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Introduction

The scope of this report is to describe all available data sources which may be useful for the purposes of navigational risk assessment. The concept of risk is central to any discussion of safety. With reference to a given system or activity, the term 'safety' is normally used to describe the degree of freedom from danger, and the concept of risk is a way of evaluating this. However, the term risk is not only used in relation to evaluating the degree of safety and the risk concept can be viewed differently depending on the context. For the purposes of this report, the risk assessment is defined as the process which main aim is to determine the probability of occurrence the undesired events (e.g. collision, grounding), and estimate the consequences of these event in terms of human, economic and/or environmental loss. Among engineers the following definition of risk is normally applied (Kristiansen 2004):

$$R = P \cdot C \quad , \qquad [1]$$

where:

P – probability of unwanted event,

C – consequences.

Risk may also be expressed in three ways (Modarres 2006):

1. in terms of quantity,
2. in terms of quality,
3. both in terms of quality and quantity.

The quantitative risk analysis attempts to estimate risk in form of probability of frequency of a loss and evaluates such probabilities to make decision and communicate the result. The use of this type of analysis is restricted to large scope risk analyses, because it is complicated, time-consuming, and expensive.

The qualitative risk analysis describes the potential loss using linguistic scales such as low, medium, and high. In this type of analysis, a matrix is constructed which characterizes risk in form of the frequency of the loss versus potential magnitude of the loss in qualitative scales. This type of analysis does not need to rely on actual data and probabilistic treatment of such data, therefore it is simple and easy to use, but also extremely subjective. It may be applied for the analysis of simple systems and straightforward processes.

The mixed method may be used in two ways, when the frequency of loss is measured qualitatively but the consequence of the loss is measured quantitatively, or vice versa.

For the purposes of this report, only quantitative risk analysis is considered. Depending on the input data and the scope of analysis, the navigational risk analysis may be split into two, as follows:

1. static risk assessment,
2. dynamic risk assessment.

The two main aims, based on the above division, are the scopes of appropriate work packages in EfficienSea project:

1. WP 6.2 - Risk analysis algorithm development, based on historical AIS-data
2. WP 6.3 - Dynamic algorithm for analyzing online-situations.

Both static and dynamic risk assessment tools have a common core; the basis for risk calculation is similar for both cases. The main difference is the level of detail, which generally is higher for the dynamic risk assessment tool. The generic box diagram for a risk assessment procedure is shown in Figure 1. The models of collision and consequences are shown here as black boxes with some input from external databases, which will be described in greater detail in the next part of report.

Both static and dynamic risk evaluation tools should be GIS based applications.

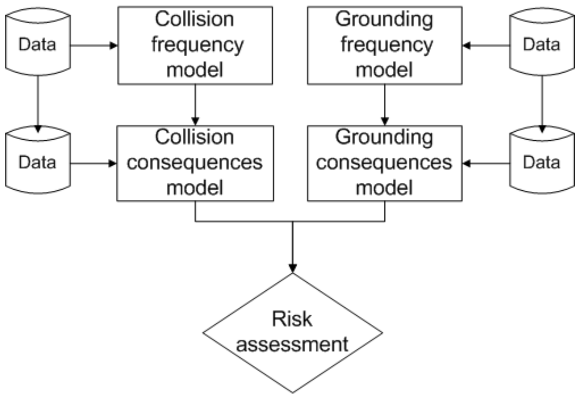

Fig.1 A generic box diagram for marine risk assessment.

In the report presented a review of existing models and available data sources that may be utilized in order to achieved the aims defined above is carried out.

1. Static risk assessment

The static risk assessment is usually carried out for the purposes of navigational analysis, comparative studies, or long term traffic management. It is mostly based on historical and statistical data, therefore it is not prone to momentary changing of environmental conditions.

The area range of static risk assessment is practically unlimited. It may be conducted for the small section of waterway, as well as for the whole route of ship.

The static risk assessment is understood as the process of risk evaluation based on historical data, with stochastic input values. The theoretical background for the collision and grounding frequency analysis has been described by several authors. The most common formulae and software that have emerged from the Baltic Sea region are (Friis-Hansen et al. 2000, Wang et al. 2006, Friis-Hansen 2007):

1. IWRAP MK II
2. GRISK
3. GRACAT

The IWRAP MK II constitutes a reduced version of the collision and grounding analysis program, the BaSSy ToolBox (GRISK) that is being developed under the BaSSy-project. The BaSSy project is a joint research project between Technical University of Denmark, GateHouse (Denmark), SSPA (Sweden), and VTT (Finland), which is funded in part by The Danish Maritime Foundation and Det Nordiske Ministerråd.

The overall goal of the BaSSy project is to contribute to the reducing of risk for ship collisions and groundings, and thereby decreasing the risk for people and environment in the Baltic Sea area. Another main goal is to analyse the ship traffic in the Baltic Sea, ship bridges and VTS (Vessel Traffic Service) centres, with special emphasis on human factors. Such results will be valuable for ship owners as well as ship bridge and VTS suppliers in gaining better understanding of critical factors and areas (Grundevik 2009).

The objective of the GRISK program is to provide the user with a tool that assists in quantifying the risks involved with vessel traffic in specific geographical areas. On the basis of a specified traffic intensity and composition, the tool allows the user to efficiently evaluate and estimate the annual number of collision and grounding in the specified navigational area. To quantify the grounding and collision risks involved in vessel traffic, rational criteria for prediction and evaluation of grounding and collision accidents must be developed. This implies that probabilities, as well as the inherent consequences must be analysed and assessed. The GRISK computer program facilitates these types of analyses and provides rational tools for evaluating and comparing the grounding and collision risk for the analysed alternatives (GateHouse Risk 2008).

The risk analysis program GRACAT is a comprehensive package developed by the Technical University of Denmark for calculating the probability of collisions, groundings, and subsequent consequences. This state-of-the-art software for grounding and collision analysis was developed within the ISESO project. Using this program, the waterway is broken into discrete reaches and bends, and available traffic data are used. A number of scenarios are then created using a combination of vessel types and differing requirements for the waterway. The results from these scenarios provide quantitative data for risk assessment within the waterway. The geographical arrangements of any waterway that are set out on a vector chart can be applied directly to the model. The values of traffic management tools in the waterway, such as radio navigation services, aids to navigation, VTS, pilotage, and AIS can be inserted in this chart. The operational traffic pattern in the model includes the number and types of ships using the waterway, ships' speeds, ships' critical domains, traffic routes, and the spatial distribution of traffic related to time. Various meteorological and hydrological conditions may also be included (Friis-Hansen et al. 2000).

It is worth mentioning that IWRAP MK II and GRISK are focused on probability of collision and grounding calculation only, and the consequences are omitted at the present stage of development of these programs. Complex risk analyses are carried out by means of GRACAT software, which is at present the state-of-art tool for computing and predicting navigation risk.

In addition to the above-mentioned software, which are free for scientific purposes, there exist several commercial tools for quantitative risk assessment. Most of have been tailored for the offshore purposes (Vinnem 2007).

There is also one EU-founded project MARNIS, the aim of which is to develop the safety structure in European waters through the use of Vessel Traffic Management (VTM) in the littoral seas. The safety structure includes continuous monitoring of high-risk vessels along the European coasts using AIS and Long Range (LR) AIS, the possibility of intervention of the coastal states to protect their coasts, the provision of safe havens, the provision of Emergency Towing Vessels (ETVs), the provision of sufficient salvage capabilities, and the integration of VTM and Search and Rescue functions into a safety preventive and remedial network along the European coasts (http://www.marnis.org).

Project MARNIS utilizes the SAMSON model for navigation risk assessment (Koldenhof 2006).

2. Dynamic risk assessment

The dynamic risk assessment is understood as risk identification in terms of dynamic traffic picture and is mostly used for the on-line traffic management purposes, as the decision support tool for the shore based VTMS centres. The aim of this analysis is to determine the high-risk vessels among the large group of vessels navigating in the area or determine the high-risk areas for the specific traffic situation. Dynamic parameters can be understood as different data sources, and the role of dynamic risk management tool is to sum these data sources and make an analysis through calculations. The risk analysis is carried out for the specific area, or specific vessels, therefore it is very sensitive to local meteorological and navigational conditions. As it is local in nature, it is not as wide in range of applications as the static risk assessment method. The results of analysis are represented as a layer in VTS operator's screen. The dynamic risk assessment tool is best understood as a system giving shore-based VTS operator information on present and future level of risk. To support intelligent traffic monitoring at a VTS, it is important to be able to differentiate among those vessels which are accident-prone compared to less critical ship traffic. The term "accident" includes both collision and grounding. It should be possible to determine which vessels and what areas correspond to an increase in the risk level and a trial or automatic remedy tool should be included.

In this field the most advanced solution has been proposed by DNV, the aim of which is to monitor ship traffic for oil spill prevention. The intended use of the DNV's model is to facilitate the comparison of crude oil tankers and to support a risk-based decision on which ships to focus attention on. The model answers the question ''which crude oil tankers are likely to produce an oil spill accident, and how much oil is likely to spill?'' The model is based on the retrieval of AIS information from each ship and the linking of this information to other sources of data(Eide, Endresen, Brett et al. 2007), (Eide, Endresen, Breivik et al. 2007).

Other authors have given their comments and ideas on the background of the dynamic risk assessment tool, most commonly are:

- Intelligent Vessel Traffic Service (Filipowicz 2007),
- Intelligent Marine Traffic System (Minh Duc Le et al. 2003), (Hasegawa et al. 2000),
- Collision Avoidance System for VTS (Kao et al. 2007),(S. Chang 2004).

3. Risk assessment – the input values

As mentioned above, the static and dynamic risk assessment tools have a much in common the idea behind the models for calculating the collision and grounding frequency and consequences model are very similar. The first and most important step in risk analysis is to define the input values for the model. As shown in Figure1 there are four main modules for collision and grounding frequency and consequences calculations. In this chapter each module is detailed and the corresponding input values are characterized.

3.1 Accident frequency modelling

An “accident” is understood as the following undesirable events:

1. Collision
    a. ship – ship collision,
    b. ship – fixed structure collision,
2. Grounding
    a. intentional grounding,
    b. drift grounding.

There are several models for calculating each above-mentioned accident. The most common are as follows:

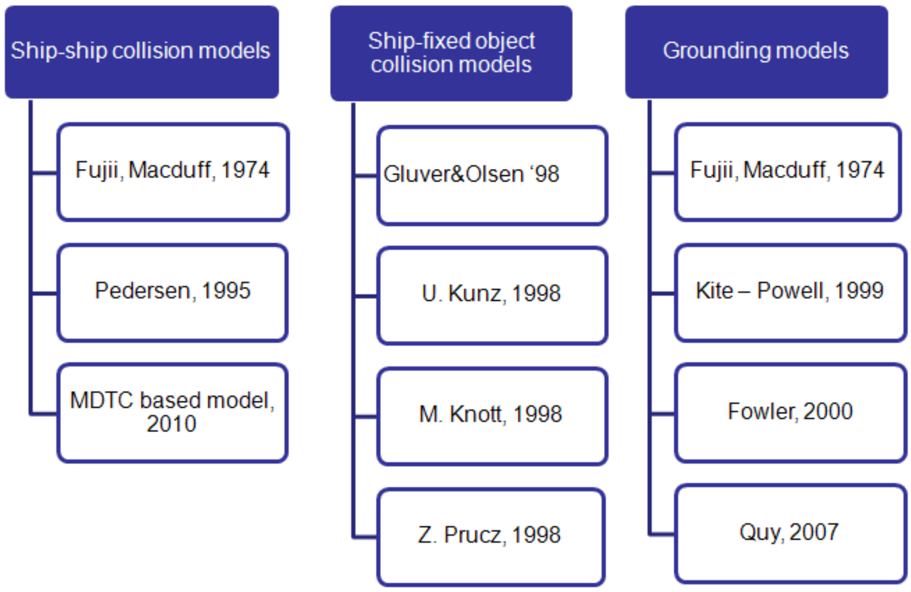

Fig.2 Models for given type of accident frequency calculation

Data needed in order to model properly the accident frequency, may be possessed from various external data-bases and data sources. These data refers to marine accident statistics, marine traffic information, or weather data. They are shortly described in the consecutive chapters.

3.1.1 Accident statistics

Until 2008, statistics of shipping accidents in Finnish waters were stored to the database called DAMA. It consists of marine casualty reports given to the Finnish Maritime Administration (FMA) and runs in a single computer. Since 2009, accidents in Finnish waters have been stored to European Marine Casualty Information Platform (EMCIP) which is managed by European

Maritime Safety Agency (EMSA). EMCIP is used via a web interface. Information from both databases is available for research use via TraFi. The accident statistics of the whole Baltic Sea are available from HELCOM. HELCOM's database includes all accidents in which a tanker over 150 GT and/or other ships over 400 GT were involved.

The problem with accident statistics is that their quality is often poor; all fields may not be filled, some information may be conflicting for the same accident in different databases or even within the same database and the categorizations of fields vary according to database. In addition, e.g., the consequences of accidents are not reported in detail which makes more difficult to draw conclusions based on the records. In some cases, comparison of the data with investigations by the Finland's Accident Investigation Board is used to get further details of the accidents. The description of available accident statistics and detailed analysis of accidents that happened in the Gulf of Finland between 1997 and 2006 are presented in extensive study performed by Kujala et al [2009].

Fig.3 Number of marine accidents by accident type and ship type in the Gulf of Finland during 1997-2006 [Kujala et al, 2009]

3.1.2 Weather information

Daily marine weather forecasts for water areas near Finland are available at the website of Finnish Meteorologial Institute: http://ilmatieteenlaitos.fi/weather/index.html. The webpage contains, e.g., information about sea level, wave height, and ice conditions. A set of statistics is available as well and more information may be requested.

System produced information

3.1.3 PortNet

PortNet is an information system for Finnish Transport Agency, Finnish Customs and the 20 largest Finnish ports. Full access to the system is provided only to authorities. The core content of the system is operative time table information and cargo information concerning maritime traffic. However, timetables may be accessed without registration through the Intermodal Portal (http://impi.atbusiness.com:8080/importal/servlet/com.atbusiness.importal.vts.servlet.MainPage ?LANG=en&CNTRY=US).

The portal could be used, e.g., to estimate traffic amount at different times of day. (FMA, 2005)

3.1.4 IBNet

IBNet is a traffic information system for icebreakers. Its aim is to help coordinating Finnish and Swedish icebreaker fleets and provides tools to improve the service quality. Satellite images, weather and ice forecasts are used to present and predict changes in ice conditions. (VTT, 2009)

3.1.5 AIS

Automatic Identification System (AIS) enables ships and Vessel Traffic Services (VTS) to automatically exchange information on Very High Frequency channels. By the end of 2004, AIS had to be installed to all passenger ships, all ships of at least 300 gross tonnage engaged in international voyages, and all cargo ships of 500 gross tonnage and upwards even if not navigating internationally. AIS enables to automatically have information about ships navigating in a certain area. AIS data includes static, dynamic, and voyage-related information. By reproducing ship tracks it is possible to, e.g., examine how close to each other ships have navigated. Data can be used to form traffic distributions across waterways and to the get information about ship dimensions, speeds, and courses (IMO 2002, IMO 2009, FMA 2009)
Unfortunately, AIS data is partially inconsistent. AIS is often not installed properly or the data is not updated as recommended by IMO (2002). For example, information ships are transmitting may contain wrong identification numbers, dimensions, or ship type. Some fields may also be left blank. Voyage related data should be updated to every journey but it is often out of date. In addition, severe weather conditions may also disturb data exchange via AIS. (Rambøll 2006, Harati-Mokhtari et al. 2007, SSPA 2009, Lloyd’s MIU 2009)

The inconsistency of AIS data is increased in the storing process. The amount of data is excessive which requires much from the storing system. The system may be occasionally down partially or totally for some periods of time. AIS messages of those periods are lost. All these issues have to be noticed when AIS data is used in the analysis.

Even though AIS data is partially inconsistent, AIS enables marine accident modelling in more advanced way than what was possible before the introduction of AIS. For example, traffic distributions across waterways may be formed with the actual traffic of a year or a season.

To summarize, AIS data is very valuable for marine accident frequency analysis but its disadvantages have to be noticed when interpreting the results and drawing conclusions.

3.1.6 Ship traffic problem areas

Particularly dangerous ship traffic areas may be identified by using information from several inputs. Maps provide information about narrow and shallow waterways, AIS data can be used to find out traffic volumes and ship types on different waterways. For example, oil tankers cause risk for the environment and the safety of large passenger vessels is of special importance as they carry a large number of people. Weather information, especially about ice conditions, can be used to assess the effects of winter on the safety of navigation. Traffic Separation Schemes (TSS) may not be in use due to ice and anyhow ships are navigating closer to each other than in summer time because navigable ice channels are often narrow. AIS data can also be used to estimate how close to each other ships have actually passed. Accident statistics can be used to check whether some locations have been particularly prone to a certain type of accidents.

In addition, several analytical tools exist to estimate, e.g., ship-ship collision probability. The use of IWRAP as a part of risk analysis is recommended by IALA (2009). IWRAP requires a large amount of input that can however be gathered from AIS data. Results are given as the frequency of head-on, overtaking, merging, crossing, and bend collisions. The relative risk of each waterway and waypoint is marked on the map. It is also possible to contemplate collision frequencies at a certain waterway or waypoint. In addition, overall collision frequencies or frequencies at certain location or of certain collision type are presented by ship type. IWRAP does not automatically take into account ice conditions and the change of traffic pattern in winter but a separate analysis with winter traffic volumes and traffic distributions across the waterways may be made.

3.2 Collision frequency modelling input data

Table 1 shows the input values needed to obtain the frequency of collision between two vessels, assuming that static risk assessment is considered. Some of these values are directly transmitted in AIS messages, but some require external databases. The detailed description of AIS message syntax is presented in Tables 3, 4, 5, and 6.

Table 1. Factors affecting the frequency of ship-ship collision, according to Pedersen and MDTC based models.

Factors/Model	Pedersen Model	MDTC based model
Vessel's factors		
Speed	+	+
Course	+	+
Length	+	+
Breadth	+	+
Draft	-	+
Type	-	+
Vessel's dynamics	-	+
External factors		
Traffic volume	+	+
Traffic composition	+	+
Collision zone	Collision Diameter	Minimum Distance To Collision
Uncertainty of input values	Not considered	Considered
Probability of collision	Single value	Distribution

Table 2 consists of input values for grounding frequency assessment models. All known models are presented, and factors contributing to geometrical and causation probability are specified, according to work presented by Mazaheri A. (2009). Detailed description of these factors and related sources are presented in Tables 10 and 11 at the end ot this report. Table 11 (Appendix 1) contains factors contributing to causation probability, which are used both for collision and grounding probability assessment. These factors and their values were determined on the basis of studies carried out by DNV which were focused on large passenger vessels (Det Norske Veritas 2003). The model is being developed now, and for the purposes of EfficienSea project it is adjusted according to individual needs.

Table 2. Factors affecting the frequency of ship groundings according to specified models.

Model	Year published	Geometrical Probability	Causation Probability
Macduff	1974	Stopping distance Ship size Ship speed Width of the waterway	Fog Snow Engine Failure Steering gear failure Panic Carelessness Ignorance
Fujii	1974	Traffic flow	Darkness

			Visibility
		Width of the waterway	
		Ship breadth	
		Ship size (GRT)	
		Linear cross section of the obstacle	
Pedersen	1995	Ship's type	
		Width of the waterway	
		Traffic distribution	
		Position checking	
		Distance from the obstacle to the bend	
Simonsen	1997	Ship's type	
		Traffic distribution	
		Position checking	
		Distance from the obstacle to the bend	
Karlsson	1998	Traffic distribution	Human factor
		Distance to the shoal	
Fowler&Sorgard	2000	Frequency of being in critical situation	
		Visibility	
		Frequency of propulsion breakdown	
		Wind Speed	
		Self repairing	
		Tug Assistance	
		Anchoring	
Otto et al.	2002	Traffic distribution	
		Linear cross section of the obstacle	
		Width of the waterway	
Kristiansen	2005	Ship's breadth	
		cross section of the obstacle	
		Width of the waterway	
		Length of the waterway	
Ramboll Danmark	2006	Ship's type	Pilot on board
		Ship's speed	
		Ship's breadth	
		Ship's length	
		Traffic distribution	
		Linear cross section of the obstacle	
		Ship's draught	
		Depth of the channel	
		Distance from the obstacle to the bend	
Gucma	2006	Traffic distribution	

Quy et al.	2007	Ship's breadth Width of the waterway Width of the waterway Ship's breadth Traffic distribution	Environm. conditions

The AIS message of class A receiver, which is a ship borne mobile equipment intended for vessels meeting the requirements of IMO AIS carriage requirement, is presented in Tables 3,4,5, and 6.

Table 3. Position report for AIS class A receiver (US Coast Guard 2009)

Parameter	No of bits	Description
Message ID	6	Identifier for this message 1, 2 or 3
Repeat indicator	2	Used by the repeater to indicate how many times a message has been repeated. See § 4.6.1, Annex 2; 0-3; 0 = default; 3 = do not repeat any more
User ID	30	MMSI number
Navigational status	4	0 = under way using engine, 1 = at anchor, 2 = not under command, 3 = restricted maneuverability, 4 = constrained by her draught, 5 = moored, 6 = aground, 7 = engaged in fishing, 8 = under way sailing, 9 = reserved for future amendment of navigational status for ships carrying DG, HS, or MP, or IMO hazard or pollutant category C, high speed craft (HSC), 10 = reserved for future amendment of navigational status for ships carrying dangerous goods (DG), harmful substances (HS) or marine pollutants (MP), or IMO hazard or pollutant category A, wing in grand (WIG); 11-14 = reserved for future use, 15 = not defined = default
Rate of turn ROT_{AIS}	8	0 to +126 = turning right at up to 708° per min o r higher 0 to –126 = turning left at up to 708° per min or h igher Values between 0 and 708° per min coded by ROT_{AIS} = 4.733 SQRT(ROT_{sensor}) degrees per min where ROT_{sensor} is the Rate of Turn as input by an external Rate of Turn Indicator (TI). ROT_{AIS} is rounded to the nearest integer value. +127 = turning right at more than 5º per 30 s (No TI available) –127 = turning left at more than 5º per 30 s (No TI available) –128 (80 hex) indicates no turn information available (default). ROT data should not be derived from COG information.
SOG	10	Speed over ground in 1/10 knot steps (0-102.2 knots) 1 023 = not available, 1 022 = 102.2 knots or higher
Position accuracy	1	The position accuracy (PA) flag should be determined in accordance with table below
Longitude	28	1 = high (= 10 m)

		0 = low (= 10 m) 0 = default Longitude in 1/10 000 min (±180º, East = positive (as per 2's complement), West = negative (as per 2's complement). 181= (6791AC0h) = not available = default)
Latitude	27	Latitude in 1/10 000 min (±90°, North = positive (as per 2's complement), South = negative (as per 2's complement). 91° (3412140h) = not available = default)
COG	12	Course over ground in 1/10 = (0-3599). 3600 (E10h) = not available = default. 3 601-4 095 should not be used
True heading	9	Degrees (0-359) (511 indicates not available = default)
Time stamp	6	UTC second when the report was generated by the electronic position system (EPFS) (0-59, or 60 if time stamp is not available, which should also be the default value, or 61 if positioning system is in manual input mode, or 62 if electronic position fixing system operates in estimated (dead reckoning) mode, or 63 if the positioning system is inoperative)
Special maneuver indicator	2	0 = not available = default 1 = not engaged in special maneuver 2 = engaged in special maneuver (i.e.: regional passing arrangement on Inland Waterway)
Spare	3	Not used. Should be set to zero. Reserved for future use.
RAIM-flag	1	Receiver autonomous integrity monitoring (RAIM) flag of electronic position fixing device; 0 = RAIM not in use = default; 1 = RAIM in use. See Table
Communication stat	19	See Rec. ITU-R M.1371-3 Table 46
Number of bits	168	

Table 4. Ship static and voyage related data, class A AIS transmitter

Parameter	No of bits	Description
Message ID	6	Identifier for this Message 5
Repeat indicator	2	Used by the repeater to indicate how many times a message has been repeated. Refer to § 4.6.1, Annex 2; 0-3; 0 = default; 3 = do not repeat any more
User ID	30	MMSI number
AIS version indicator	2	0 = station compliant with Recommendation ITU-R M.1371-1 1 = station compliant with Recommendation ITU-R M.1371-3 2-3 = station compliant with future editions
IMO number	30	1-999999999; 0 = not available = default
Call sign	42	7 = 6 bit ASCII characters, @@@@@@@ = not available = default
Name	120	Maximum 20 characters 6 bit ASCII "@@@@@@@@@@@@@@@@@@@@" = not available = default
Type of ship and cargo type	8	0 = not available or no ship = default 1-99 = as defined below 100-199 = reserved, for regional use 200-255 = reserved, for future use
Overall dimension/ reference for position	30	Reference point for reported position. Also indicates the dimension of ship (m) (see below)
Type of electronic position fixing	4	0 = undefined (default) 1 = GPS 2 = GLONASS

device		3 = combined GPS/GLONASS 4 = Loran-C 5 = Chayka 6 = integrated navigation system 7 = surveyed 8 = Galileo, 9-15 = not used
ETA	20	Estimated time of arrival; MMDDHHMM UTC Bits 19-16: month; 1-12; 0 = not available = default Bits 15-11: day; 1-31; 0 = not available = default Bits 10-6: hour; 0-23; 24 = not available = default Bits 5-0: minute; 0-59; 60 = not available = default
Maximum present static draught	8	In 1/10 m, 255 = draught 25.5 m or greater, 0 = not available = default; in accordance with IMO Resolution A.851
Destination	120	Maximum 20 characters using 6-bit ASCII; @@@@@@@@@@@@@@@@@@@@ = not available
DTE	1	Data terminal equipment (DTE) ready (0 = available, 1 = not available = default)
Spare	1	Spare. Not used. Should be set to zero. Reserved for future use.
Number of bits	424	Occupies 2 slots

Table 5. Type of ships

Identifiers to be used by ships to report their type, where the identifier should be constructed by selecting the appropriate first and second digits.			
	Other ships		
First digit	Second digit	First digit	Second digit
1 – Reserved for future use	0 – All ships of this type	–	0 – Fishing
2 – WIG	1 – Carrying DG, HS, or MP, IMO hazard or pollutant category A	–	1 – Towing
3 – See right column	2 – Carrying DG, HS, or MP, IMO hazard or pollutant category B	3 – Vessel	2 – Towing and length of the tow exceeds 200 m or breadth exceeds 25 m
4 – HSC	3 – Carrying DG, HS, or MP, IMO hazard or pollutant category C	–	3 – Engaged in dredging or underwater operations
5 – See above	4 – Carrying DG, HS, or MP, IMO hazard or pollutant category D	–	4 – Engaged in diving operations
	5 – Reserved for future use	–	5 – Engaged in military operations
6 – Passenger ships	6 – Reserved for future use	–	6 – Sailing
7 – Cargo ships	7 – Reserved for future use	–	7 – Pleasure craft
8 – Tanker(s)	8 – Reserved for future use	–	8 – Reserved for future use
9 – Other types of ship	9 – No additional information	–	9 – Reserved for future use

Table 6. Type of special purposes' ships

Identifiers to be used by ships to report their type	
Identifier No.	**Special craft**
50	Pilot vessel
51	Search and rescue vessels
52	Tugs
53	Port tenders
54	Vessels with anti-pollution facilities or equipment
55	Law enforcement vessels
56	Spare – for assignments to local vessels
57	Spare – for assignments to local vessels
58	Medical transports (as defined in the 1949 Geneva Conventions and Additional Protocols)
59	Ships according to RR Resolution No. 18 (Mob-83)

3.2.1 Vessel-related data

According to the data presented in the previous tables, the following information may be imported to the collision and grounding frequency estimation models from AIS messages:

- speed over ground (from internal or external sensor),
- course over ground (from internal or external sensor),
- vessel's length (fixed value),
- vessel's breadth (fixed value),
- vessel's draught (manual input)
- vessels identification number (fixed value)
    - IMO number
    - MMSI number
- vessel's type (fixed value):
    - passenger,
    - tanker,
    - HSC,
    - fishing,
    - towing,
    - pleasure craft,
    - sailing boat,
    - cargo vessel,
    - special purposes vessels.

These information is not enough to determine vessel's dynamics. The model of ship's motion used in MDTC based model is sensitive for the type of vessel, whereas the AIS message identifies only two vessel types that MDTC based model recognizes: tankers and passenger vessels. The group defined in AIS message as ”cargo vessels” is too wide to be well defined in ship's motion model. In Figure 4 main types of vessels navigating in the Gulf of Finland are presented. The graph is based on AIS information gathered during two months observation in March and June 2006.

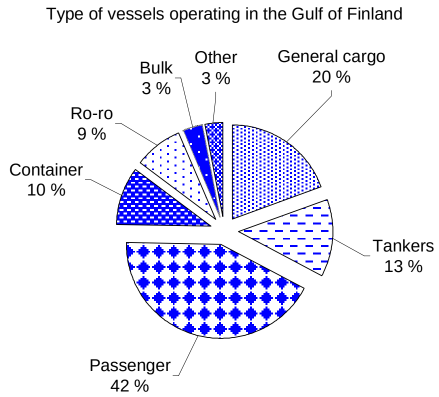

Fig. 4.Types of vessels operating in the Gulf of Finland in year 2006

It may be noticed, that among cargo vessels there are at least three large groups: general cargo, containers, and ro-ro vessels. Each of these groups has different manoeuvring characteristics, therefore it is vital to divide the whole number of ships into these specific groups. Splitting the ”cargo vessel” group into more detailed groups requires external ship databases. Using these data-bases additional information is also gathered, concerning ship propulsion, which is required as an input for motion modelling used in both static and dynamic risk assessment models. The input data for ship motion model are classified in table below.

Table 7. Ship motion model's input data

Input	**Risk assessment model**		**Source**	
	Static	Dynamic	AIS	External database (DB) or computation (C)
Length	+	+	+	
Breadth	+	+	+	
Draught	+	+	+	
Type of vessel	+	+/-	+/-	DB
Water density	+	+	-	
Block coefficient	+	+	-	C
Displacement	+	+	-	DB, C
Main engine power	+	+	-	DB, C
Diameter of propeller	+	+	-	DB, C
Hydrodynamic coefficient	+	+	-	C

For the purposes of the static risk assessment model, two ship databases were studied. One is provided online by ClassNK (Nippon Kaiji Kyokai 2009), the Japanese classification society's ship database, which contains the data of vessels being registered in this society. This database was used to extract data concerning tankers, container carriers, and ro-ro vessels.

Other sources of vessel particulars were the bulletins issued by operators of passengers vessels which cruise across the Gulf of Finland (Tallink Group 2009, Viking Line 2009).

Every classification society must publish their vessels' data, therefore several individual databases exist. The most common are as follows:

- Nippon Kaiji Kyokai: http://www.classnk.or.jp
- Det Norske Veritas: https://exchange.dnv.com/exchange/main.aspx
- American Bureau of Shipping: http://www.eagle.org
- Buerau Veritas: http://www.veristar.com/

Those bases are able to be searched for the following variables:

- vessel name
- IMO number,
- register number,
- ship type,
- ship flag.

For the purposes of statistics and the static risk assessment model the databases were searched by ship type, to obtain manoeuvring characteristics for the main types of vessels, that are navigating in the Gulf of Finland (Figure 3). But for the purpose of the dynamic risk assessment tool the databases are to be listed by vessel ID (IMO number or vessel's name) to retrieve the individual data.

The access to these databases is free of charge. It should be borne in mind, that these bases contain information concerning vessels which are registered in the given classification society. For the statistical purposes or to build relationships needed for the ship motion model it is feasible to use one of the above mentioned databases. Unfortunately it has not proven use for the dynamic risk analysis. For that purpose, some databases which include the whole world fleet are required, or at least a combination of the databases of the biggest classification societies, that are covering most vessels navigating in the Baltic Sea.

The most-well know annual publications showing the composition of the current self-propelled, sea-going merchant fleet of 100 GT or above is World Fleet Statistics, and Register of Ships, published by Lloyd's Register Fairplay and available for a fee (http://www.lrfairplay.com/).

3.2.2 Traffic related data

Both collision and grounding frequency estimation models require traffic data as an input value. Traffic volume is usually described as follows:

- number of vessels proceeding along given route in given time,
- vessel type distribution,
- speed distribution given vessel type,
- courses distribution.

At present the traffic profile is usually created on the basis of AIS observation. Long-term traffic analysis allows the description of marine traffic. During the last few years, several documents were presented about traffic distribution on major routes in the Baltic Sea. Some of them discuss about traffic in the Gulf of Finalnd: (Kujala et al. 2009), (Ylitalo et al. 2008),(Berglund & Huttunen 2008). Some authors use the marine traffic model to generate traffic along defined routes and analyze navigation risk afterwards (Gucma & Przywarty 2007). These models usually use the historical data concerning traffic as an input, and create a statistic from these values. They are quite simple, but also robust. The model presented by Gucma and Przywarty has been validated in Southern Baltic Sea and in Adriatic Sea.

Using previously gathered AIS information describing ships routes one may predict marine traffic in the future. Knowing vessels routes, their distribution, and economical forecast published by authorities and univeristies (Swedish Maritime Administration et al. 2006), (Kalli & Tapaninen 2008), (Kuronen et al. 2008) such prediction appears realistic.

For modelling purposes, vessels routes may be established both on the basis of AIS observations and IMO regulations. During the last few decades the number of ships, their size and quantity of hauled goods significantly grew. At present, the global tendency is to increase the dimensions of vessels. In light of navigation safety, these global changes force incorporation of new patterns of vessel traffic regulation, the aim of which is to prevent navigational accidents like collisions and grounding. Vessels are being made deeper and deeper, but in many cases the natural depths of waterways are too shallow to accommodate them. The Baltic Sea is a relatively small and shallow area, at the entrance to the Baltic Sea, south of Gedser Point maximum vessel's draft is set to 15 meters due to shallows. Also depths along the routes across Southern Baltic and Gulf of Finland are limited. Therefore traffic across the Baltic Sea has become more and more organized. New traffic separation schemes and recommended routes have been established during the last years. The current quantity of cargo being carried over the Baltic Sea, as well and plans for future transit of crude oil and LNG, necessitate establishment of new regulations that ensure acceptable level of navigation safety.

These regulations force vessels to proceed along given routes, favouring some areas and avoiding others, which are more sensitive or more dangerous from the navigational point of view. Therefore marine traffic may be modeled upon these recommended routes and traffic lanes adopted by IMO. In the Figure 5 traffic separation schemes and recommended routes for the Gulf of Finland are presented according to the official Mariners' routing guide published by HELCOM. Another way to describe traffic volume and distribution is to estimate the number of ships in given area on the basis of registered ship calls in harbours which lay in this area and the recommended routes and traffic separation schemes. This way of describing the traffic profile may be useful also for the future traffic prediction. On the basis of available prediction of cargo turnover, and registered number of ship calls at present, future traffic may be estimated. This approach apparently may by less precise then models based on AIS data, but its value as a prediction tool is high. The input data for this model are:

- recorded number of ship calls to given harbour, available in port statistics (Saurama et al. 2008),
- AIS based traffic lanes (P. Kujala et al. 2009),
- recommended routes and traffic separation schemes (HELCOM 2009).

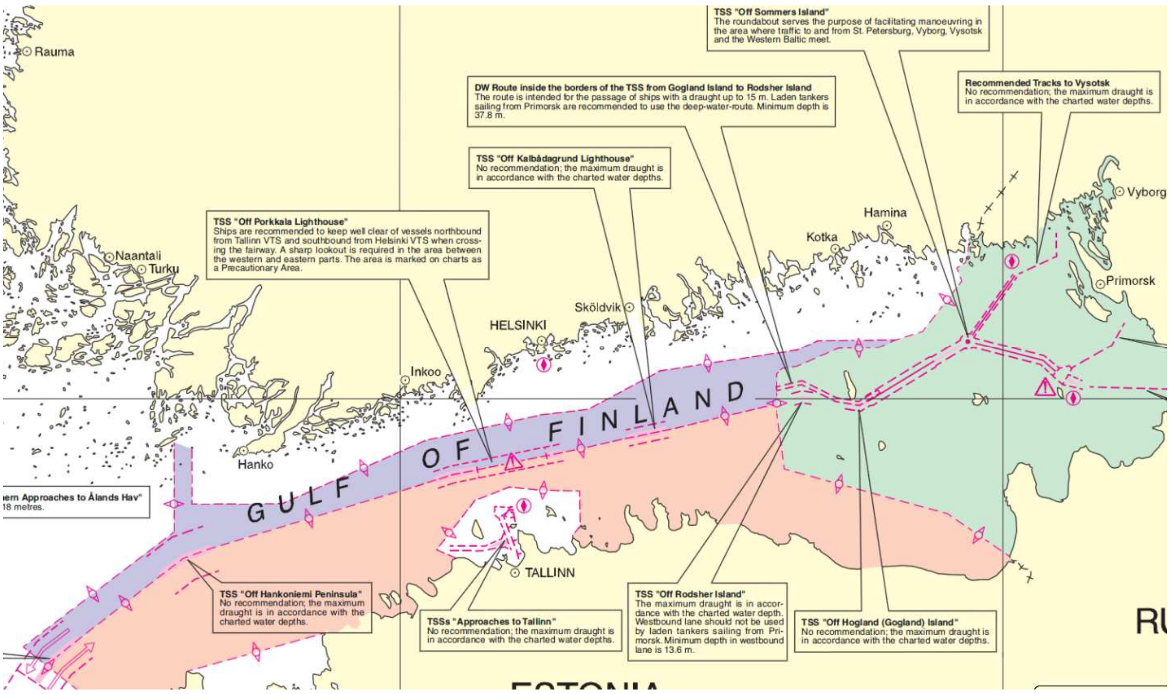

Fig.5. Mariners' routing guide for the Baltic Sea (HELCOM 2009)

3.2.3 Environment related data

For the purposes of static risk assessment the environmental data do not play so important role. The statistical analysis of traffic lanes may answer the question if and where the traffic profile is dependent on environmental conditions. It is quite obvious that in some arctic or icing regions the traffic profiles differs in summer and in winter; therefore more attention should be paid to these regions. One may assume that if two traffic profiles are described (summer and winter), the environmental conditions are already taken into consideration in these profiles and no more studies are required.

In dynamic risk assessment environmental conditions play a vital role. The wind speed and current velocity may determine the direction of potential oil slick movement or determine in which area the vessel may be stranded due to technical failures on board. Wind and current data may be imported directly from observation stations which are distributed along the Finnish coast. The wind speed may be measured directly in the VTS centre and current velocity may be modelled from statistics.

3.3 Accident consequences modelling

The accident's consequences will be modelled in four parts, determining the following:

1. collision or grounding energy,
2. size of crack due to accident,
3. quantity of oil spilled in the accident,
4. oil spill impact.

3.3.1 Collision and grounding energy determination

Input values for the model determining the energy released during a accident are tabulated below. Due to the relatively small amount of data available, the expected model can not be sophisticated. There are several models for collision energy calculation but they are mostly too far complicated. However Zhang's model (1999), due to its robust and simple nature is appropriate (Ritvanen 2006).

3.3.2 Size of crack determination

The type of model to be chosen for oil spill calculation is under consideration. In the case of some simplified models, there is no need to calculate the size of crack due to collision and grounding; therefore this topic may be disregarded.

In the event that a more sophisticated model is chosen, requiring crack size as an input value, then it will be modelled, but at present stage of research this topic is not considered.

Table 8. Factors affecting the collision energy according to Zhang's model

Collision Energy		
Variable	Source	Note
Ship's Mass	Calculation	
Added Mass	Zhang (1999)	
Ship's velocity	AIS	Ship type, fairway specific distributions
Length	AIS	Ship type, fairway specific distributions
Breadth	AIS	Ship type, fairway specific distributions
Draft	AIS	Voyage specific in AIS
Block Coefficient	Calculation	Estimated distribution for each ship type, only vessels able to enter GOF
Ship Type	AIS, Databases	
Heading	AIS	Ship type, fairway specific distributions
Course over Ground (COG)	AIS	
Collision angle	Accident Reports, calculation	Fairway specific distributions
Collision point	Accident Reports, Tuovinen(2005)	
Coefficient of Friction	Material data sheets	
Mass inertia	Calculation	Some estimation needed
Sea water density	Manual input	

3.3.3 Quantity of oil spill determination

There are several models used for oil spill size approximation. The most popular ones are:

- SAFEDOR (Skjong et al. 2007)
- IMO (IMO 2004)
- Smailys and Cesnauskis (Smailys & Česnauskis 2006)
- Eide et al (Eide, Endresen, Breivik et al. 2007)

In the year 2004, IMO published resolution for accidental oil outflow performance (IMO 2004) which contained the methodology for oil spill quantity calculation for a series of double hull tankers. Accidental oil outflow was calculated for 96 common tanker designs representing most of the world's tanker fleet. A wide range of sizes, cargo tank arrangements, and wing and double hull dimensions were represented. When applying this method, detailed information about tank volumes and positions are needed as well as main particulars of the hull. This data is often stored only by the ship owner and ship yard and is unavailable for expeditious use. Therefore a need arose for some simplification.

A modified version of the simplified probabilistic methodology for calculation of accidental oil outflow from a tanker involved in a casualty has been proposed by Smailys and Cesnauskis (2006). The modified methodology requires less input data than standard IMO methodologies, and estimations can be performed in a short time span. The aim of the modified methodology is to estimate cargo oil outflow as precisely as possible using IMO-approved methodologies, but with very limited information related to the accident. In order to minimize the amount of input data, it is assumed that the number of constructive designs of tankers is limited in certain sea regions. The authors' analysis of tankers of different sizes and design types revealed that the length of all arranged cargo tanks for a majority of tankers is the same.

According to Maxim and Niebo (2001) the lognormal distribution provides an adequate representation of oil spill volume data. It is not exact, but is a useful tool when estimating oil spill probabilities and spill sizes. The statistical model is widely applied in a variety of fields for several reasons. It can depending on its parameters assume a variety of shapes, including distributions with long right tails. The lognormal distribution was applied by Juntunen (2005) when estimating oil outflow from ship casualties in the Baltic Sea area. The mean outflow parameters were evaluated using oil outflow data provided by Herbert Engineering Corp. (1998). Standard deviation was calculated based on an assumption that every 100 casualties where a cargo tank is damaged will lead to loss of entire cargo in damaged tank.

3.3.4 Oil spill impact determination

As the final step, the oil spill environmental impact is to be estimated. There exist many papers and publications on the subject, but at present the appropriate model has not been defined yet.

4. Validation of the adopted models

Models which are to be used for risk assessment will be validated in several stages during construction. Each single sub model is to be validated based on statistical data concerning the output of the model.

The accident frequency models may be validated by comparison of modelled number of accidents with recorded number of accidents. Drawing inferences about navigational safety from the accidents statistics only or caring out the validation of models which assess the collision probability on the basis of number of accidents only, which are very rare, is quite difficult and highly uncertain. Therefore it is justified to analyze the safety of navigation on the basis of numbers both accidents and near miss situations, which may better reflect the collisions hazard. Berglund&Huttunen in their report (Berglund & Huttunen 2008) analyzed the meeting situations in the Gulf of Finland for the summer traffic (May, July, July) in 2006, 2007, and 2008. They provided data concerning near misses for crossing, overtaking and head on encounters. The near miss situation was defined there as a meeting of two vessels, being on collision courses, with distance less than 0.3 Nm.

As collision frequency is a product of number of collision candidates and causation probability, one may compare number of collision candidates obtained by geometrical model, which in some models may be equal to near miss situations, with real number of the near misses. The near miss statistics published by Berglund&Huttunen concern traffic along and across Gulf of Finland between Helsinki and Tallinn look promising, and may be used as validating tool for the geometrical model.

Looking further, as soon as the validation is done, one may compare the number of modelled accidents with numbers provided by statistics, and then adjust the causation probability (causation factors). For the present stage of research these are only expectations, and plans for nearest future's researches.

The accident frequency model validation may be carried out with use of accident databases. There are several databases which contain detailed information concerning marine accidents. For the Baltic Sea area the most common and detailed database is provided by HELCOM (HELCOM 2008). The database contains the following information:

- date and time of accident,
- geographical position of accident,
- ship names,
- ship types,
- type of accident,
- hull types,
- size of ships.

The base contains all marine accidents which occurred in the Baltic Sea both in the open sea and in harbours. The base is dated back to 1988. There are also national accident databases, the most popular are DMA (2008), MAIB (2008), for the Gulf of Finland both Finland and Estonia are collecting very detailed accident statistics Statistical Office of Estonia (Statistics Estonia 2009), HELCOM (2008). The national databases concern accidents that:

- occurred in the national waters of given country,
- Involved a vessel under flag of given country.

However, due to very detailed information that HELCOM databases accumulate there is open question if there is a need to use national databases.

Appendix 1

Table. 9 The detailed factors affecting grounding models (Mazaheri 2009)

Author	Year	Geometrical Probability	How do we get the data	Causation Probability	How do we get the data
Macduff	1974	Stopping distance	Size and Speed of the ship	Fog	<Unspecified>
		Width of the waterway	<Unspecified> *(Probably from specified location)*	Snow	<Unspecified>
				Engine Failure	<Unspecified>
				Steering gear failure	<Unspecified>
				Panic	<Unspecified>
				Carelessness	<Unspecified>
				Ignorance	<Unspecified>
Fujii	1974	Speed and density of the traffic flow	<Unspecified> *(Probably from Statistics)*	Brightness	An equation of Traffic Volume and Number of Accidents (Statistics)
		Width of the waterway	Specified location	Visibility	<Unspecified>
		Ship breadth	Statistics (Marine Traffic Accident Library)	Mismaneuvering (per hour)	(Number of stranding in 5 years/5*365*24)/(traffic volume density*width of shallow)
		Ship size (GRT)	Statistics (Marine Traffic Accident Library)		
		Linear croos section of the obstacle	Specified location		
Pedersen	1995	Ship's type	Available accident data (Statistics)		
		Width of the waterway	<Unspecified> *(Probably from specified location)*		
		Traffic Frequency for each type of ship	<Unspecified> *(Probably from Statistics)*		
		Traffic distribution	Available accident data (Statistics)		
		Position checking	<Unspecified>		
		Distance from the obstacle to the bend	Specified location		
Simonsen	1997	Ship's type	<Unspecified> *(Probably from Statistics)*		
		Traffic Frequency for each type of ship	<Unspecified> *(Probably from Statistics)*		

		Traffic distribution	<Unspecified> *(Probably from Statistics)*		
		Position checking	Assuming to fit a Poisson distribution		
		Distance from the obstacle to the bend	<Unspecified> *(Probably from specified location)*		
Karlsson	1998	Traffic distribution	Assumed to be 98% Gausian and 2% Uniform	Human factor	Fujii, 1983
		Distance to the shoal	Specified location and also assumption	Pilot on board	<Unspecified>
Fowler & Sørgård	2000	Ship's type	Statistics (COAST), Expert judgment	Incapacitation error	Statistics or expert judgment
		Width of the waterway	Specified Location	Human performance error	Statistics or expert judgment
		Traffic Frequency	Statistics (COAST)	Internal vigilance	Statistics or expert judgment
		Ship's size	Statistics (COAST), Expert judgment	External vigilance (VTS)	Statistics or expert judgment
		Ship's speed	Statistics (COAST), Expert judgment (average for each type)		
		Drift speed	Modeling		
		Location and effect of VTS	External operational data! (specified case and assumption)		
		Depth of the channel	Specified Location		
		Location of coastline	Specified Location (Digitial Chart of the World)		
		Frequency of being in critical situation	FTA, Interview and Expert judgment, DNV report		
		Visibility	Statistics (DAMA,LMIS), Assumption (more than 4 km is good)		
		Frequency of propulsion breakdown	FTA, Interview and Expert judgment, DNV report		
		Wind Speed	Fuzzy modeling (Calm, Fresh, Gale, Storm)		
		Self repairing	Developed distribution function (MTTR)		
		Tug Assistance, performance, availability	External operational data! (specified case and assumption)		
		Anchoring	Specified Location and also Wind		

			speed		
Otto et al.	2002	Traffic Intensity	Subjective	Visibility (Rain and Fog)	Statistics (BN)
		Linear croos section of the obstacle	Assumed (an example)	Daylight	Statistics (BN)
		Width of the waterway	Assumed (an example)	Weather	Statistics (BN)
		Ship's type	Subjective	Manoeuvering Time	Subjective
		Ship's speed	Mathematically !	Visual Distance	Subjective
				Training of the officer of the watch	Statistics (BN)
				Stress Level	Subjective
				Officer of the Watch (OOW) task	Subjective
				Alarm Transfer	Statistics (BN) and Specified Subject
				Looking frequency	Subjective
				Radar Status	Statistics (BN)
				Radar Distance	Subjective
				Radar Frequency	Subjective
				OOW visual	Mathematically !
				OOW Radar !	Mathematically !
				OOW acts	Mathematically !
				Time for Visual !	Mathematically !
				Visual Time !	Mathematically !
				Time for Radar !	Mathematically !
				Radar Time !	Mathematically !
				Omission of position checking	Taken as P=0.01
Kristiansen	2005	Ship's breadth	<Unspecified>		
		cross section of the obstacle	<Unspecified>		
		Width of the waterway	<Unspecified>		
		Length of the waterway	<Unspecified>		
Ramboll Danmark	2006	Ship's type	AIS or other databases like Lloyds (Statistics)	Pilot on board	Registrations belong to Danish and Swedish Authorities
		Ship's speed	AIS or other databases like Lloyds (Statistics)		

		Ship's breadth	AIS or other databases like Lloyds (Statistics)		
		Ship's length	AIS or other databases like Lloyds (Statistics)		
		Traffic distribution	AIS and Observation (Comparison)		
		Linear croos section of the obstacle	Specified location		
		Ship's draught	AIS or other databases like Lloyds (Statistics)		
		Depth of the channel	Specified route		
		Distance from the obstacle to the bend	Specified location		
Gucma	2006	Traffic distribution	Estimated statistical distribution	Human Factor	Real time simulation
		Ship's speed	Estimated statistical distribution		
		Ship's course	Estimated statistical distribution		
		Width of the waterway	<Unespesified> *(Probably specified location)*		
Quy et al.	2007	Width of the waterway	Subjective (Specified Location)	Environmental Conditions Frequency	Statictical Data + A linear programming method by Brigges et al. (2003) (The environmental conditions as external forces and moments exerting on the ship, The ship is navigable only if the force is less than 2000 kN or the moment is less than 180000 kN.m)
		Ship's breadth	<Unspecified> *(Probably the Statistical Data)*	Ship's Maneuverability	Judgment (Fuzzy method)
		Traffic distribution	<Unspecified> *(Probably the Statistical Data)*		

Table. 10 The sources and databases for factors affecting grounding models (Mazaheri 2009)

Name	**Provider**	**Reference**	**Who did use it?**
Japan Marine Traffic Accident Library	*<Unknown>*	*<Unknown>*	Fujii
COAST	Dovre Safetec	Dovre Safetec, "Shipping Pattern Data for SAFECO", Technical Nte Ref.No. DST-98-CR-052, Aberdeen,UK (1998)	Fowler & Sørgård
LMIS (Lioyds Maritime Information System)	Lloyds	Lioyd's Maritime Information Services, Ships Editorial-Casualty System Guide (Maritime Information Publishing Group, 1995) T.Fowler and E. Sørgård, "Demonstration of Risk Assessment Techniques for Ship Transportation in European Waters", SAFECO WP III.1.2-3, Technical Report No.98-2021,Det Norske Veritas, Høvik, Norway (1998)	Fowler & Sørgård
DAMA	*<Unknown> (Probably Norwegian Authorities)*	M.O.Kristoffersen and I. Monnier, "Statistical Analysis of Ship Incidents", SAFECO WP III.2, DNV Technical Report No. 97-2039, Det Norske Veritas, Høvik, Norway (1997) H. Moen and L. Hansson, "Fire and Explosion", SAFECO WP II.6, Marintek Report No. 002517, Marintek, Trondheim, Norway (1998) E.A.Dahle, T. Fowler, M.Hauso and L.Kristoffersen, "Risk Assessment Methodology", SAFECO WP III.1, DNV Report No. LAKR/97 AAACUI, Det Norske Veritas, Høvik, Norway (1997)	Fowler & Sørgård
Digital Chart of the World	*<Unknown> (Probably available via WWW)*	Digital Chart of the World, Defense Mapping Area, United States of America, Fairfax, VA (July 1992)	Fowler & Sørgård
MTTR (is not a database, it is a function=Mean Time To Repair)		T.Fowler and E. Sørgård, "Demonstration of Risk Assessment Techniques for Ship Transportation in European Waters", SAFECO WP III.1.2-3, Technical Report No.98-2021,Det Norske Veritas, Høvik, Norway (1998) E.Kiær and L.Hansson, "Identified Critical Functions and Planning for Reliability", SAFECO WP II.6, DNV Report No.97-0276, Det Norske Veritas and Marintek, Norway, 1997	Fowler & Sørgård

Table. 11 Factors affecting causation probability applied in collision and grounding models (Det Norske Veritas 2003)

Node	States	Possible sources for probability values
Able to radar detection	Yes No	Literature, expert elicitation, bridge simulator
Able to visual detection	Yes No	Literature, expert elicitation, bridge simulator
Action	Correct Wrong	Literature, expert elicitation, bridge simulator
AIS detection	Yes No	Literature, expert elicitation, bridge simulator
AIS other ship	Function Not function Not installed	Technical reliability records
AIS own ship	Function Not function Not installed	Technical reliability records
AIS signal on radar screen	Yes No	Literature, expert elicitation
Assessment	Correct Wrong No assessment	Literature, expert elicitation, bridge simulator
Attention	High attention Low attention Not able to pay attention	Literature, expert elicitation, bridge simulator
Bridge design	Standard Beyond standard Sub-standard	Literature, expert elicitation
Bridge view	Good Standard	Literature, expert elicitation
BRM	BRM system exists No BRM system	Literature, expert elicitation
Collision	Yes No	*joins two nodes, only logical prob. input*
Collision avoidance alarms	Yes No No, not used	Literature, expert elicitation
Communication level	Beyond standard Standard Substandard	Literature, expert elicitation
Communication with	Yes	Literature, expert elicitation

other vessel	No	
Competence	Excellent Standard Low	Literature, expert elicitation
Daylight	Day Night	AIS+sunrise/sunset times at locations at 15.3. and 15.7.
Detection	Yes No	*joins two nodes, only logical prob. input*
Distraction level	Low Moderate High	Literature, expert elicitation
Duties	Normal High Extreme	Literature, expert elicitation
Familiarisation	Familiar Quite familiar Not familiar	Literature, expert elicitation
Give way	Own ship changes course Other ship changes course Neither ship changes course Both ships change course	Literature, expert elicitation
Give way situation	Meeting, supposed to give way Crossing, supposed to give way Crossing, not supposed to give way	meeting situations in the studied locations
Incapacitated	Capable Reduced capability Incapable	Literature, expert elicitation
Internal vigilance	Yes No	*joins three nodes, only logical prob. input*
Location	Helsinki-Tallinna crossing Tallinn Kotka Sköldvik Sommers Primorsk StPetersburg_headon Kotka_headon Vyborg_headon	*variable used for calculating the probabilities in a certain location (that state is set to 1)*

Loss of control	Loss of control No loss of control	*joins two nodes, only logical prob. input*
Maintenance routines	Followed Not followed	Literature, expert elicitation
Navigational aids in use	More time to detection Not more time to detection	Literature, expert elicitation
Navigation system detection	Yes No	Literature, expert elicitation, bridge simulator
Officer no2 vigilance	Able to correct Not able to correct Not present	Literature, expert elicitation, bridge simulator
Other internal vigilance	Able to correct Not able to correct No other vigilance	Literature, expert elicitation, bridge simulator
Other distractions	Few Many	Literature, expert elicitation
Other ship size	<100 100-200 >200	AIS
Other ship type	Passenger vessel HSC Cargo ship Tanker Other ship	AIS
Own ship type	Passenger vessel HSC Cargo ship Tanker Other ship	AIS
Performance	Excellent Standard Poor Not able to perform	Literature, expert elicitation
Personal condition	Fit Unfit Not able to perform	Literature, expert elicitation
Pilot vigilance	Able to correct Not able to correct No pilot	Literature, expert elicitation
Radar detection	Yes No	Literature, expert elicitation, bridge simulator

Radar function	Yes No	Technical reliability records
Radar tuning	Adjusted to conditions Not adjusted to conditions	Literature, expert elicitation
Safety culture	own ship type	Technical reliability records
Signal quality	Good Poor	Literature, expert elicitation
Steering failure	Function Not function	Technical reliability records
Stress level	High Standard	Literature, expert elicitation, simulator studies
Task responsibilities	Clear responsibilities Unclear responsibilities	Literature, expert elicitation
Time of year	Summer Winter	*variable used for calculating the probabilities at summer or winter (that state is set to 1)*
Tired	Yes No	Literature, expert elicitation
Vigilance	Yes No	*joins three nodes, only logical prob. input*
Visibility	> 1 nm < 1 nm	Literature, expert elicitation
Visual detection	Yes No	Literature, expert elicitation, simulator studies
VTS	Yes No	Assumption: VTS is present in all locations
VTS vigilance	Yes No	Literature, expert elicitation
Weather	Good Storm/rain Windy Fog	Weather statistics

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