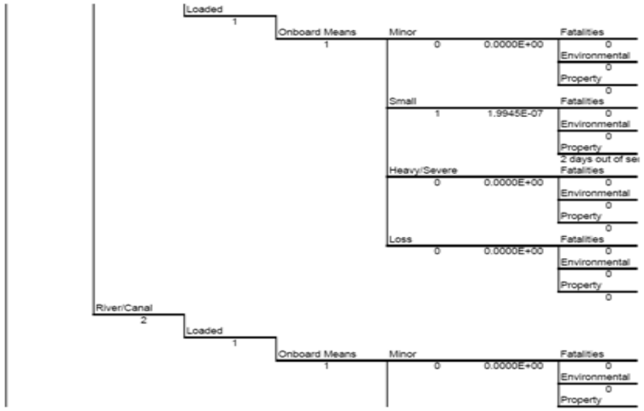
4
4
0 0.0000E+00
0
Environmental
0
Property
0
Small
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
3 5.9835E-07
Fatalities
0
Environmental
0
Property
5-12 days out of
Loss
1 1.9945E-07
Fatalities
0
Environmental
0
Property
whole ship
River/Canal
1
Loaded
1
External Assistance
1
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
1 1.9945E-07
Fatalities
0
Environmental
0

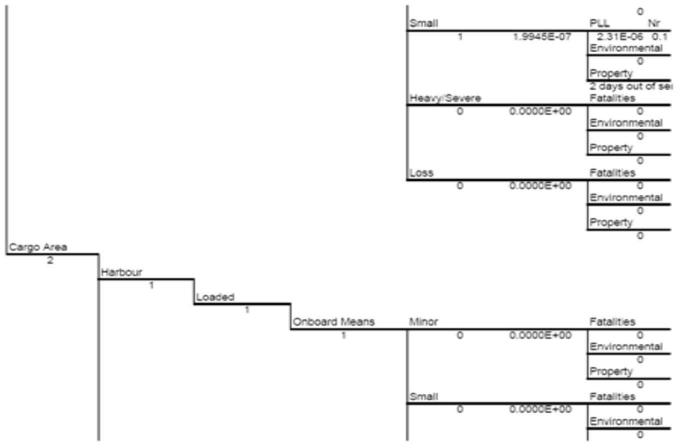


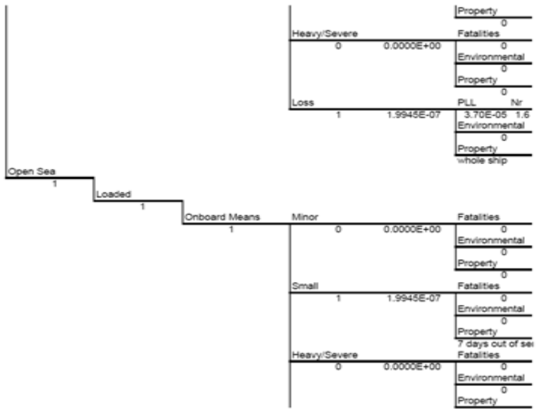
Property
2 days out of se
Heavy/Severe
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Explosion
8
Engine Room
6
Coastal Waters
3
Empty
1
Onboard Means
1
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
1 1.9945E-07
PLL Nr
2.55E-05 1.1
Environmental
0
Property
repair cost
Heavy/Severe
0 0.0000E+00
Fatalities
0
Environmental
0
Property

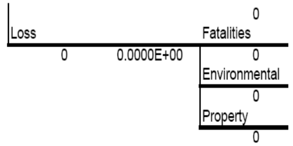


0
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loaded
1
Onboard Means
1
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
1 1.9945E-07
Fatalities
0
Environmental
0
Property
repair cost
Heavy/Severe
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Open Sea
1

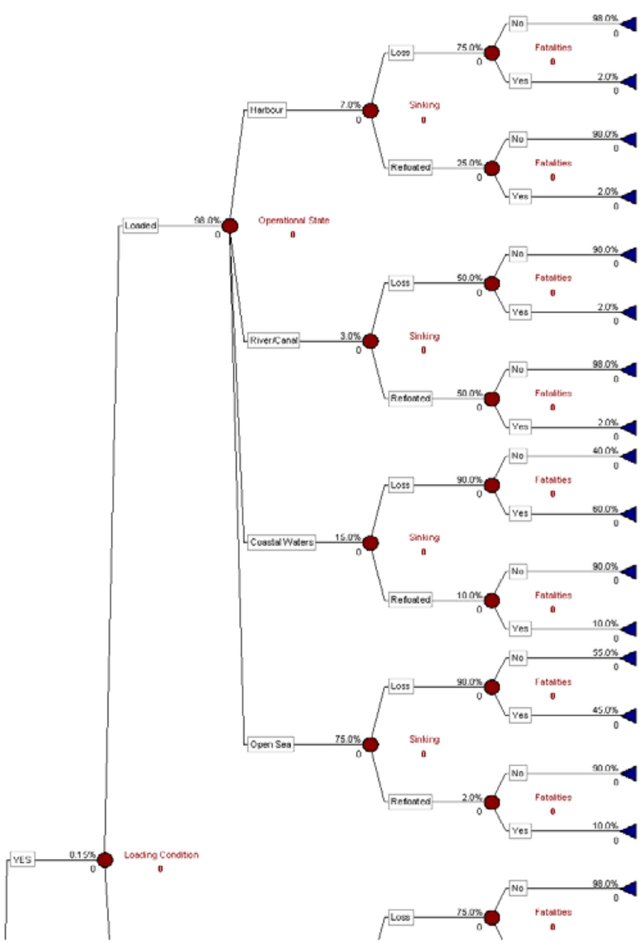

Loaded
1
Onboard Means
1
Minor
0
0.0000E+00
Fatalities
Environmental
Property
Small
1
1.9945E-07
Heavy/Severe
Loss
River/Canal
2


Small
1
1.9945E-07
PLL
Nr
2.31E-06
0.1
Environmental
Property
Heavy/Severe
0
0.0000E+00
Fatalities
Loss
Cargo Area
2
Harbour
1
Loaded
1
Onboard Means
1
Minor

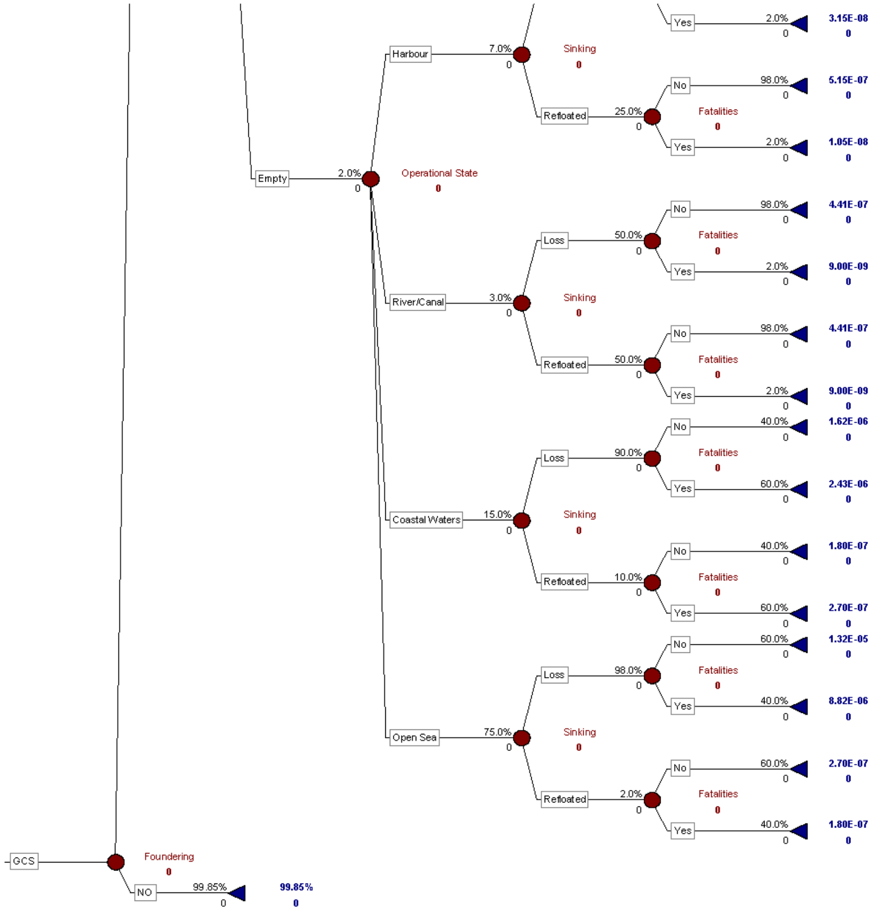

Property
Heavy/Severe
0
0.0000E+00
Fatalities
Environmental
Loss
1
1.9945E-07
PLL
Nr
3.70E-05
1.6
whole ship
Open Sea
1
Loaded
1
Onboard Means
1
Minor
Small
1.9945E-07


Loss
0
0.0000E+00
Fatalities
Environmental
Property

Foundering

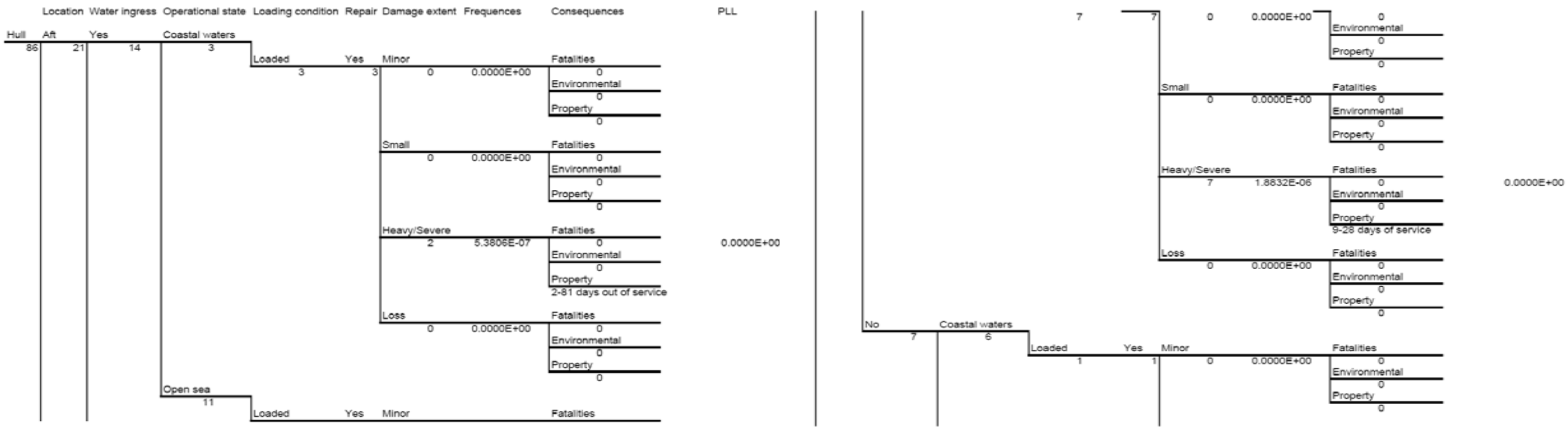


Probability of scenario		No Accidents per ship year	Sequence No	Consequences: Human fatalities crew	Environment Oil leakage [tonnes]	Ship damage	Loss	Cumultative risk contribution: PLL Potential Loss of Life per ship year Crew	Bunker spill tonnes per ship year	Property [€/ship year]	PLS Potential Loss of Ship per ship year
	1	0.0015						5.22E-03	0.1575432	0	0.00140625
7.56E-05		7.56E-05	1	0	0		1	0.00E+00	0.00E+00	0.00E+00	7.56E-05
1.54E-06		1.54E-06	2	1	120		1	1.54E-06	1.85E-04	0.00E+00	1.54E-06
2.52E-05		2.52E-05	3	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.15E-07		5.15E-07	4	1	120			5.15E-07	6.17E-05	0.00E+00	0.00E+00
2.16E-05		2.16E-05	5	0	0		1	0.00E+00	0.00E+00	0.00E+00	2.16E-05
4.41E-07		4.41E-07	6	1	120		1	4.41E-07	5.29E-05	0.00E+00	4.41E-07
0.0022%		2.16E-05	7	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.41E-07		4.41E-07	8	1	120			4.41E-07	5.29E-05	0.00E+00	0.00E+00
7.94E-05		7.94E-05	9	0	120		1	0.00E+00	9.53E-03	0.00E+00	7.94E-05
0.0119%		1.19E-04	10	12	120		1	1.43E-03	1.43E-02	0.00E+00	1.19E-04
0.002%		1.98E-05	11	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.21E-06		2.21E-06	12	12	120			2.65E-05	2.65E-04	0.00E+00	0.00E+00
5.94E-04		5.94E-04	13	0	120		1	0.00E+00	7.13E-02	0.00E+00	5.94E-04
4.86E-04		4.86E-04	14	7.5	120		1	3.65E-03	5.83E-02	0.00E+00	4.86E-04
1.98E-05		1.98E-05	15	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.21E-06		2.21E-06	16	7.5	120			1.65E-05	2.65E-04	0.00E+00	0.00E+00
1.54E-06		1.54E-06	17	0	0		1	0.00E+00	0.00E+00	0.00E+00	1.54E-06

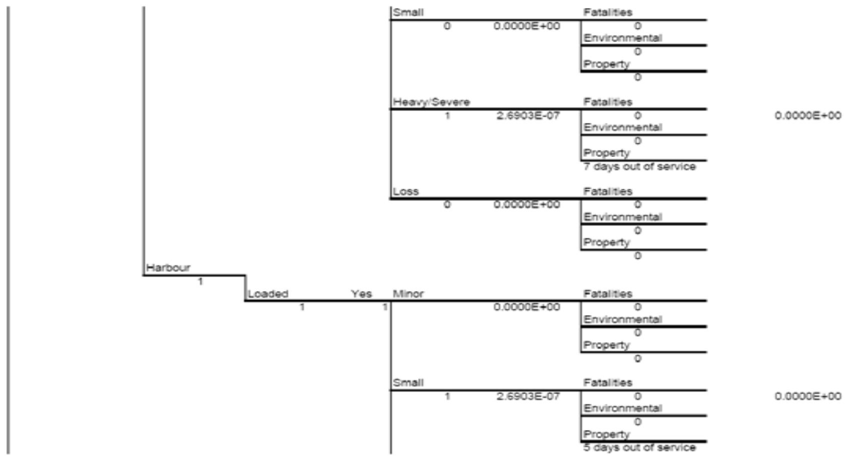


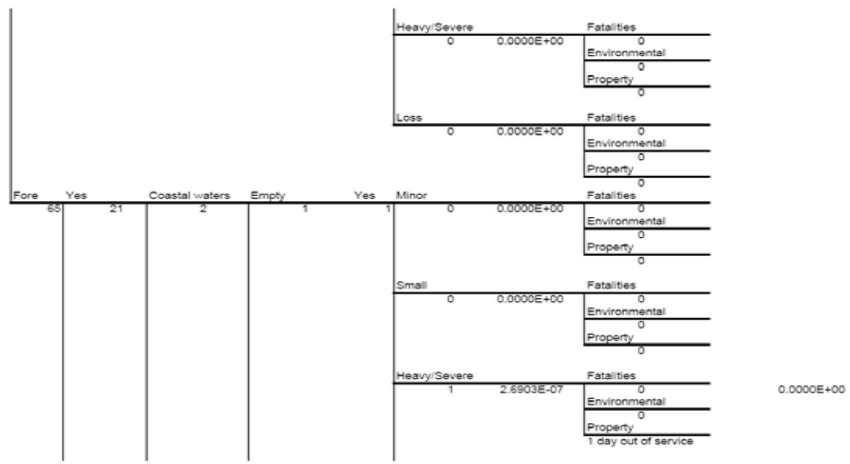
3.15E-08	18	1	120		1	3.15E-08	3.78E-06	0.00E+00	3.15E-08
5.15E-07	19	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.05E-08	20	1	120			1.05E-08	1.26E-06	0.00E+00	0.00E+00
4.41E-07	21	0	0		1	0.00E+00	0.00E+00	0.00E+00	4.41E-07
9.00E-09	22	1	120		1	9.00E-09	1.08E-06	0.00E+00	9.00E-09
4.41E-07	23	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
9.00E-09	24	1	120			9.00E-09	1.08E-06	0.00E+00	0.00E+00
1.62E-06	25	0	120		1	0.00E+00	1.94E-04	0.00E+00	1.62E-06
2.43E-06	26	12	120		1	2.92E-05	2.92E-04	0.00E+00	2.43E-06
1.80E-07	27	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.70E-07	28	12	120			3.24E-06	3.24E-05	0.00E+00	0.00E+00
1.32E-05	29	0	120		1	0.00E+00	1.59E-03	0.00E+00	1.32E-05
8.82E-06	30	7.5	120		1	6.62E-05	1.06E-03	0.00E+00	8.82E-06
2.70E-07	31	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.80E-07	32	7.5	120			1.35E-06	2.16E-05	0.00E+00	0.00E+00

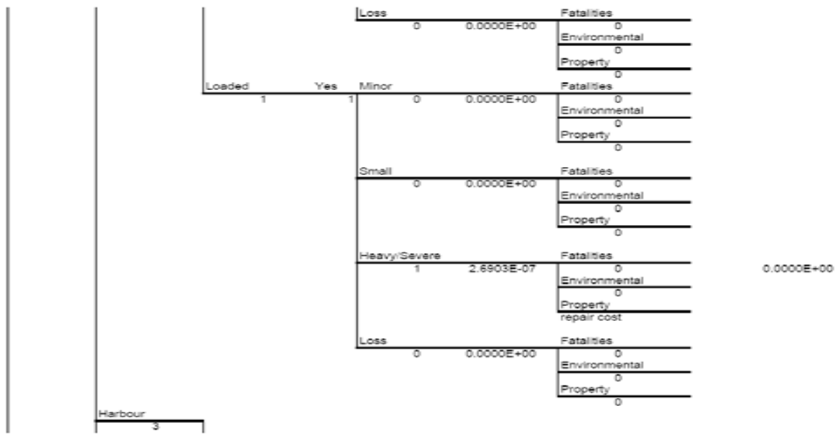
Hull

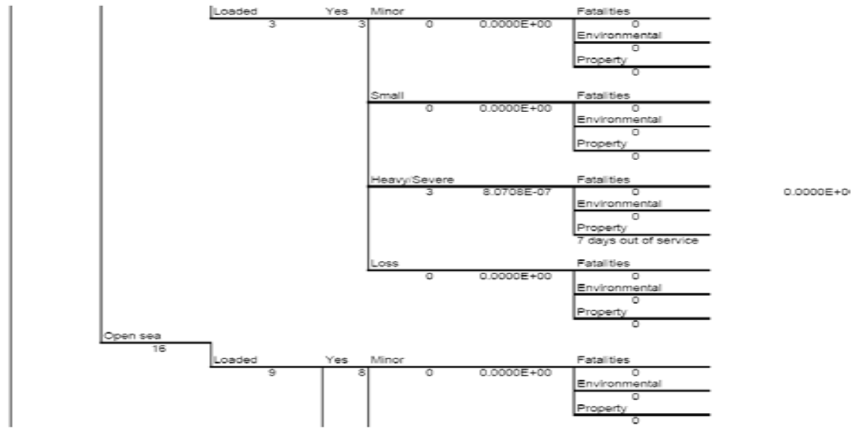


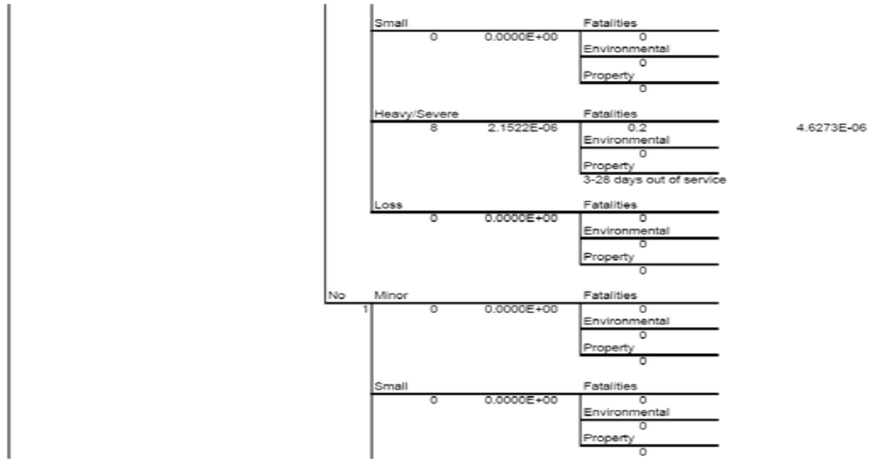
Location
Water ingress
Operational state
Loading condition
Repair
Damage extent
Frequences
Consequences
PLL
Hull
86
Aft
21
Yes
14
Coastal waters
3
Loaded
3
Yes
3
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
2
5.3806E-07
Fatalities
0
Environmental
0
Property
2-81 days out of service
0.0000E+00
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Open sea
11
Loaded
Yes
Minor
Fatalities
7
7
0
0.0000E+00
0
Environmental
0
Property
0
Small
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
7
1.8832E-06
Fatalities
0
Environmental
0
Property
9-28 days of service
0.0000E+00
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
No
7
Coastal waters
6
Loaded
1
Yes
1
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0

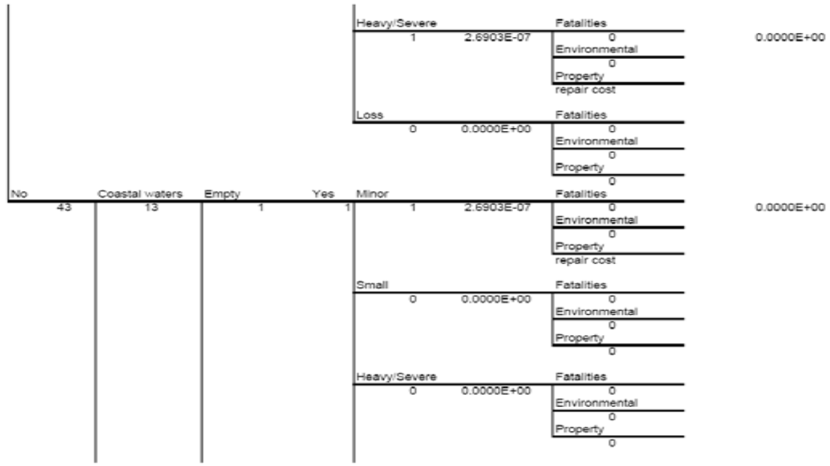

Small
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
1 2.6903E-07
Fatalities
0
Environmental
0
Property
7 days out of service
0.0000E+00
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Harbour
1
Loaded
1
Yes
1
Minor
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
1 2.6903E-07
Fatalities
0
Environmental
0
Property
5 days out of service
0.0000E+00

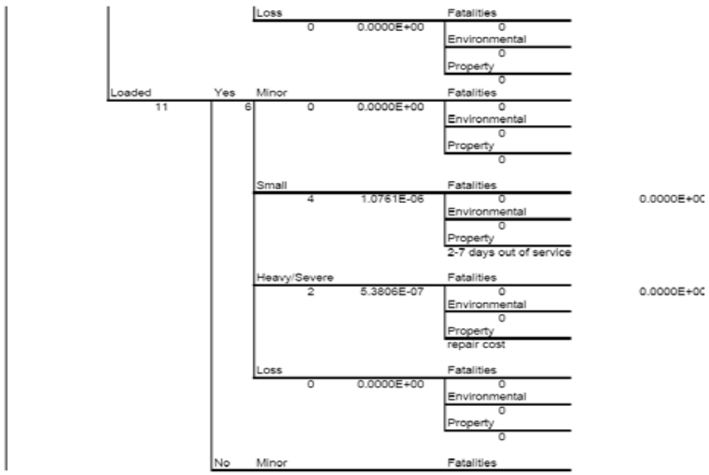

Heavy/Severe
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Fore
65
Yes
21
Coastal waters
2
Empty
1
Yes
1
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
1 2.6903E-07
Fatalities
0
Environmental
0
Property
1 day out of service
0.0000E+00

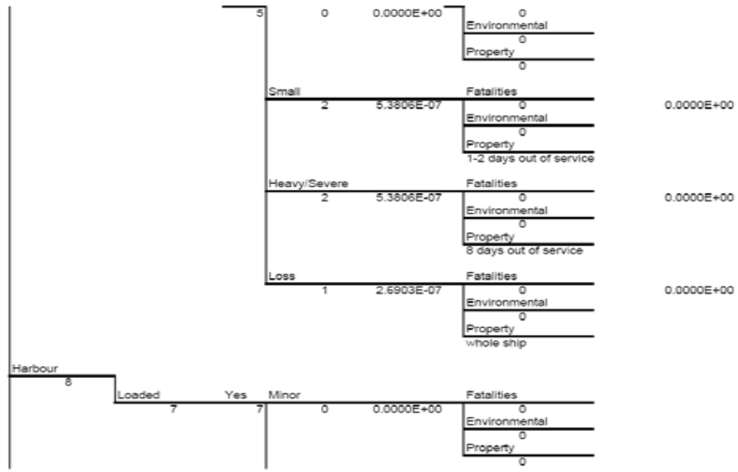

Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loaded
1
Yes
1
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
1 2.6903E-07
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Harbour
3

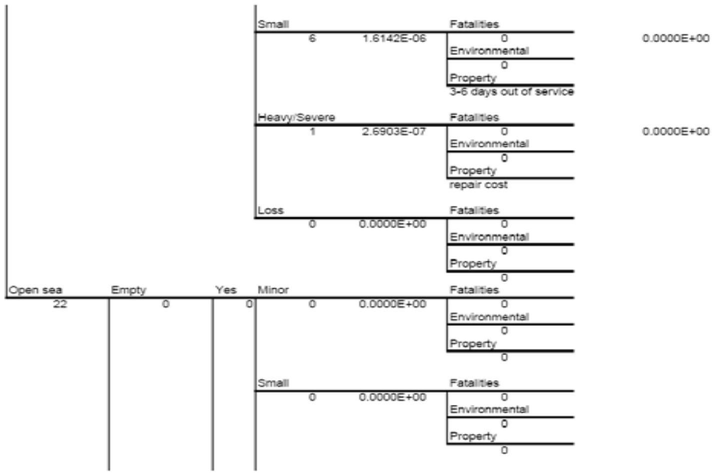

Loaded
3
Yes
3
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
3 8.0708E-07
Fatalities
0
Environmental
0
Property
7 days out of service
Loss
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0
Open sea
16
Loaded
9
Yes
8
Minor
0 0.0000E+00
Fatalities
0
Environmental
0
Property
0

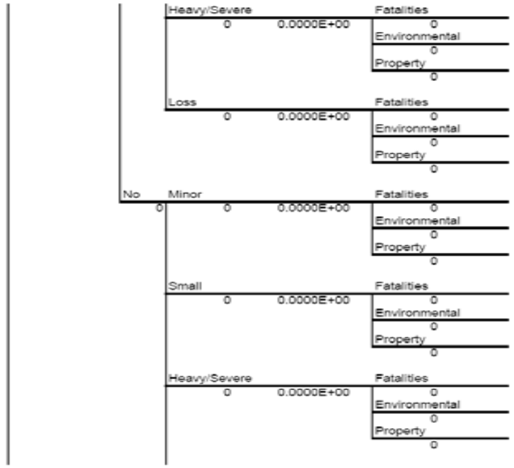

Small
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
Heavy/Severe
8 2.1522E-06 Fatalities 0.2 Environmental 0 Property 3-28 days out of service
4.6273E-06
Loss
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
No 1 Minor
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
Small
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0

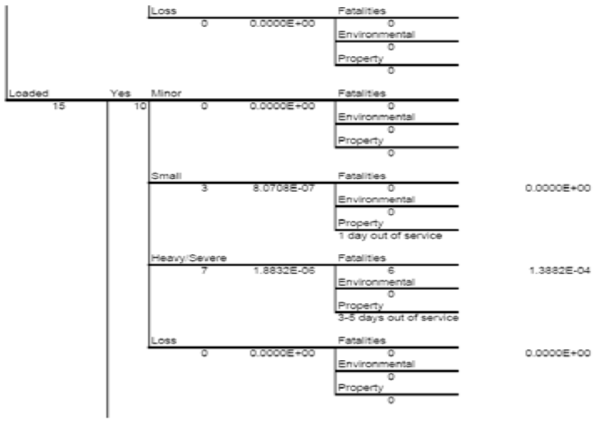

Heavy/Severe
1 2.6903E-07 Fatalities 0 Environmental 0 Property repair cost
0.0000E+00
Loss
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
No 43 Coastal waters 13 Empty 1 Yes 1 Minor
1 2.6903E-07 Fatalities 0 Environmental 0 Property repair cost
0.0000E+00
Small
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
Heavy/Severe
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0

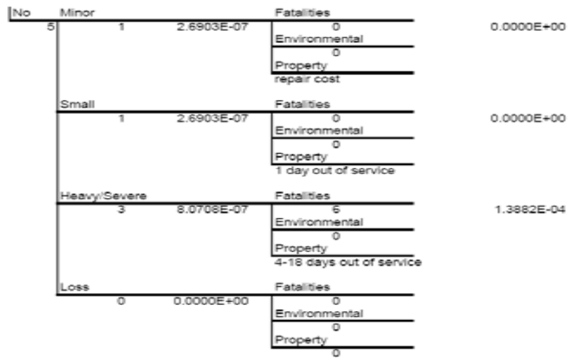

Loss
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
Loaded 11 Yes 6 Minor
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
Small
4 1.0761E-06 Fatalities 0 Environmental 0 Property 2-7 days out of service
0.0000E+00
Heavy/Severe
2 5.3806E-07 Fatalities 0 Environmental 0 Property repair cost
0.0000E+00
Loss
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0
No Minor Fatalities


5 0 0.0000E+00 0 Environmental 0 Property 0
Small
2 5.3806E-07 Fatalities 0 Environmental 0 Property 1-2 days out of service
0.0000E+00
Heavy/Severe
2 5.3806E-07 Fatalities 0 Environmental 0 Property 8 days out of service
0.0000E+00
Loss
1 2.6903E-07 Fatalities 0 Environmental 0 Property whole ship
0.0000E+00
Harbour 8 Loaded 7 Yes 7 Minor
0 0.0000E+00 Fatalities 0 Environmental 0 Property 0

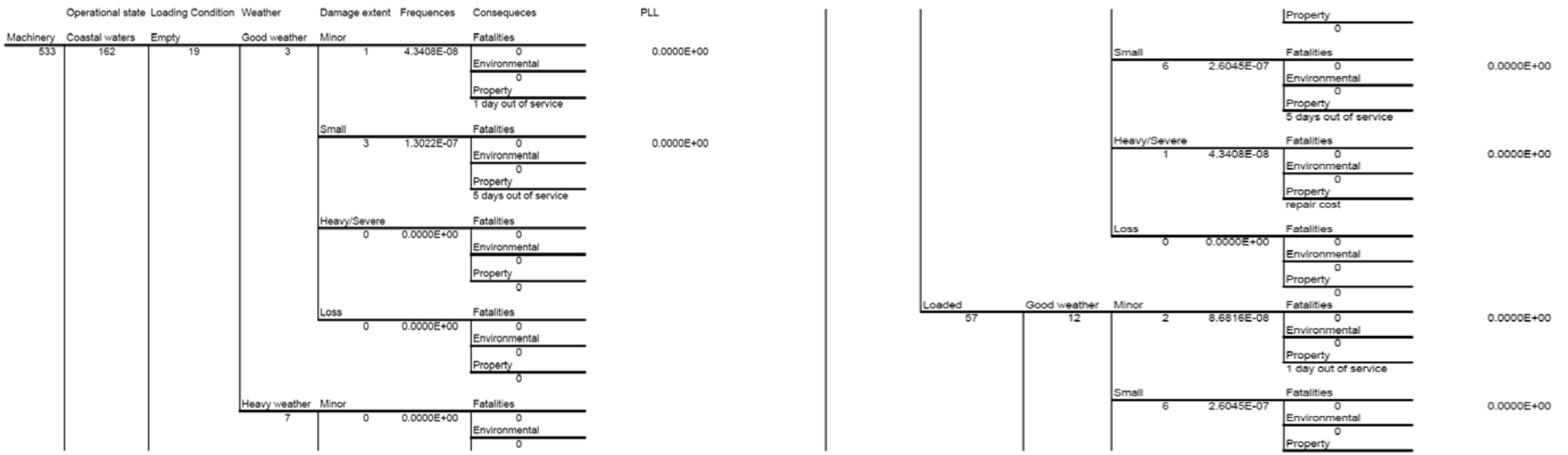

Small
6
1.6142E-06
Fatalities
0
Environmental
0
Property
3-5 days out of service
0.0000E+00
Heavy/Severe
1
2.6903E-07
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Open sea
22
Empty
0
Yes
0
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0


Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
No
0
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0

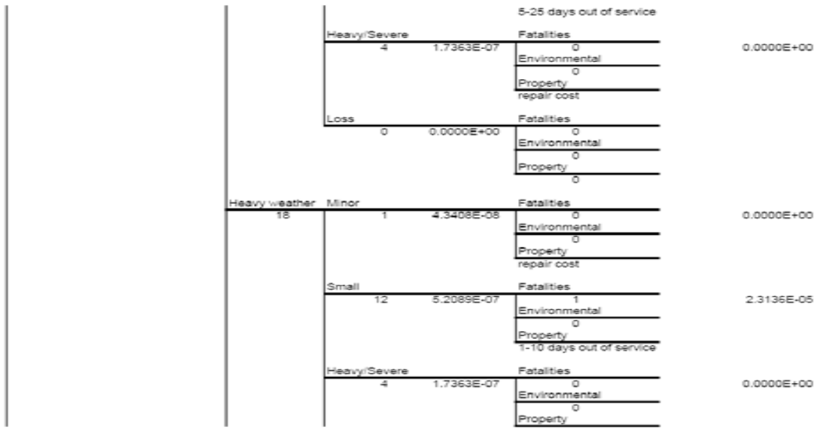

Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loaded
15
Yes
10
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
3
8.0708E-07
Fatalities
0
Environmental
0
Property
1 day out of service
0.0000E+00
Heavy/Severe
7
1.8832E-06
Fatalities
6
Environmental
0
Property
3-5 days out of service
1.3882E-04
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
0.0000E+00

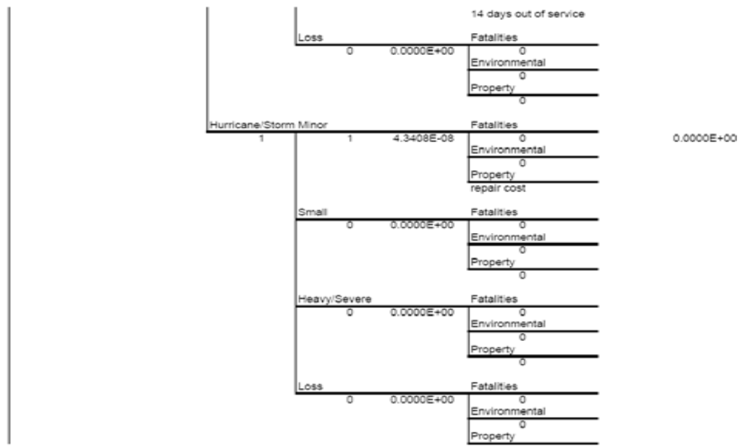

No
5
Minor
1
2.6903E-07
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Small
1
2.6903E-07
Fatalities
0
Environmental
0
Property
1 day out of service
0.0000E+00
Heavy/Severe
3
8.0708E-07
Fatalities
6
Environmental
0
Property
4-18 days out of service
1.3882E-04
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0

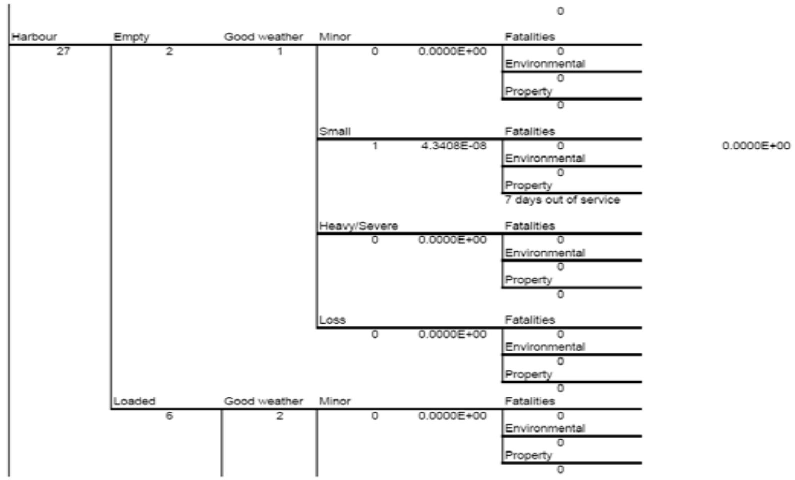
Machinery

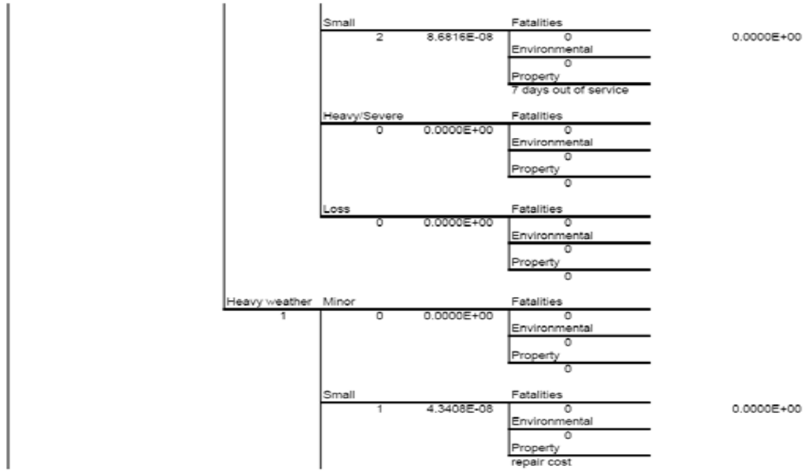


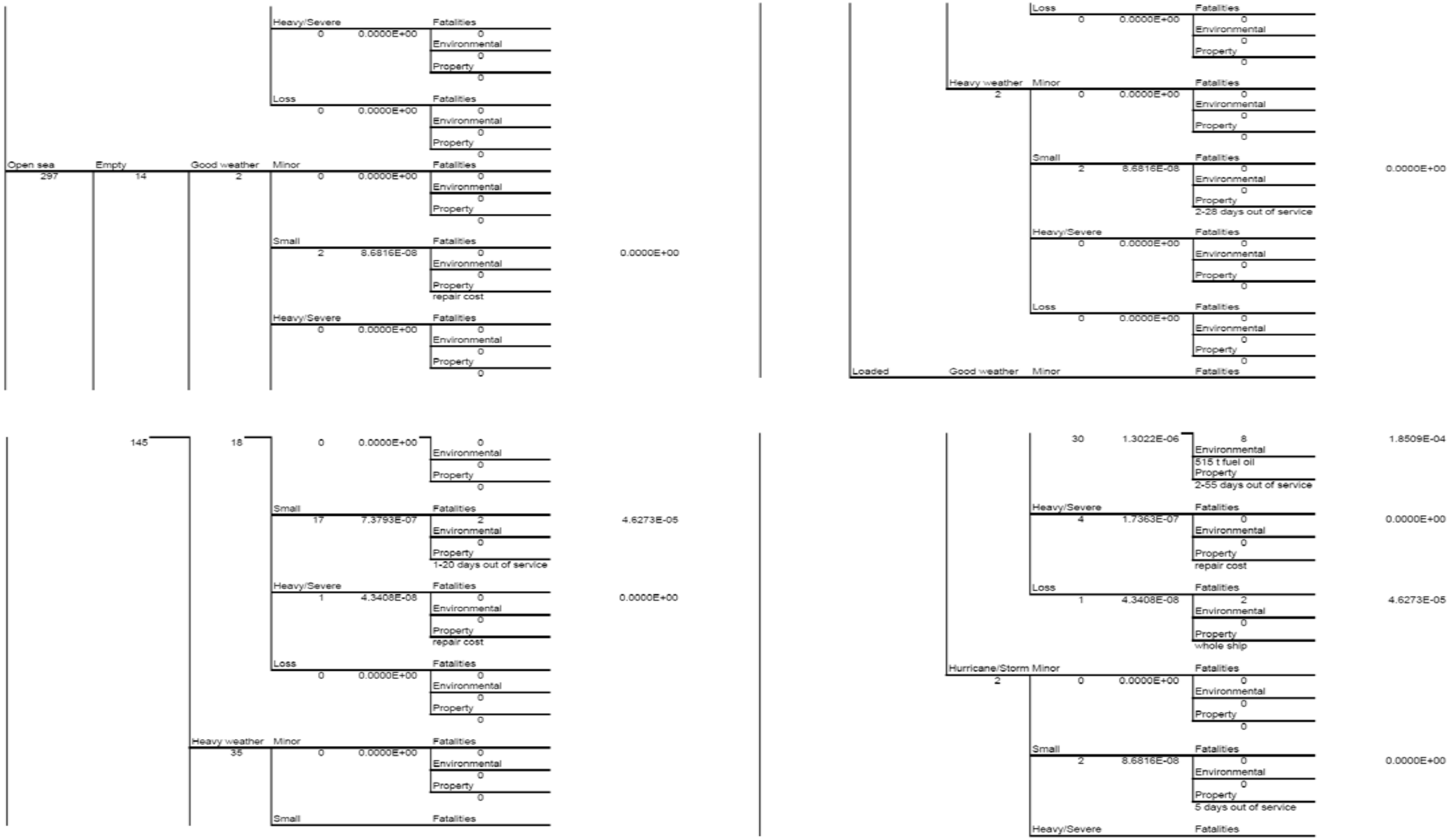
Operational state Loading Condition Weather Damage extent Frequences Consequeces PLL
Machinery 533
Coastal waters 162
Empty 19
Good weather 3
Minor 1 4.3408E-08
Fatalities 0 Environmental 0 Property 1 day out of service
0.0000E+00
Small 3 1.3022E-07
Fatalities 0 Environmental 0 Property 5 days out of service
0.0000E+00
Heavy/Severe 0 0.0000E+00
Fatalities 0 Environmental 0 Property 0
Loss 0 0.0000E+00
Fatalities 0 Environmental 0 Property 0
Heavy weather 7
Minor 0 0.0000E+00
Fatalities 0 Environmental 0
Property 0
Small 6 2.6045E-07
Fatalities 0 Environmental 0 Property 5 days out of service
0.0000E+00
Heavy/Severe 1 4.3408E-08
Fatalities 0 Environmental 0 Property repair cost
0.0000E+00
Loss 0 0.0000E+00
Fatalities 0 Environmental 0 Property 0
Loaded 57
Good weather 12
Minor 2 8.6816E-08
Fatalities 0 Environmental 0 Property 1 day out of service
0.0000E+00
Small 6 2.6045E-07
Fatalities 0 Environmental 0 Property
0.0000E+00

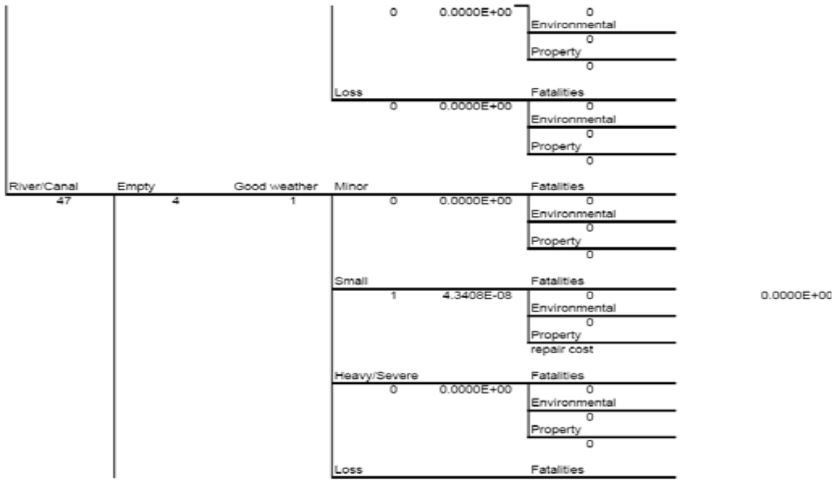

5-25 days out of service
Heavy/Severe
4
1.7363E-07
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy weather
18
Minor
1
4.3408E-08
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Small
12
5.2089E-07
Fatalities
1
Environmental
0
Property
1-10 days out of service
2.3136E-05
Heavy/Severe
4
1.7363E-07
Fatalities
0
Environmental
0
Property
0.0000E+00

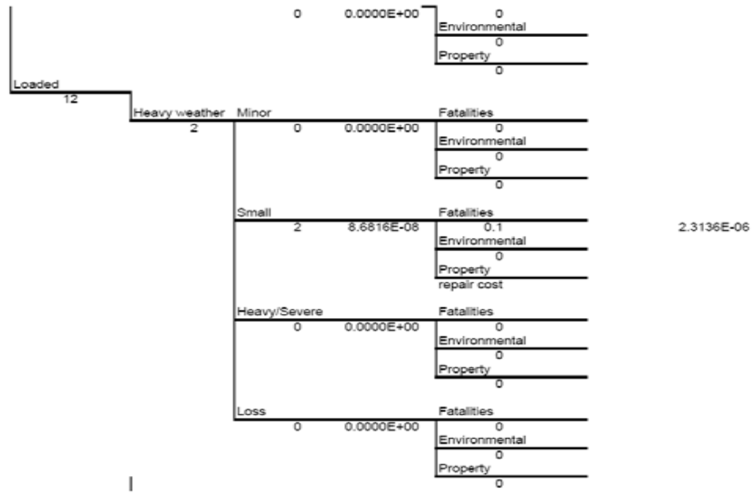

14 days out of service
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Hurricane/Storm
1
Minor
1
4.3408E-08
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Small
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property


0
Harbour
27
Empty
2
Good weather
1
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
1
4.3408E-08
Fatalities
0
Environmental
0
Property
7 days out of service
0.0000E+00
Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loaded
6
Good weather
2
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0

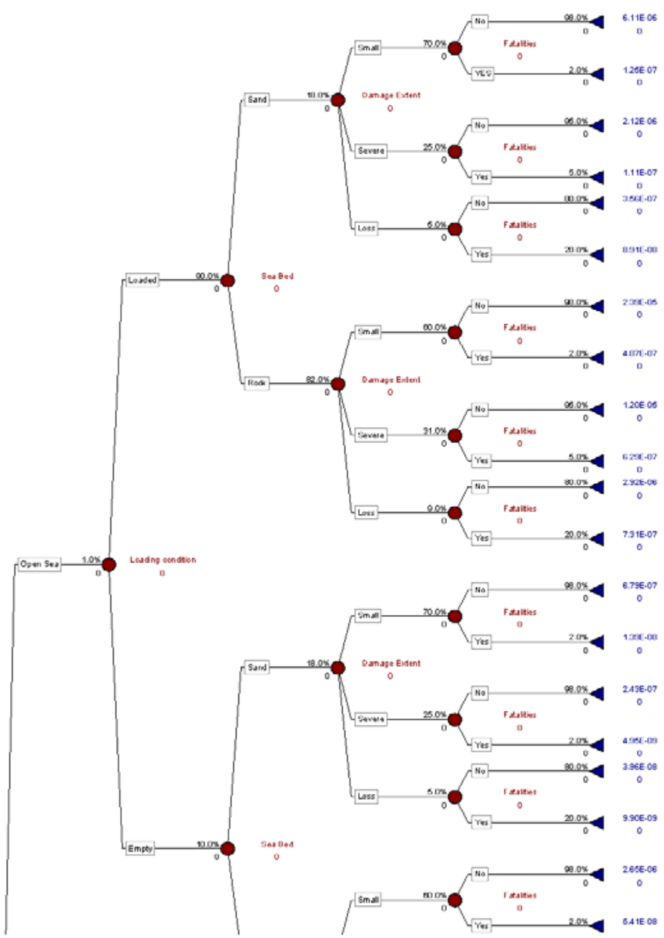

Small
2
8.6816E-08
Fatalities
0
Environmental
0
Property
7 days out of service
0.0000E+00
Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy weather
1
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
1
4.3408E-08
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00


Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Open sea
297
Empty
14
Good weather
2
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
2
8.6816E-08
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
145
18
0
0.0000E+00
0
Environmental
0
Property
0
Small
17
7.3793E-07
Fatalities
2
Environmental
0
Property
1-20 days out of service
4.6273E-05
Heavy/Severe
1
4.3408E-08
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy weather
35
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
Fatalities
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Heavy weather
2
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
2
8.6816E-08
Fatalities
0
Environmental
0
Property
2-28 days out of service
0.0000E+00
Heavy/Severe
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loss
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Loaded
Good weather
Minor
Fatalities
30
1.3022E-06
8
Environmental
515 t fuel oil
Property
2-55 days out of service
1.8509E-04
Heavy/Severe
4
1.7363E-07
Fatalities
0
Environmental
0
Property
repair cost
0.0000E+00
Loss
1
4.3408E-08
Fatalities
2
Environmental
0
Property
whole ship
4.6273E-05
Hurricane/Storm
2
Minor
0
0.0000E+00
Fatalities
0
Environmental
0
Property
0
Small
2
8.6816E-08
Fatalities
0
Environmental
0
Property
5 days out of service
0.0000E+00
Heavy/Severe
Fatalities

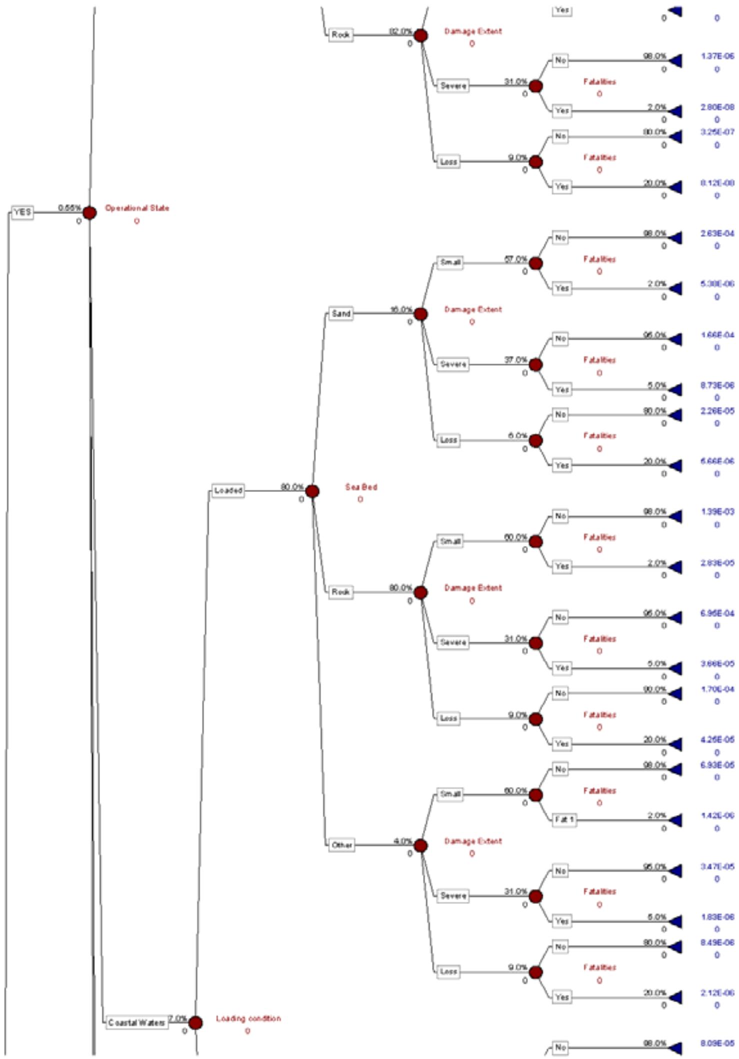

0
0.0000E+00
0
Environmental
0
Property
0
Loss
Fatalities
0
0.0000E+00
0
Environmental
0
Property
0
River/Canal
47
Empty
4
Good weather
1
Minor
Fatalities
0
0.0000E+00
0
Environmental
0
Property
0
Small
Fatalities
1
4.3408E-08
0
0.0000E+00
Environmental
0
Property
repair cost
Heavy/Severe
Fatalities
0
0.0000E+00
0
Environmental
0
Property
0
Loss
Fatalities


0
0.0000E+00
0
Environmental
0
Property
0
Loaded
12
Heavy weather
2
Minor
Fatalities
0
0.0000E+00
0
Environmental
0
Property
0
Small
Fatalities
2
8.6816E-08
0.1
2.3136E-06
Environmental
0
Property
repair cost
Heavy/Severe
Fatalities
0
0.0000E+00
0
Environmental
0
Property
0
Loss
Fatalities
0
0.0000E+00
0
Environmental
0
Property
0

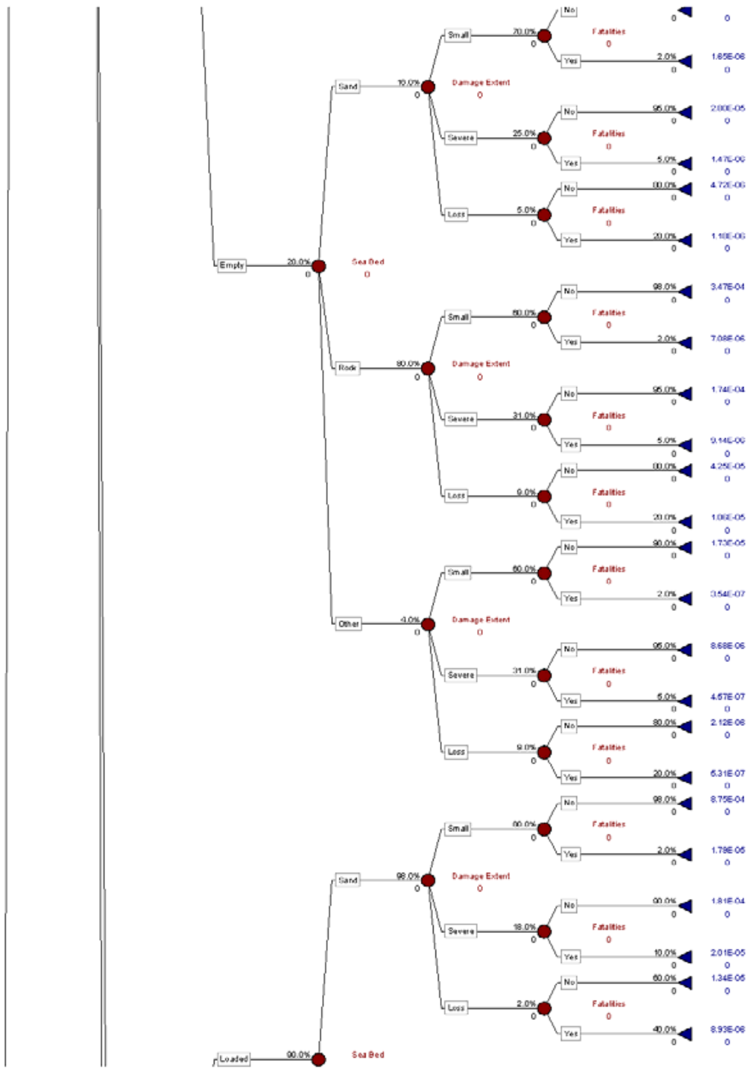
Wrecked/Stranded



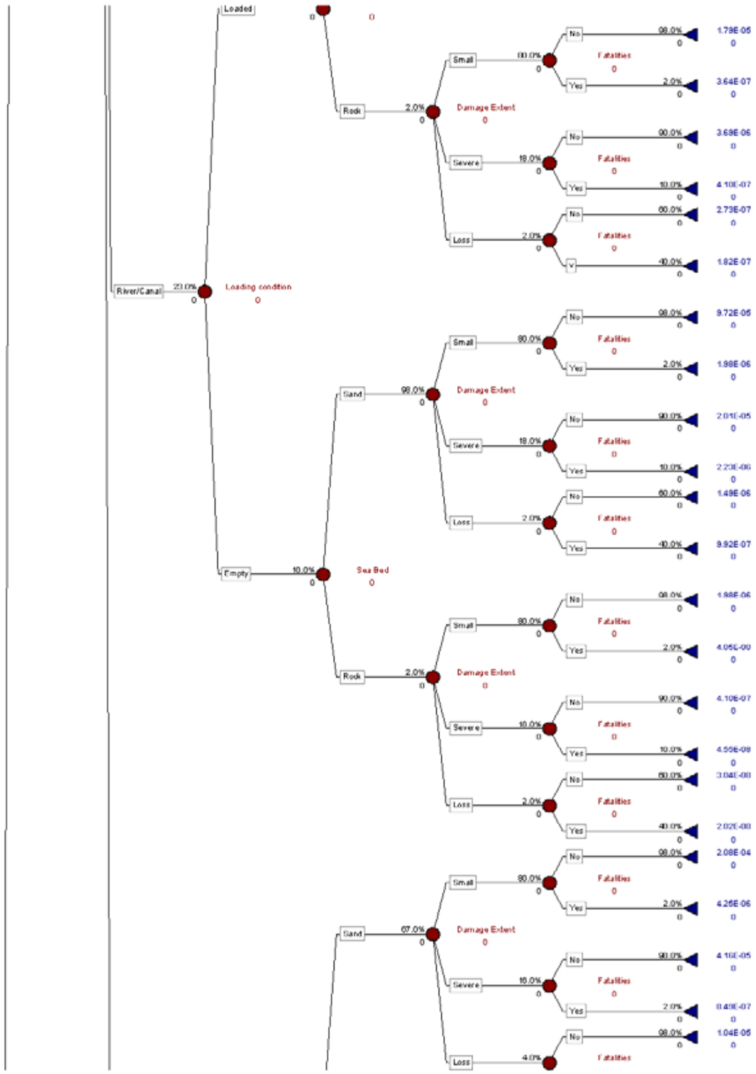
				Consequences				Cumultative risk contribution			
Probability of scenario		*No Accidents per ship year*	*Sequence No*	Human fatalities crew	Environment Oil leakage [tonnes]	Ship damage	Loss	PLL Potential Loss of Life per ship year Crew	Bunker spill tonnes per ship year	Property [€/ship year]	PLS Potential Loss of Ship per ship year
	1	0.0055						1.05E-03	9.06E-03	0.00E+00	0.00E+00
		6.11E-06	1	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
		1.25E-07	2	1	0			1.25E-07	0.00E+00	0.00E+00	0.00E+00
		2.12E-06	3	0	2			0.00E+00	4.23E-06	0.00E+00	0.00E+00
		1.11E-07	4	2	2			2.23E-07	2.23E-07	0.00E+00	0.00E+00
		3.56E-07	5	0	4			0.00E+00	1.43E-06	0.00E+00	0.00E+00
		8.91E-08	6	12	4			1.07E-06	3.56E-07	0.00E+00	0.00E+00
		2.39E-05	7	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
		4.87E-07	8	1	0			4.87E-07	0.00E+00	0.00E+00	0.00E+00
		1.20E-05	9	0	4			0.00E+00	4.70E-05	0.00E+00	0.00E+00
		6.29E-07	10	2	4			1.26E-06	2.52E-06	0.00E+00	0.00E+00
		2.92E-06	11	0	15			0.00E+00	4.38E-05	0.00E+00	0.00E+00
		7.31E-07	12	12	15			8.77E-06	1.10E-05	0.00E+00	0.00E+00
		6.79E-07	13	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
		1.39E-08	14	1	0			1.39E-08	0.00E+00	0.00E+00	0.00E+00
		2.43E-07	15	0	2			0.00E+00	4.85E-07	0.00E+00	0.00E+00
		4.95E-09	16	2	2			9.90E-09	9.90E-09	0.00E+00	0.00E+00
		3.96E-08	17	0	4			0.00E+00	1.58E-07	0.00E+00	0.00E+00
		9.90E-09	18	12	4			1.19E-07	3.96E-08	0.00E+00	0.00E+00
		2.65E-06	19	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
		5.41E-08	20	1	0			5.41E-08	0.00E+00	0.00E+00	0.00E+00



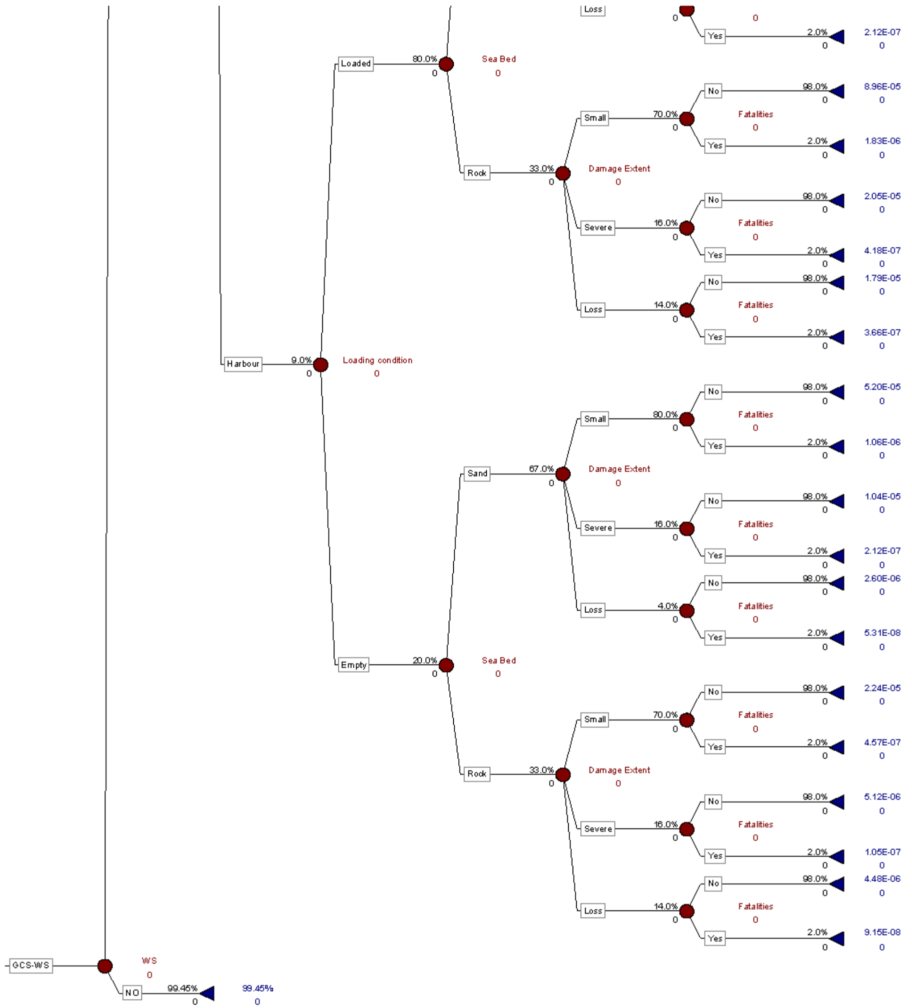
1.37E-06	21	0	4			0.00E+00	5.48E-06	0.00E+00	0.00E+00
2.80E-08	22	1	4			2.80E-08	1.12E-07	0.00E+00	0.00E+00
3.25E-07	23	0	15			0.00E+00	4.87E-06	0.00E+00	0.00E+00
8.12E-08	24	12	15			9.74E-07	1.22E-06	0.00E+00	0.00E+00
2.63E-04	25	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.38E-06	26	1	0			5.38E-06	0.00E+00	0.00E+00	0.00E+00
1.66E-04	27	0	2			0.00E+00	3.32E-04	0.00E+00	0.00E+00
8.73E-06	28	2	2			1.75E-05	1.75E-05	0.00E+00	0.00E+00
2.26E-05	29	0	4			0.00E+00	9.06E-05	0.00E+00	0.00E+00
5.66E-06	30	8	4			4.53E-05	2.26E-05	0.00E+00	0.00E+00
1.39E-03	31	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.83E-05	32	1	0			2.83E-05	0.00E+00	0.00E+00	0.00E+00
6.95E-04	33	0	4			0.00E+00	2.78E-03	0.00E+00	0.00E+00
3.66E-05	34	2	4			7.31E-05	1.46E-04	0.00E+00	0.00E+00
1.70E-04	35	0	15			0.00E+00	2.55E-03	0.00E+00	0.00E+00
4.25E-05	36	8	15			3.40E-04	6.37E-04	0.00E+00	0.00E+00
6.93E-05	37	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.42E-06	38	1	0			1.42E-06	0.00E+00	0.00E+00	0.00E+00
3.47E-05	39	0	4			0.00E+00	1.39E-04	0.00E+00	0.00E+00
1.83E-06	40	2	4			3.66E-06	7.31E-06	0.00E+00	0.00E+00
8.49E-06	41	0	15			0.00E+00	1.27E-04	0.00E+00	0.00E+00
2.12E-06	42	8	15			1.70E-05	3.18E-05	0.00E+00	0.00E+00
8.09E-05	43	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00



1.65E-06	44	1	0			1.65E-06	0.00E+00	0.00E+00	0.00E+00
2.80E-05	45	0	2			0.00E+00	5.60E-05	0.00E+00	0.00E+00
1.47E-06	46	2	2			2.95E-06	2.95E-06	0.00E+00	0.00E+00
4.72E-06	47	0	4			0.00E+00	1.89E-05	0.00E+00	0.00E+00
1.18E-06	48	8	4			9.43E-06	4.72E-06	0.00E+00	0.00E+00
3.47E-04	49	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.08E-06	50	1	0			7.08E-06	0.00E+00	0.00E+00	0.00E+00
1.74E-04	51	0	4			0.00E+00	6.95E-04	0.00E+00	0.00E+00
9.14E-06	52	2	4			1.83E-05	3.66E-05	0.00E+00	0.00E+00
4.25E-05	53	0	15			0.00E+00	6.37E-04	0.00E+00	0.00E+00
1.06E-05	54	8	15			8.49E-05	1.59E-04	0.00E+00	0.00E+00
1.73E-05	55	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.54E-07	56	1	0			3.54E-07	0.00E+00	0.00E+00	0.00E+00
8.68E-06	57	0	4			0.00E+00	3.47E-05	0.00E+00	0.00E+00
4.57E-07	58	2	4			9.14E-07	1.83E-06	0.00E+00	0.00E+00
2.12E-06	59	0	15			0.00E+00	3.18E-05	0.00E+00	0.00E+00
5.31E-07	60	8	15			4.25E-06	7.96E-06	0.00E+00	0.00E+00
8.75E-04	61	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.79E-05	62	1	0			1.79E-05	0.00E+00	0.00E+00	0.00E+00
1.81E-04	63	0	2			0.00E+00	3.61E-04	0.00E+00	0.00E+00
2.01E-05	64	7	2			1.41E-04	4.02E-05	0.00E+00	0.00E+00
1.34E-05	65	0	4			0.00E+00	5.36E-05	0.00E+00	0.00E+00
8.93E-06	66	18	4			1.61E-04	3.57E-05	0.00E+00	0.00E+00



1.79E-05	67	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.64E-07	68	1	0			3.64E-07	0.00E+00	0.00E+00	0.00E+00
3.69E-06	69	0	4			0.00E+00	1.48E-05	0.00E+00	0.00E+00
4.10E-07	70	7	4			2.87E-06	1.64E-06	0.00E+00	0.00E+00
2.73E-07	71	0	15			0.00E+00	4.10E-06	0.00E+00	0.00E+00
1.82E-07	72	18	15			3.28E-06	2.73E-06	0.00E+00	0.00E+00
9.72E-05	73	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.98E-06	74	1	0			1.98E-06	0.00E+00	0.00E+00	0.00E+00
2.01E-05	75	0	2			0.00E+00	4.02E-05	0.00E+00	0.00E+00
2.23E-06	76	7	2			1.56E-05	4.46E-06	0.00E+00	0.00E+00
1.49E-06	77	0	4			0.00E+00	5.95E-06	0.00E+00	0.00E+00
9.92E-07	78	18	4			1.79E-05	3.97E-06	0.00E+00	0.00E+00
1.98E-06	79	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
	8								
4.05E-08	80	1	0			4.05E-08	0.00E+00	0.00E+00	0.00E+00
4.10E-07	81	0	4			0.00E+00	1.64E-06	0.00E+00	0.00E+00
4.55E-08	82	7	4			3.19E-07	1.82E-07	0.00E+00	0.00E+00
3.04E-08	83	0	15			0.00E+00	4.55E-07	0.00E+00	0.00E+00
2.02E-08	84	18	15			3.64E-07	3.04E-07	0.00E+00	0.00E+00
2.08E-04	85	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.25E-06	86	1	0			4.25E-06	0.00E+00	0.00E+00	0.00E+00
4.16E-05	87	0	2			0.00E+00	8.32E-05	0.00E+00	0.00E+00
8.49E-07	88	2	2			1.70E-06	1.70E-06	0.00E+00	0.00E+00
1.04E-05	89	0	4			0.00E+00	4.16E-05	0.00E+00	0.00E+00



2.12E-07	90	1	4			2.12E-07	8.49E-07	0.00E+00	0.00E+00
8.96E-05	91	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.83E-06	92	1	0			1.83E-06	0.00E+00	0.00E+00	0.00E+00
2.05E-05	93	0	4			0.00E+00	8.20E-05	0.00E+00	0.00E+00
4.18E-07	94	2	4			8.36E-07	1.67E-06	0.00E+00	0.00E+00
1.79E-05	95	0	15			0.00E+00	2.69E-04	0.00E+00	0.00E+00
3.66E-07	96	5	15			1.83E-06	5.49E-06	0.00E+00	0.00E+00
5.20E-05	97	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.06E-06	98	1	0			1.06E-06	0.00E+00	0.00E+00	0.00E+00
1.04E-05	99	0	2			0.00E+00	2.08E-05	0.00E+00	0.00E+00
2.12E-07	100	2	2			4.25E-07	4.25E-07	0.00E+00	0.00E+00
2.60E-06	101	0	4			0.00E+00	1.04E-05	0.00E+00	0.00E+00
5.31E-08	102	5	4			2.65E-07	2.12E-07	0.00E+00	0.00E+00
2.24E-05	103	0	0			0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.57E-07	104	1	0			4.57E-07	0.00E+00	0.00E+00	0.00E+00
5.12E-06	105	0	4			0.00E+00	2.05E-05	0.00E+00	0.00E+00
1.05E-07	106	2	4			2.09E-07	4.18E-07	0.00E+00	0.00E+00
4.48E-06	107	0	15			0.00E+00	6.72E-05	0.00E+00	0.00E+00
9.15E-08	108	5	15			4.57E-07	1.37E-06	0.00E+00	0.00E+00