



TRAINMOS II



Safety and energy efficient marine operations

Risk analysis of Passenger Ships

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FSA of Passenger ships

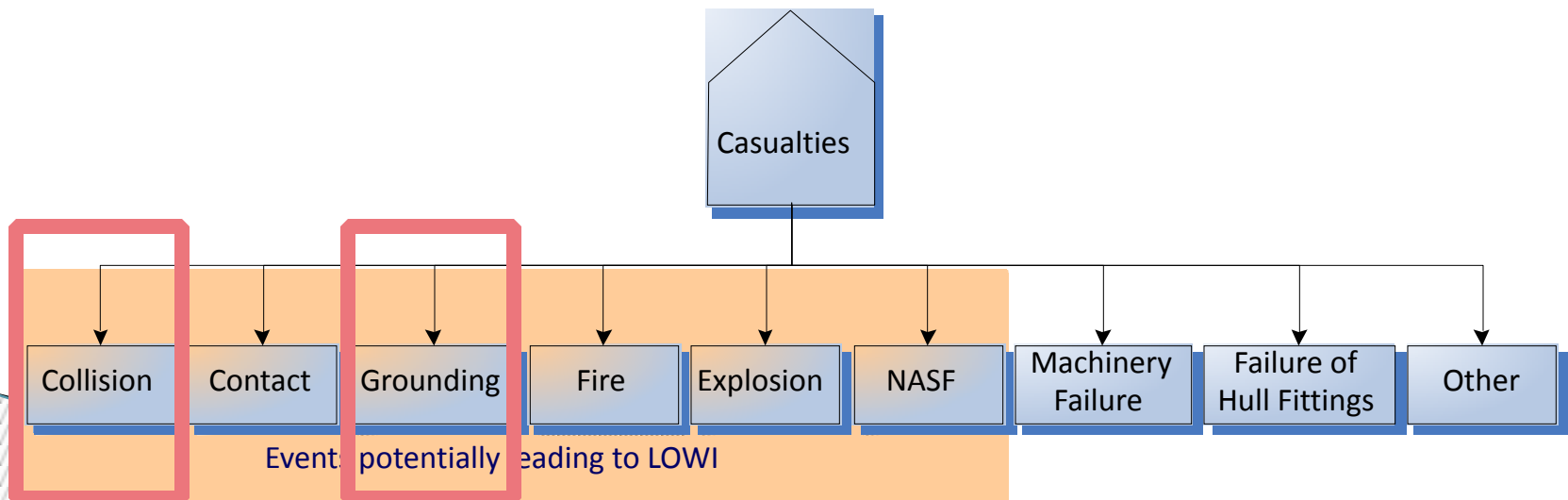
- ▶ First FSA studies concerned mainly the time period 1990 (or 1993) to 2004, depending on the availability of data, performed within EU funded project SAFEDOR (2005-2009).
- ▶ For some ship types, it was considered necessary to update the historical analysis of casualty data and consequently the risk assessment of particular FSA study.
- ▶ Focusing on the passenger ships, two sequential thorough re-investigations were done through the EU funded project GOALDS (Papanikolaou et al. 2013) and the EMSA III project (Pagiaziti et al. 2015).



GOALDS - Initiating Events

GOALDS is focusing on the probabilistic damage stability regulatory framework (*ship safety against side collision*), thus the particular investigation considers only accident categories of **collision (CN) type** and not all high level events that may potentially lead to LOss Of Watertight Integrity (LOWI).

Since, one of the main objectives of the GOALDS project is the additional consideration of grounding events, this should also within the pre-mentioned framework and **grounding events (GR)** were also analysed.





Accidents in post-2000

In the post-2000, six accidents have been recorded, resulting to the total loss of passenger ship following a contact or a grounding accident:

- ▶ **Express Samina** (RoPax, 2000): contact with the rocky islet (Greece, Paros) resulting to three raking damages below and above WL. The vessel sunk within half an hour leading to death 80 passengers and crewmembers.
- ▶ **Sea Diamond** (Passenger ship, 2007): ran aground on a volcano reef (Greece Santorini). Ship lost the watertight integrity resulting to ship's listing up to 12 degrees. Ship was sunk after 27 hours , leaving 2 passengers missing.



Accidents in post-2000

- ▶ **Explorer** (Passenger, 2007): sank in a position 25 miles southeast of King George Island. All POB abandoned the ship. The ship sank after striking ice and sustained damage to the hull.
- ▶ **Princess of the Stars** (RoPax, 2008): vessel was en-route when encountered the winds & waves of Typhoon “Fengshen”. Vessel sustained engine failure and stranding (drift grounding). Finally capsized with 523 reported fatalities and 308 missing persons.



Accidents in post-2000

- ▶ **Ariake** (RoPax, 2009): travelling from Tokyo in high winds developed a 22 degree list due to a large scale cargo shift. Vessel ran aground and capsized at Mihama. All POB safely rescued.
- ▶ **Costa Concordia** (Cruise, 2012): struck submerged rock (Italy), sustained severe damage, took water and partly capsized. 32 lives were lost in the accident.

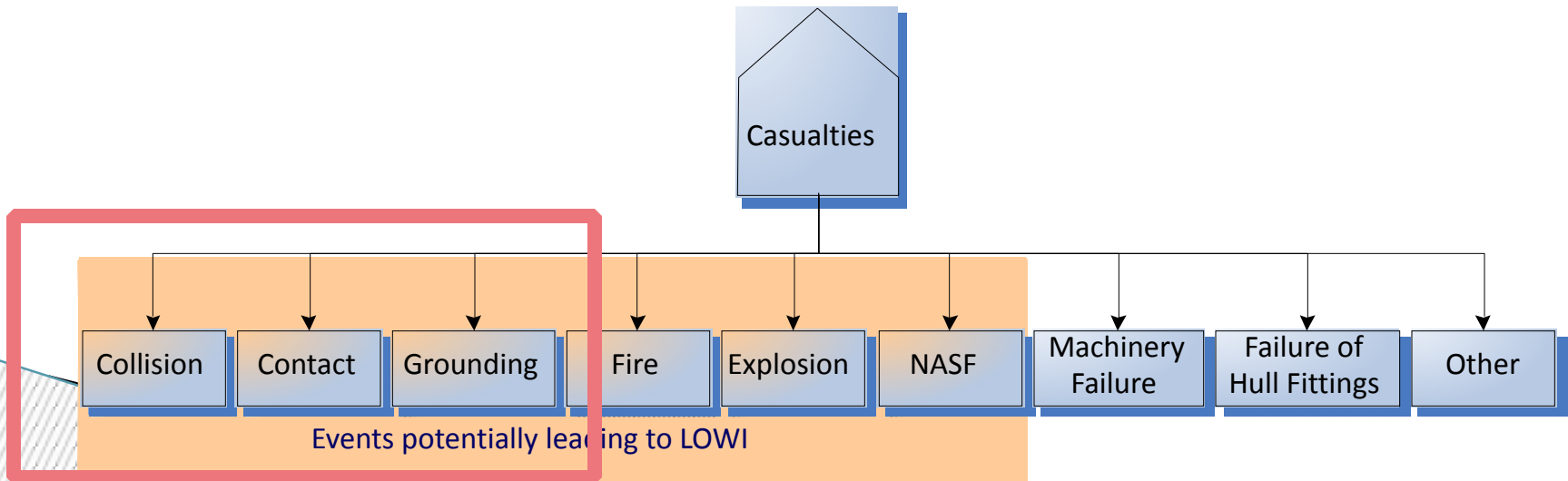


EMSA Study-Initiating Events

Considering the importance of grounding accidents,

A research project was assigned recently by EMSA (**EMSA III**) aiming to assess the risk level of passenger ships related to damage stability.

One of the main objectives of this study is to evaluate the risk from grounding accidents, with emphasis on side-raking damages (in view of the accident of the cruise ship *Costa Concordia* in January 2102) and to propose possible amendments to the regulatory framework.





Ship subtypes

IHS database

Ship type	Level5Decode	Description	IHS StatCode
Ro-Pax	Passenger/Ro-Ro Ship (Vehicles)	A ro-ro cargo ship with accommodation for more than 12 passengers	A36A2PR
Ro-Pax-Rail	Passenger/Ro-Ro Ship (Vehicles/Rail)	A ro-ro cargo ship for the additional carriage of rail-vehicles and with accommodation for more than 12 passengers	A36A2PT
Cruise	Passenger/Cruise	A vessel certificated to carry more than 12 passengers, all of whom may be accommodated in cabins	A37A2PC
Pax	Passenger Ship	A vessel certificated to carry more than 12 passengers, some of whom may be accommodated in cabins	A37B2PS



Fleet at risk & Casualty Records

- ▶ Source: IHS Fairplay

- ▶ Selection criteria:
 - Ship types: RoPax, RoPax-Rail, Cruise and Pax
 - GT \geq 1000
 - L \geq 80 m
 - Built date after 1.st Jan. 1982
 - Period 1994 to 2010 (revision of study 2000-2010)
 - IACS Class
 - to minimize the effect of under-reporting (for most ship categories accident frequency of IACS ships is higher than for other)
 - Froude No. \leq 0,5 -> filtering out all High Speed Crafts (including multi-body/catamaran vessels), the damage stability of which is determined by other provisions

- ▶ In the particular study, two ship categories were considered:
 - Cruise -> Cruise ships and Passenger ships
 - RoPax -> RoPax and RoPaxRail

NTUA-SDL Casualty database



A new casualty database was developed by NTUA-SDL in order to:

- ▶ post-process/review the available casualty reports,
- ▶ register the information of the complementary texts in a proper manner so that the information could be easily retrieved and systematically analysed with respect to risk.
- ▶ provide conditional probabilities for the event trees for collision and grounding initiating events.



Studying carefully the casualty reports, we found some inconsistencies and fixed them to the extent possible. For example:

Registered casualty type: collision, striking

C.T.: Due to bad weather conditions, the moorings were broken, ship was drifted and then collided with another ship.

It was decided to remove this case from the collision sampling plan.

▶ **Classification of serious accident: RoPax of 175 m length, collision, striking**

C.T.: The RoPax collided with an under 100 GT fishing vessel

This accident is not serious for a Ro-Pax of 175 m length which collides with a fishing vessel under 100 GT. It is a serious incident for the struck fishing vessel and not for the Ro-Pax.

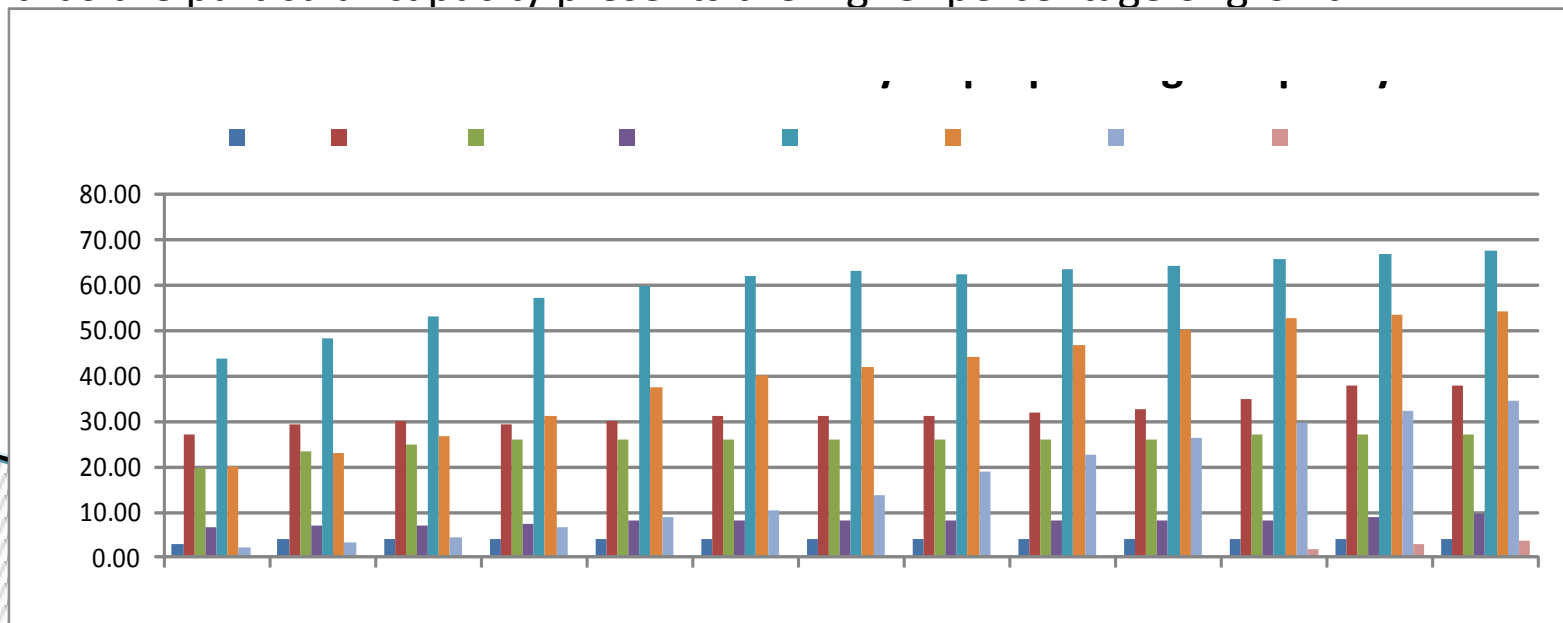
It was decided to remove this case from the collision sampling plan.



Fleet at Risk – Cruise ships

Focusing on 2000-2012, and categorising Cruise ship fleet by ship's nominal passenger capacity, the following can be observed:

- ▶ The larger part of Cruise ship fleet is coming from ships having a passenger capacity of 1,500-2,500 persons.
- ▶ Cruise ships carrying 2,500-3,500 passengers are the second largest part of Cruise operational ship fleet.
- ▶ Cruise ships with passenger capacity larger than 4,500 persons appeared after 2009 thus the particular capacity presents the higher percentage of growth.

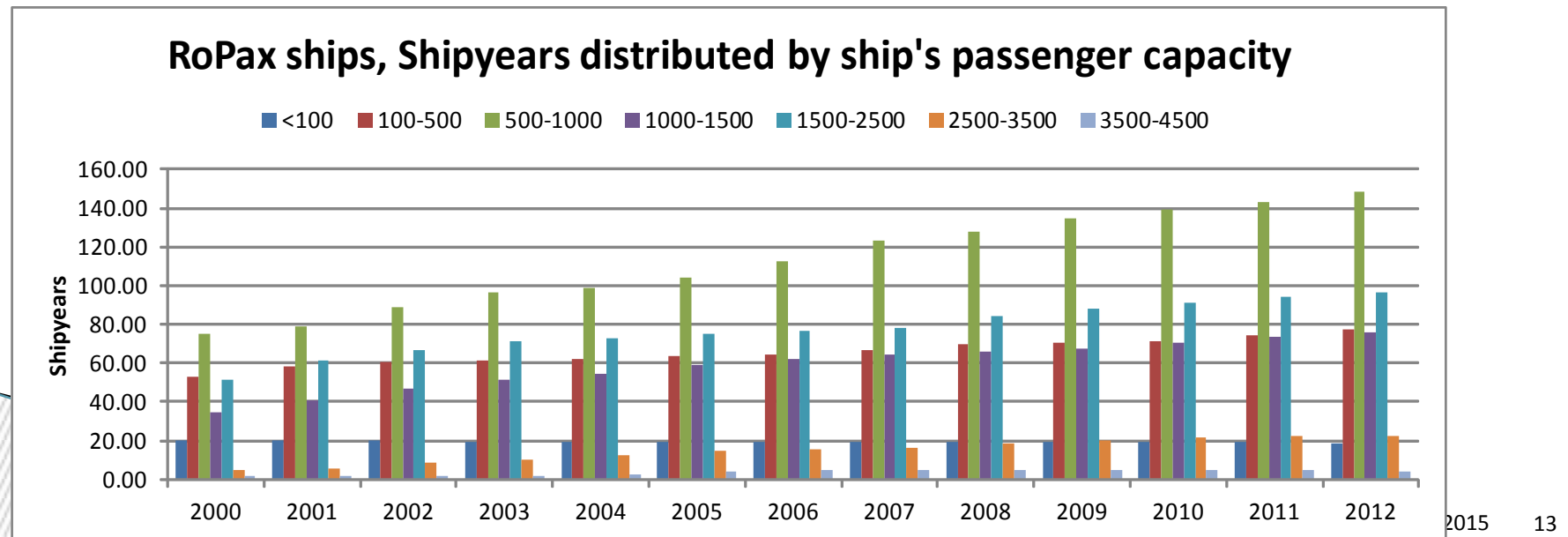




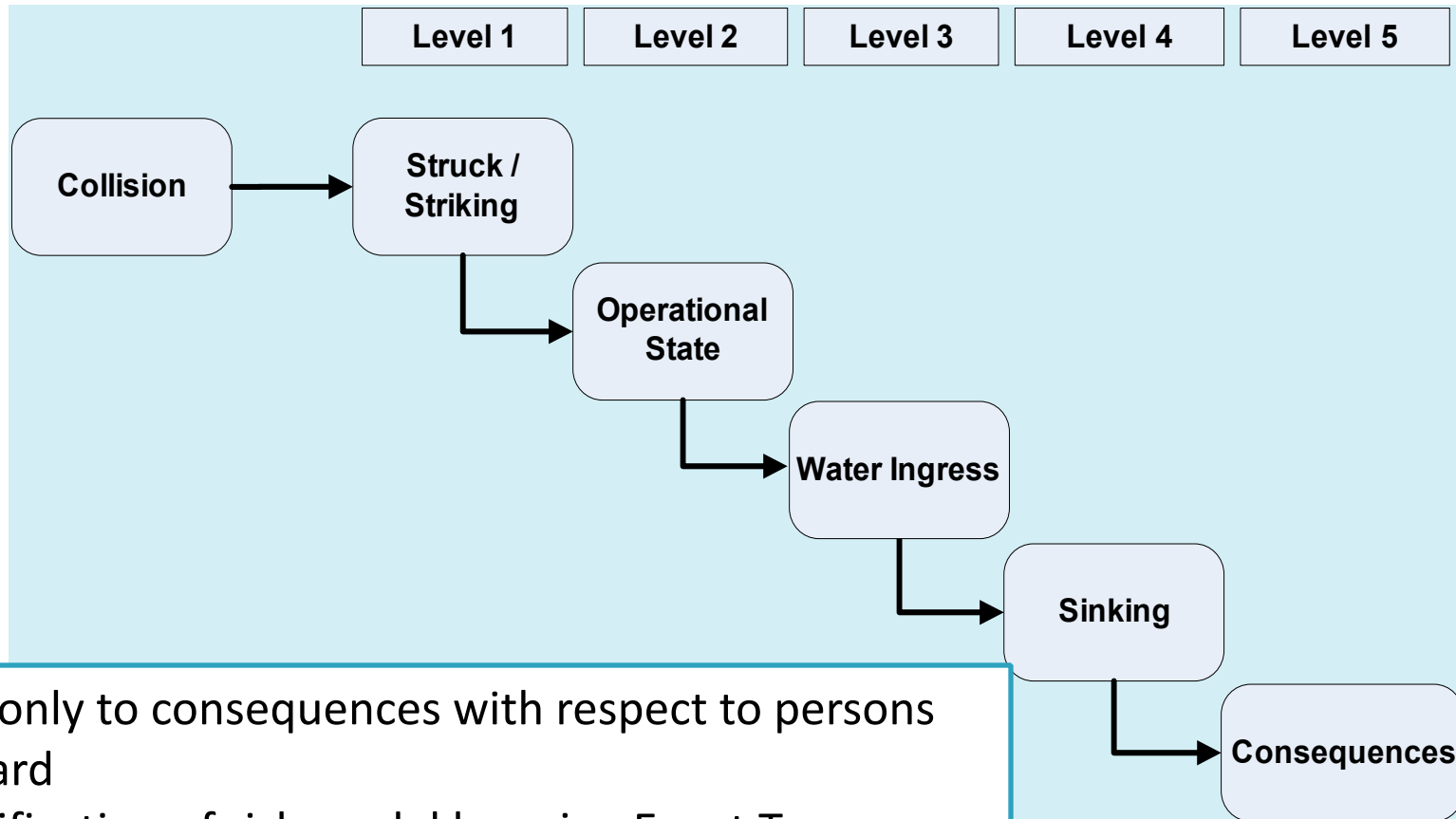
Fleet at Risk – RoPax ships

Focusing on 2000-2012, and categorising Ropax ship fleet by ship's nominal passenger capacity, the following can be observed:

- ▶ The larger part of RoPax fleet is coming from ships having a passenger capacity of 500-1,000 persons and it is continuously increasing over the years.
- ▶ RoPax ships carrying 1,000-1,500 passengers is the second larger part of RoPax operational ship fleet.
- ▶ Growth rates vary up to 10% after year 2005 with respect to the ships up to 2,500 passengers.
- ▶ In annual base, the largest number of passengers is carried by RoPax ships with passenger capacity in the range of 1,500-2,500.



Collision: High level event sequence



Focus only to consequences with respect to persons on board

Quantification of risk model by using Event Tree method

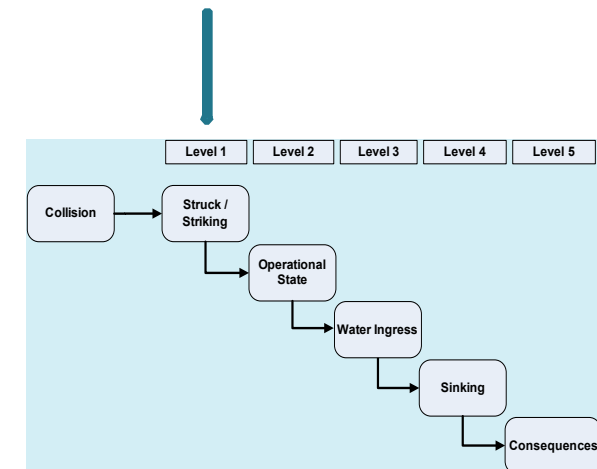
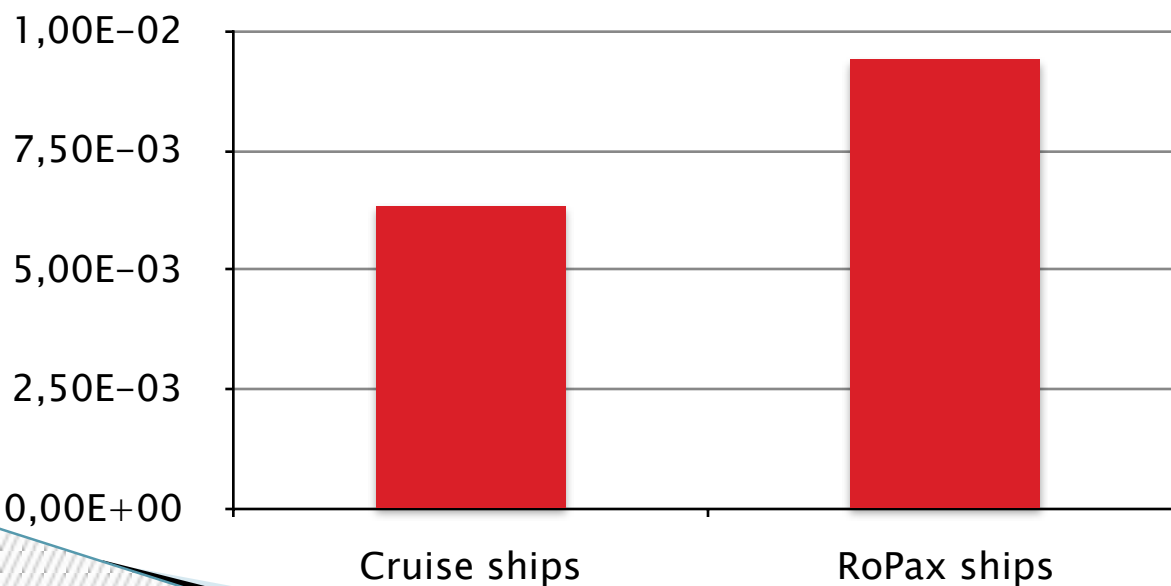
Two risk model were developed:

- Cruise and pure passenger ship
- RoPax and RoPaxRail



Initial frequencies

	Collision initial frequency
<i>Cruise ships</i>	$6.36E-03$
<i>RoPax ships</i>	$9.38E-03$





Quantification of risk model

- ▶ On average **struck/striking** probability is about 50% (struck: 43% cruise, 58% RoPax)

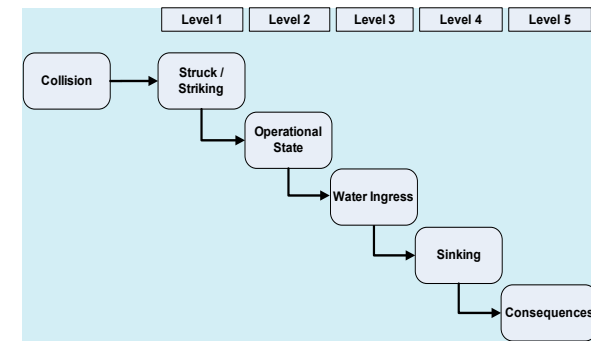
Collision damage stability risk is only relevant when ship was struck
Same probability for Cruise & RoPax



Operational area

In order to adequately consider this two operational areas were distinguished

- Terminal with typical low speed operation and ships berthed
- All other areas (Extend of hull damage heavily relates to impact energy which depends on ship speed and mass)



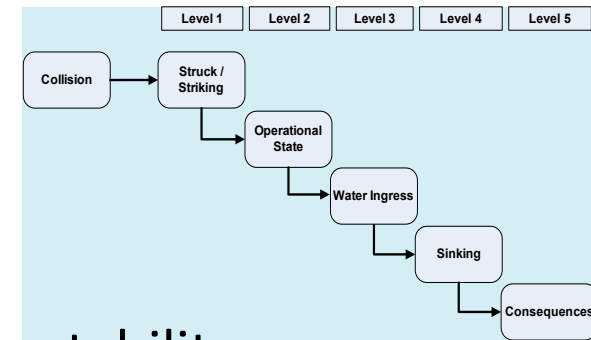


Quantification of risk model

Water ingress

- Probability of water ingress is one third in all areas and about 7% in terminal areas

Same probability for Cruise & RoPax



Probability of sinking

Is determined on basis of SOLAS 2009 damage stability requirements.

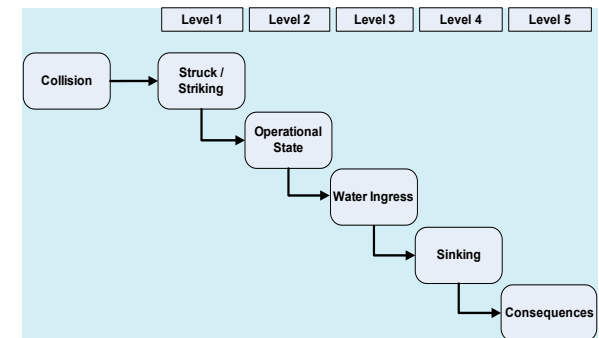
Probability of sinking equal to 1 minus attained index (A-Index).



Quantification of risk model

Consequences

- Related to persons on board
- Two representative fatality rates used for the scenarios
 - Fast sinking/capsizing 80% of persons on board
 - Slow sinking 5% of persons on board
 - For sinking in terminal areas only 5% fatality rate used for all scenarios





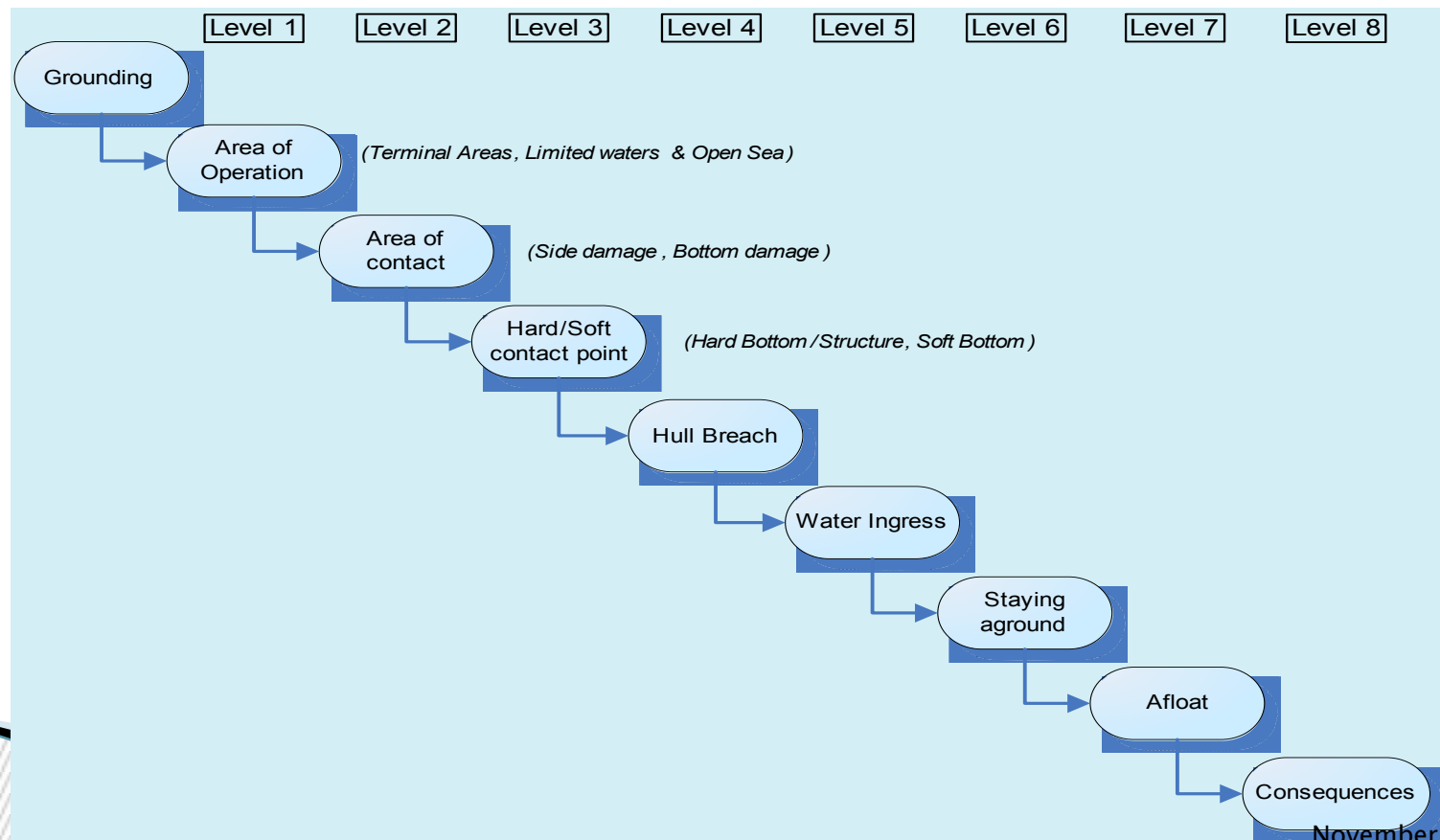
General conclusions

- ▶ Risk analyses on cruise ships demonstrated impressively that collision and grounding accidents are major risk contributors.
- ▶ This risk mainly caused by water ingress after collision and grounding



Grounding risk model

The same structure of risk model for grounding accidents is used for both types of ships, RoPax and cruise ships





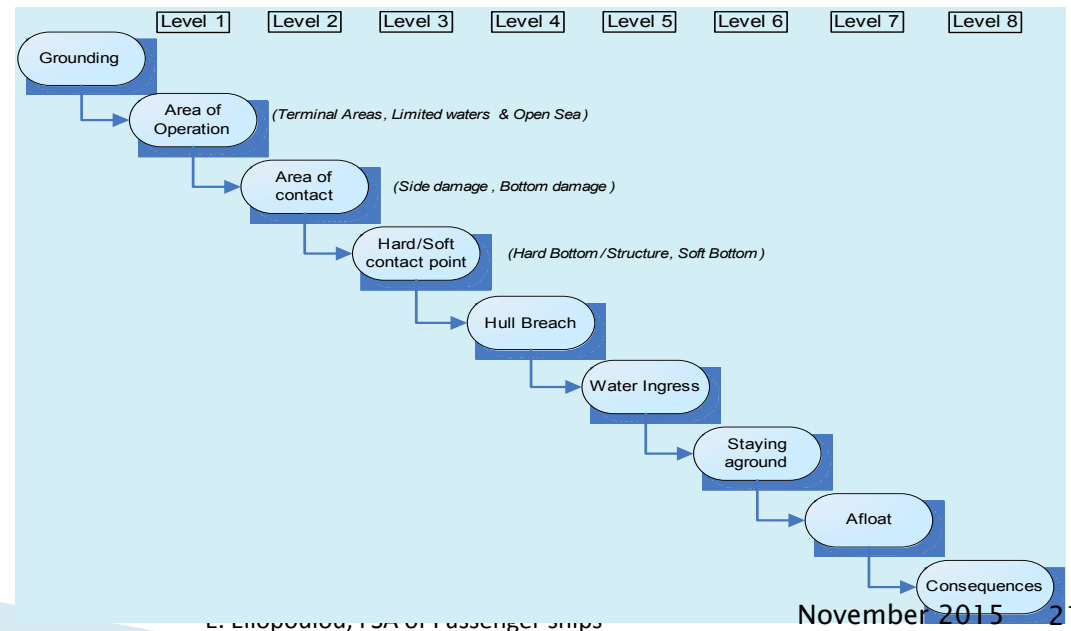
Grounding risk model

The same risk model for grounding accidents is used for both types of ships, RoPax and cruise ships with the following two differences:

- ▶ Initial accident frequencies are determined separately for each ship type.
- ▶ The probability of fast sinking is set equal to 18% for cruise ships and 50% for RoPax ships.

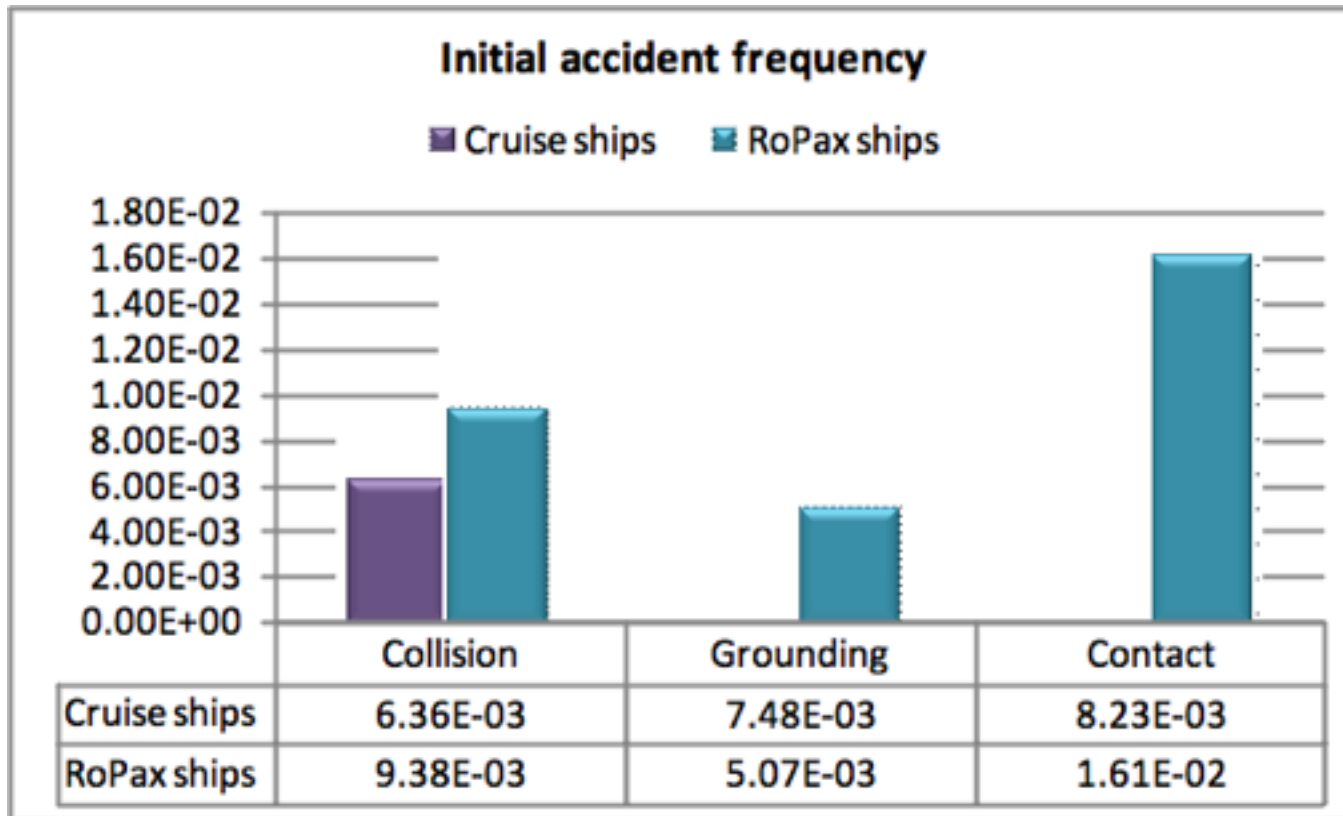
Regarding the consequences, the followings has been considered with respect to ship sinking or capsizing and the number of expected fatalities:

- 80% of POB (Persons on Board) fatalities in case of fast sinking/capsizing in limited waters or in the open sea;
- 5% of POB fatalities in case of slow sinking/capsizing, or in case the accident takes place in terminal areas.





Initial accident frequency

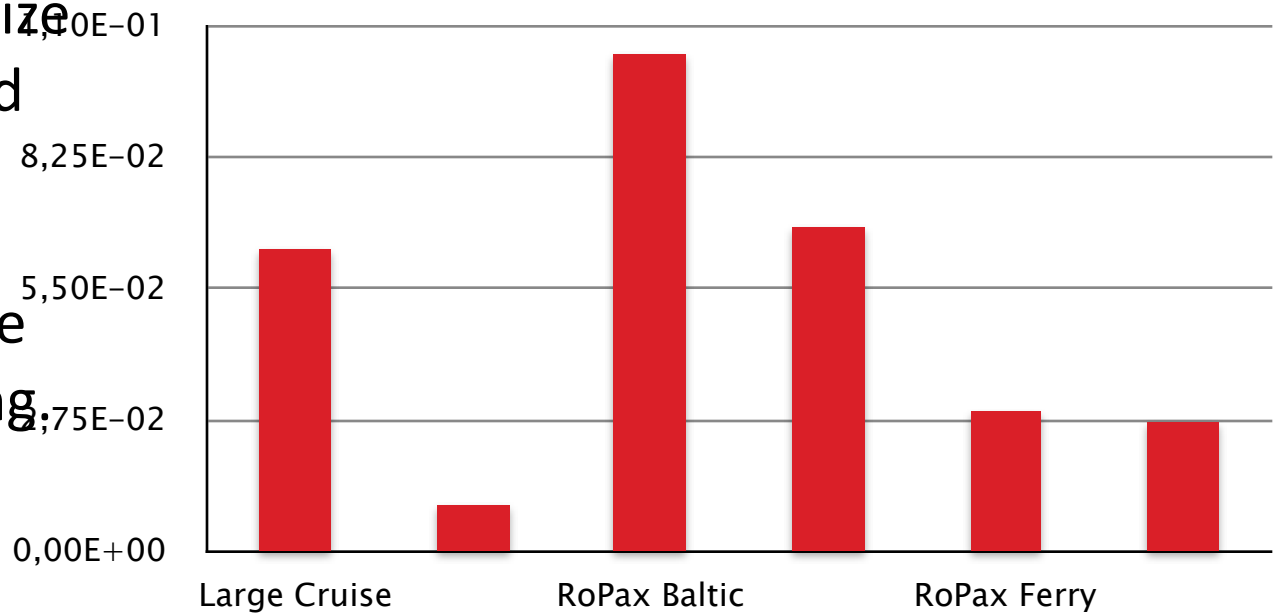




Collision risk

Risk in terms of PLL increased with number of persons on board which is quite obvious because the risk model considers the ship size only via the attained index and corresponding POB when estimating the probability of sinking

Ship type and Size	PLL	POB
Large Cruise	6.32E-02	6730
Small Cruise	9.67E-03	478
RoPax Baltic	1.04E-01	3280
RoPax Med	6.80E-02	1700
RoPax Ferry	2.95E-02	625





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Thank you for your kind
attention!

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