SafePASS

Next generation of life Saving appliances and systems for Safe and swift evacuation operations on high capacity PASSenger ships in extreme scenarios and conditions

EU Call MG-2-2-2018 Marine Accident Response
EU Grant No. 815146

SafePASS Risk Model

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Submission Date:	

Acronyms and Abbreviations

DWT	Deadweight Tonnage
EMCIP	European Marine Casualty Information Platform
EMSA	European Maritime Safety Agency
ET	Event Tree
GISIS	Global Integrated Shipping Information System
HSCs	High-speed Crafts
IHS	Information Handling Services
LSAs	Life-saving Appliances
PLL	Potential Loss of Life
POB	Persons On Board
RMT	Risk Modelling Tool
RoPAX	Roll-on Roll-off Passenger Ship
SAR	Search and Rescue
TTC	Time to Capsize
TTE	Time to Evacuate
TUC	Time to reach Untenable Conditions

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Executive Summary

This document is summarising the findings of the relevant research work conducted in the EU-funded SafePASS Project and is described in two parts.

In the first part, a brief summary introducing the new SafePASS accident database and subsequent data analysis has been presented. The presented database is a comprehensive collection of both quantitative and qualitative information of accidents related to large passenger ships (Cruise and RoPAX) collected over the last 20 years.

A significant effort in terms of time and workforce has been involved in ensuring the completeness and validation of each accident case by investigating various existing databases, reports, and other public sources. Each accident has been treated with great care to ensure that missing information has been filled as far as possible by referring to various investigation reports and databases.

All the data has been cleaned, removed duplicates, merged, filtered, and sorted into different stages based on accident type and period, ship type and size, and human casualties. Because different data sources use different approaches to store the data, a new data taxonomy has been developed characterised by a uniform format for data entry to capture all the requisite information.

In the second part, the statistical analysis of the Database is being presented, focusing on passenger evacuation (including mustering, abandonment, survival at sea and search & rescue) in extreme flooding, fire & explosion scenarios. The analysis serves as an up-to-date investigation on the frequency of grounding, collision and fire & explosion accidents on large passenger ships (Cruise and RoPaX) over the past 20 years. It provides useful insight on parameters such as the natural light, geographical location of accidents, and the number of casualties involved, which will direct the research on Risk Control Options. More importantly, though, the analysis is a step closer to quantify the risk and calculate potential fatalities on various stages of the mustering, abandonment and search and rescue.

The third part is dedicated to the SafePASS Risk Model, starting with the high-level sequence of events for emergency and abandonment. The following sections include details and examples of the influence diagrams and the last section explains the reasoning behind the gates of the SafePASS evacuation and abandonment Event Tree.

1. SafePASS Accident Database

The accident database provides the platform for any risk assessment study. The ship flooding and fire & explosion accidents are typically considered to be rare events that require in-depth data acquisition and analysis. The latest available accident database includes casualty records until 2013 developed by the eSAFE and EMSA III projects, updated from the GOALDS and HARDER projects. In addition, this database was limited to flooding accidents. With the continuous developments in ship design, size, operational procedures, safety regulations, and fleet size, the situation demands a continuous update of the accidents and a review of the past accidents to assess their cause and consequence in improving flooding, fire & explosion risk assessment and management. The following sub-sections briefly provide the details of the new SafePASS accident database.

1.1. Data Collection Process

The SafePASS Accident Database is a product of a merger of data from primarily three sources, namely Sea-web Database (owned by IHS Markit), IMO GISIS and EMSA EMCIP databases.

To validate the collated information and fill the gap in the accident cases, the investigation reports of the cases, in particular, significant interest to the scope of SafePASS were examined. In terms of accessing the accident reports of specific cases, a list of 17 different sources and accident database from SHOPERA were reviewed, in addition to the reports obtained from IMO-GISIS and EMSA-EMCIP: While recording the data, preference is given to the data in the investigation reports, if there is a discrepancy in the information recorded between the databases and reports. It is important to mention at this point that discrepancies in the accident reporting procedures in certain regions can significantly influence the statistical results. For example, European Authorities such as EMSA have dedicated and up to date platforms for reporting accidents (EMCIP) that can explain partially the relative higher number of reported accidents of certain types in these regions (e.g. refer to Figure 3).

1.2. Data Categorisation

Keeping in mind the objectives of the SafePASS project, the main inclusion criteria used are the ship type and size, accident type and period, human casualty, and severity level. Based on these criteria, the accident cases to be included in the database were obtained in two stages.

Stage 1 – Serious accidents with casualties:

At this stage, the main focus is on the accidents involving human casualties and rescue operations, considering all types of accidents. Following filters were used to extract the data:

- Ship type: RoPAX, RoPAX Rail, Cruise, and Pure Passenger
- Ship size: ≥ 3500 GT (large passenger ship)
- Accident period: 1999 to 2020 (last 20 years)
- Accident type: collision, stranded, contact, fire/explosion, foundered, and hull/machinery.
- Accident severity level: serious

- Human casualty: yes

Stage 2 – Serious accidents with no casualties:

In an effort to expand the search of accidents within the scope of the SafePASS project, stage 2 of inclusion criteria looked into 'serious' accidents that did not necessarily include human casualties. At the same time, this stage employs the same filter; however, limiting accident types and ship sizes as follows:

- Ship type: same as in stage 1
- Ship size: ≥ 3500 GT
- Accident period: 1999 to 2020
- Accident type: collision, stranded, and fire/explosion
- Accident severity level: serious
- Human casualty: no

1.3. Data Taxonomy and Organisation

Table 1 provides the details of the data taxonomy developed with a list of various data groups, data fields, and its description. The newly developed updated taxonomy is a result of the available fields followed in the various data sources (see Section 1.1).

Table 1 Details of data fields

Information Group	Data Field	Description
Event Details	**Event Date**	Date of the accident (in *DD/MM/YYYY*)
	Event Time	The local time during the accident (in *HH:MM:SS AM/PM*)
	Natural Light	A function of location, time, and date (*Daylight/Night/Twilight*)
	Accident Type	Accident type
Ship Details	**Ship Type**	Codification of the ship type
	Ship Length (L_{OA})	The overall length of the ship in [m]
	Built Year	The year of delivery of the vessel
	Flag	The flag state of the vessel during the accident
	GT	Gross Tonnage (GT) is a function of the moulded volume of all enclosed space of the ship
	DWT	The weight of cargo, stores, fuel, passengers, and crews carried by the ship when loaded to her maximum summer draught in [tonnes]

	Cargo Load Status	Loaded/Loading/ Empty/Ballast/Unknown
	Ship Detail Status	On Voyage/ Moored-Anchored/ On Trials/ Manoeuvring/ Manoeuvring without Assistance/ In Dry-floating dock/ Alongside Shore Facility
No. of people on-board	**Crew**	Number of crew on-board at the time of the accident
	Passengers	Number of passengers on-board at the time of the accident
Weather	**H_s/sea-state**	Significant wave height/sea state description based on the Douglas sea scale in [m]
	Visibility	Poor/Clear/Good/Fog/Mist/Rain/etc. in [nm]
	Wind – knot/ Beaufort scale	Wind speed/force in [knots] or Beaufort scale
Event Location	**Latitude**	The geographical coordinate of the ship at the time of the accident in DD
	Longitude	The geographical coordinate of the ship at the time of the accident in DD
	Environment	At Sea/ In Port/ En Route/ Restricted Waters/ in Shipyard-dock
	Zone	Based on the Zone definitions provided by the IHS Markit Sea-web database
Ship Casualty	**Severity**	Serious
	Total Loss	Yes/No
	Damage Component	Details on the component of the vessel that was damaged (e.g., hull structure bottom)
	Damage Position (Unknown/Whole)	Details on the specific location of the components damaged (e.g., engine room, cabin, and deck)
	Damage Position (*x*)	Longitudinal location of damage position (Stern/Aft/Amidship/Fwd/Bow)
	Damage Position (*y*)	Transverse location of damage position (Starboard/Port)
	Damage Position (*z*)	Vertical location of damage position (Above/Below the Waterline)
	External Item	External item to ship relevant to accident type e.g., Bottom of Sea/Pier/Jetty, Wreck, and Iceberg (for grounding events)
	Number of ships involved	Number of Ships involved (usually applicable for the collision accident type)

	Damage Extent (*L*)	Length of damage in [m]
	Damage Extent (*W*)	Width of damage in [m]
	Damage Extent (*D*)	The penetration depth of damage in [m]
	Damage Extent (*R*)	The radius of damage in case of a circular hole/indentation in [m]
	Casualty Action	The first action in the event e.g., collision/collision-struck by/contact-struck
Crew Casualties	**Killed**	Number of crew killed
	Injured	Number of crew injured
	Missing	Number of crew missing
Passenger Casualties	**Killed**	Number of passengers killed
	Injured	Number of passengers injured
	Missing	Number of passengers missing
People Rescued	**Crew**	Number of crew rescued
	Passengers	Number of passengers rescued
SAR Operations	**SAR intervention**	Yes/No
	Nearby vessels	Details on the number and type of nearby vessels involved in SAR
	Helicopters	Details on the number of helicopters used for SAR operation
	Event Flow	e.g., collision followed by grounding
	Safety Recommendation	
	Actions Taken	During emergency response

1.4. Data Record

Table 1 shows a summary of the total number of accidents in the database for different types of accidents recorded in stages 1 and 2.

Table 2 Number of accidents recorded per accident type

Stage	Collision	Stranded	Fire/ Explosion	Contact	Foundering	Hull/ Machinery Damage
Stage 1	20	6	57	6	2	11
Stage 2	165	144	171	-	-	-
Stage 1+2	185	150	228	-	-	-

2. Statistical Analysis

This section provides the key results, discussion and insights developed based on the detailed statistical analysis of various data collated in the SafePASS database. Accordingly, three major accident types- collision, grounding, and fire & explosion are discussed separately in the following sub-sections.

2.1. Collision

As shown in Table 2, the number of collision accidents recorded in the database are categorised based on serious accidents with and/or without casualties. Excluding high-speed crafts (HSCs), 185 serious accidents were collated. Amongst them, only 20 cases involve casualties, and the remaining 165 cases involve no casualties.

Figure 1. Breakdown of collision accidents based on ship type shows the number of accidents grouped based on the ship type. In the following discussion, pure passenger ships and cruise ships are grouped into 'Cruise', and RoPAX and RoPAX rail are combined into 'RoPAX'.

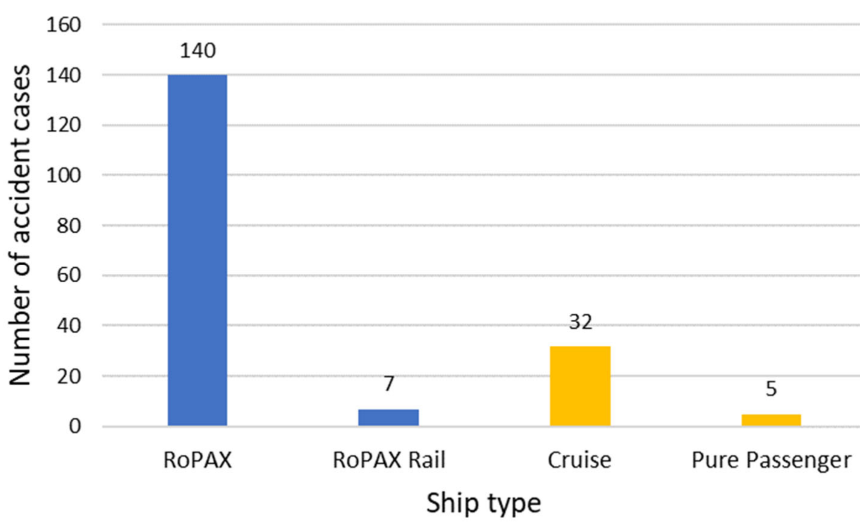
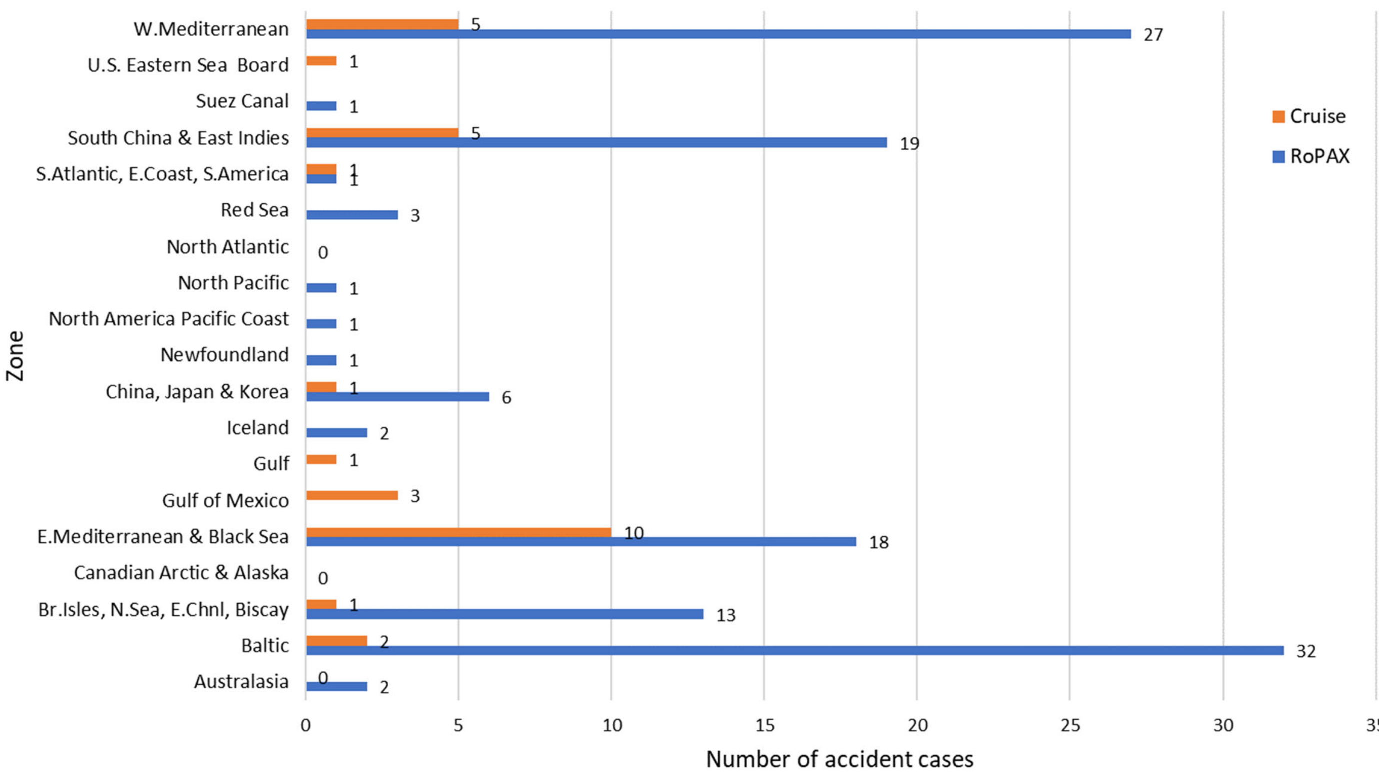


Figure 1. Breakdown of collision accidents based on ship type

Figure 2 (a) shows a holistic picture of the distribution of collision accidents around the world, including both serious accidents with and without casualties. In addition, Figure 2 (b) shows the distribution of the accident by sea zone. The majority of the reported collisions have occurred in the Baltic Sea (32) followed by Western Mediterranean (27) for RoPAX. On the other hand, the Eastern Mediterranean and Black Sea (10) is mostly prone to collisions involving Cruise ships.

(a)



(b)

Figure 2. The geographical distribution of collision accidents for RoPAX and Cruise ship: (a) worldwide and (b) Zone

Figure 3 shows the age of the ship registered at the time of the accident, where the most frequent collision accidents generally occurred with ships aged less than 40 years, regardless of the ship type. About 89% and 76% of all accidents occurred under the ship age of 35 for RoPAX and Cruise, respectively, where the maximum number of casualties has been recorded between 5 to 10-year-old RoPAX ships.

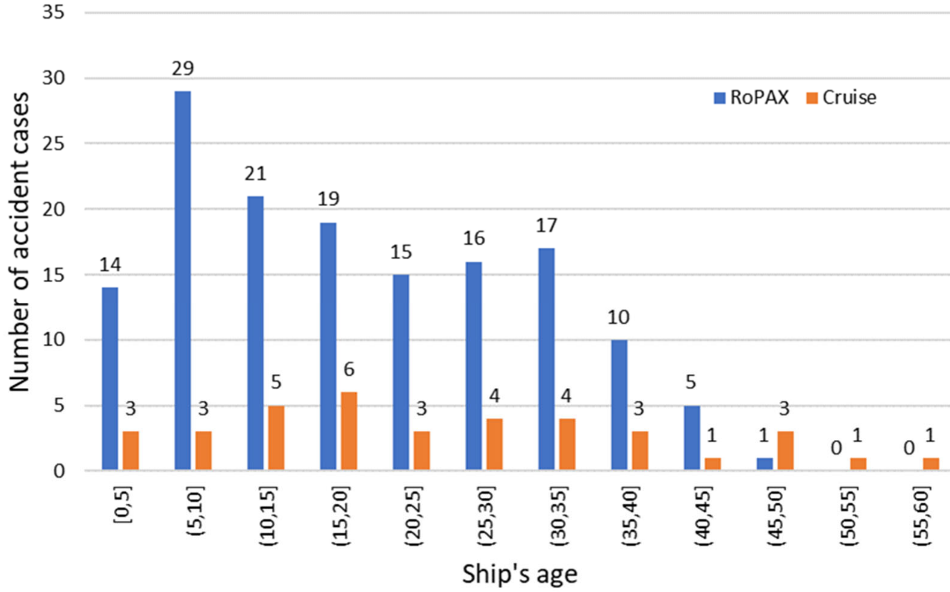


Figure 3. Distribution of the age of Cruise and RoPAX ships involved in collision accidents

Natural light at the time of accidents is an essential factor from the viewpoint of Search and Rescue (SAR) operations. In the case of the investigated collision accidents, as shown in Figure 4, the collision occurred during daylight marginally dominates the night. A similar trend can be observed for both RoPAX and Cruise ships.

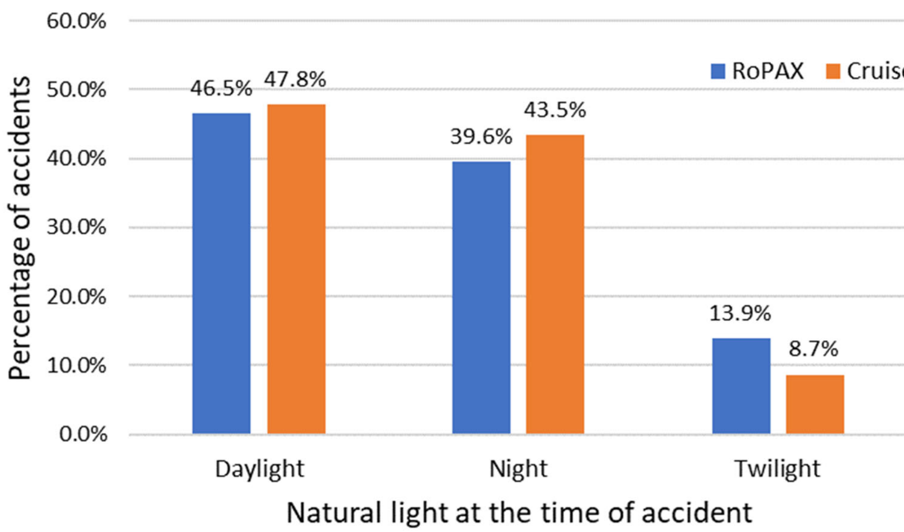
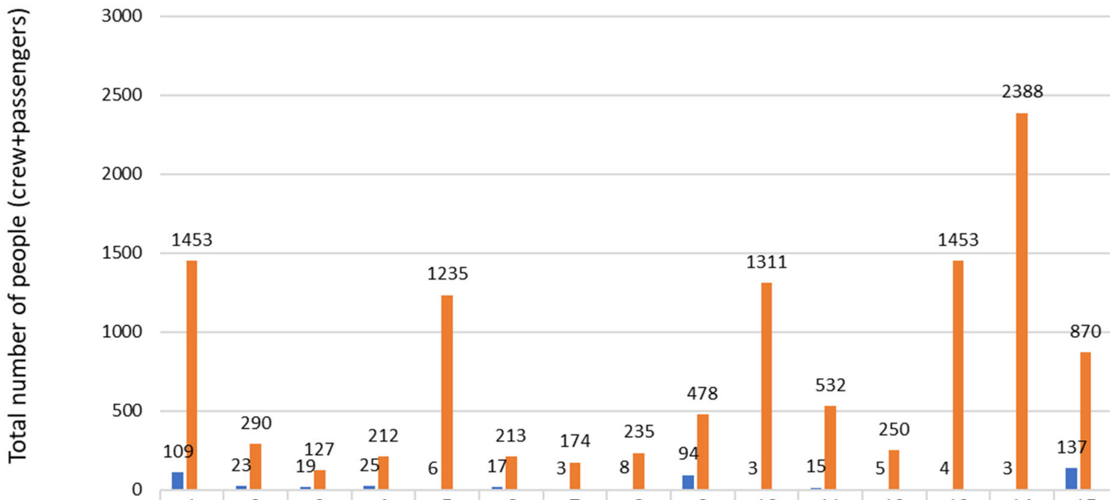


Figure 4. Distribution of natural light during the collision accidents

Figure 5 shows the total fatalities and people on board registered in the database (POB) for each of the RoPAX and Cruise ships. The fatalities include those who were killed, injured, or missing during the collision accidents. The most serious collision accident showed 15.7% of the fatality ratio, occurred on 16-08-2013 with the ship named 'St Thomas of Aquinas' where

116 people were killed, and 21 went missing out of 870 people on board (POB), which include 116 crew and 754 passengers.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fatalities	109	23	19	25	6	17	3	8	94	3	15	5	4	3	137
POB	1453	290	127	212	1235	213	174	235	478	1311	532	250	1453	2388	870
Fatality ratio	7.5%	7.9%	15.0%	11.8%	0.5%	8.0%	1.7%	3.4%	19.7%	0.2%	2.8%	2.0%	0.3%	0.1%	15.7%

Accident scenario

Figure 5. Number of fatalities and people on board (POB) recorded during collision accidents

2.2. Grounding

Similar to collision accidents, the number of grounding accidents recorded in the database is categorised based on the serious accident with and/or without casualties. A total of 151 serious accidents were collated, and amongst them, 6 cases are involved fatalities, and the remaining 145 cases recorded no fatalities. Figure 6 shows the number of grounding accidents classified according to the ship type.

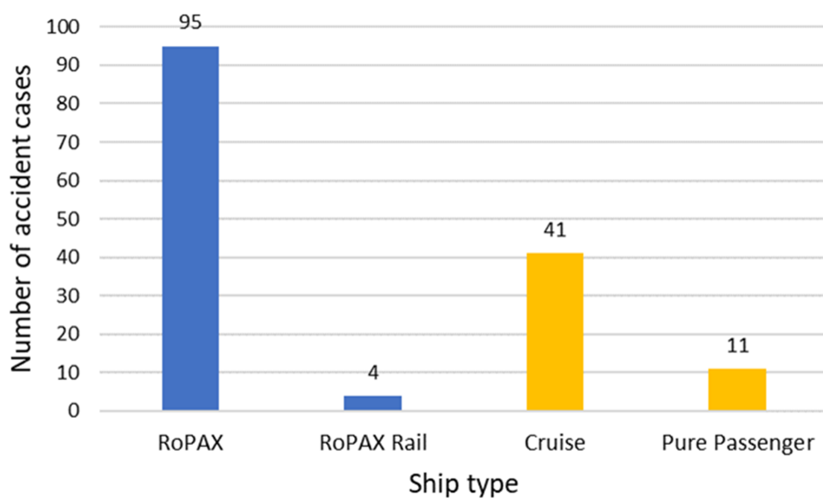


Figure 6. Breakdown of grounding accidents based on ship type

As shown in Figure 7, more than 80% of all grounding accidents occurred with the ship aged under 35, where the maximum number of casualties (17) occurred between 30 to 35 aged RoPAX ships. Again, older ships of greater than 45 years involve lesser grounding accidents.

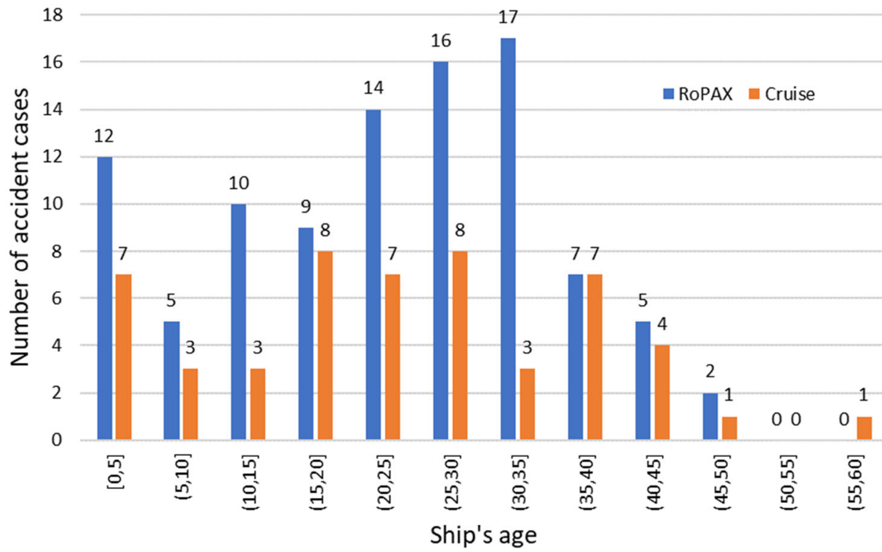
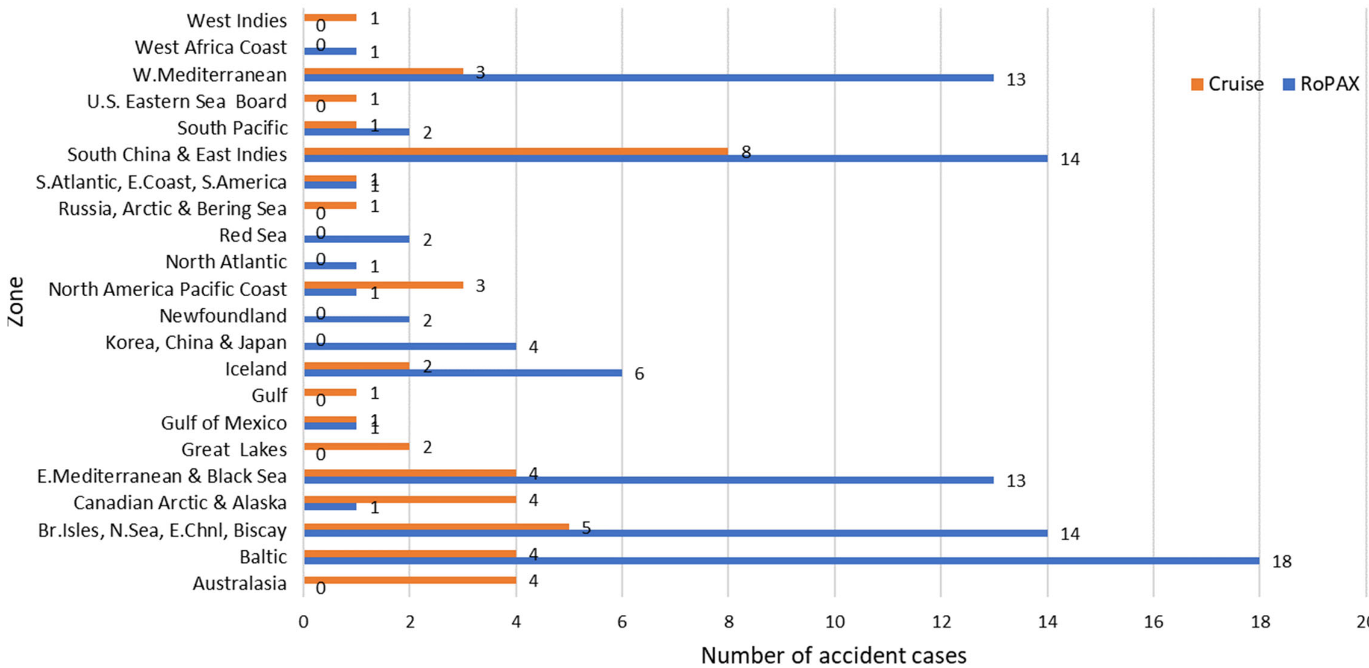


Figure 7 Distribution of the age of Cruise and RoPAX ships involved in grounding accidents

Figure 8(a*)* shows the worldwide distribution of grounding accidents, including both serious accidents with and without casualties. In addition, Figure 8(b) shows the distribution of the accident by sea zone, where the most grounding accidents are observed in the Baltic Sea (18) for RoPAX and South China & East Indies (8) for Cruise ships.

(a)



(b)

Figure 8. The geographical location of grounding accidents for RoPAX and Cruise ships: (a) worldwide and (b) Zone

The distribution of natural light at the time of grounding events is shown in Figure 9, where most of the accidents occurred during the night (50%) for RoPAX and during the daylight (44%) for Cruise. Also, there is an increased number of accident cases were reported during Twilight for Cruise ships.

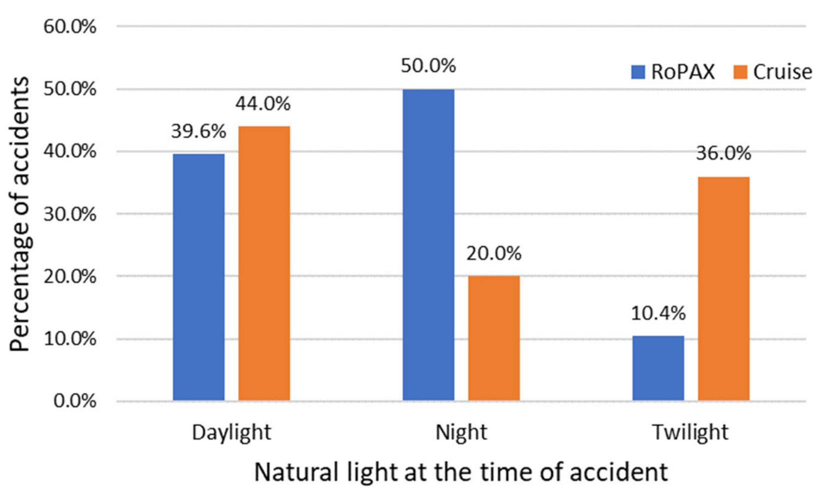
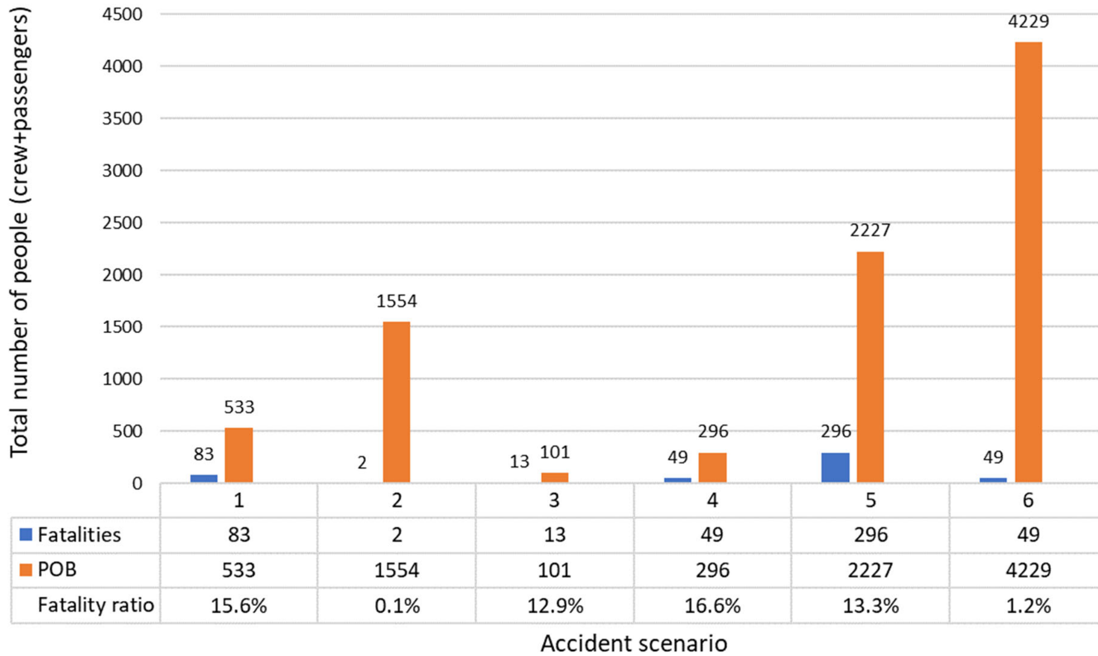


Figure 9. Distribution of natural light during the grounding accidents

Figure 10 shows the total fatalities and people on board (POB) registered in the database for each of the RoPAX and Cruise ships. The highest fatality ratio (16.6%) is associated with scenario-4, i.e., which involves 49 fatalities (30 killed, 17 injured, and two went missing cases) and 296 POB (140 crew and 156 passengers).



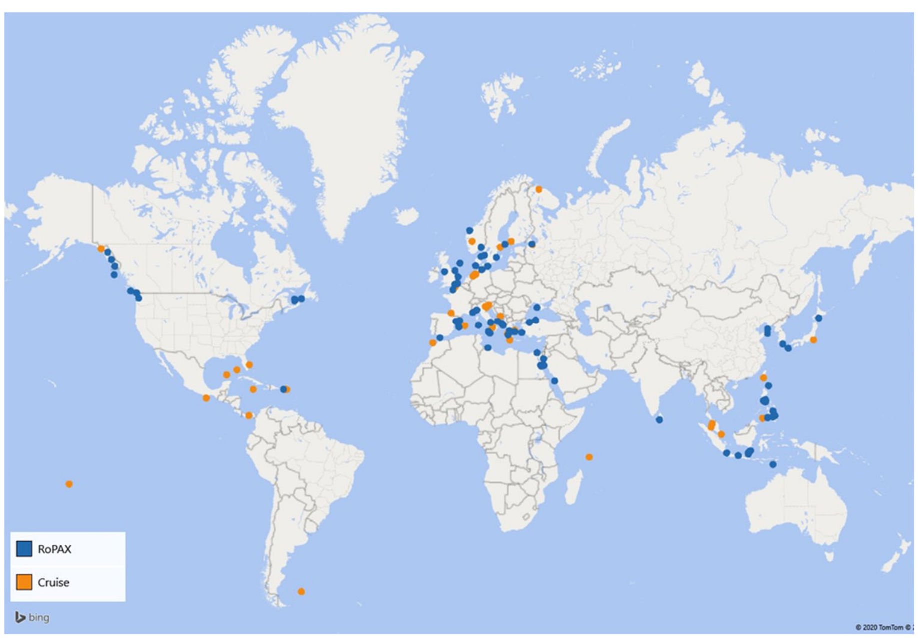
	1	2	3	4	5	6
Fatalities	83	2	13	49	296	49
POB	533	1554	101	296	2227	4229
Fatality ratio	15.6%	0.1%	12.9%	16.6%	13.3%	1.2%

Figure 10. Number of fatalities and people on board (POB) recorded during grounding accidents

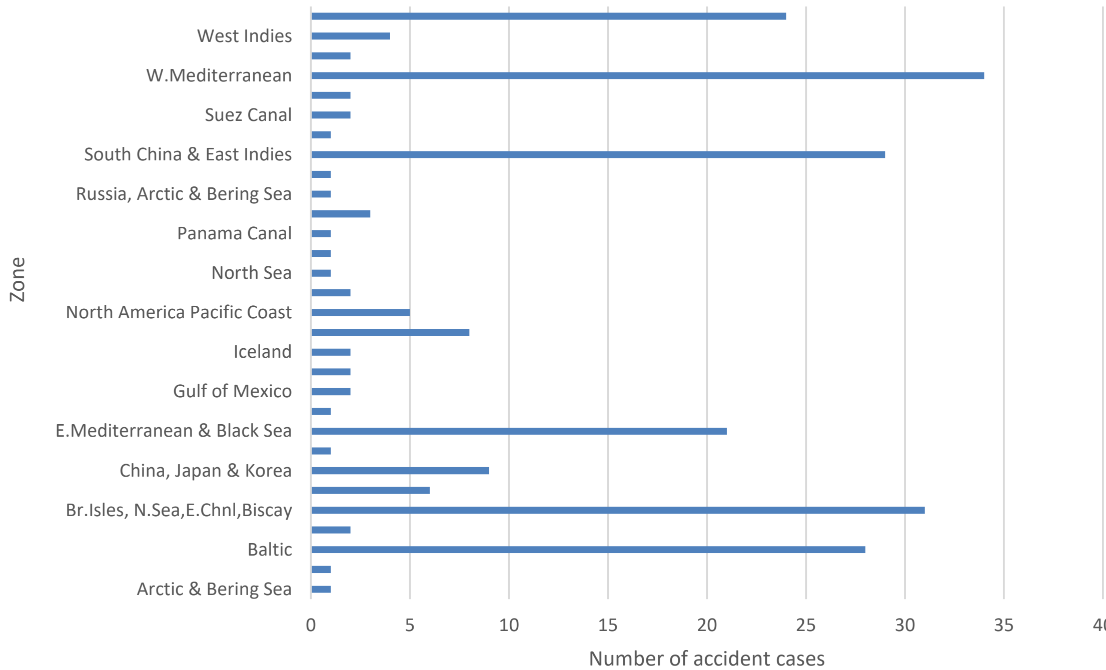
2.3. Fire & Explosion

A total of 227 serious accidents were collated in the database, and amongst them, 56 cases are involved with the casualties and the rest, 171 cases, have no casualties.

Figure 11 (a) shows the distribution of fire & explosion accidents around the world, including both serious accidents with and without casualties. In addition, Figure 11(b) shows the distribution of the accident cases by sea zone, where the maximum number of casualties has been recorded in the West Mediterranean Sea.



(a)



(b)

Figure 11. Location of fire & explosion accidents involving RoPAX and Cruise ships: (a) worldwide and (b) Zone

Figure 12 shows the number of accidents according to the ship type, where the number of accidents involving RoPAX ships is more than 3 times higher than Cruise ships. In Figure 13, the distribution of the age for these RoPax and Cruise ships involved in the accidents, is presented. It is interesting to note that for both RoPax and Cruise vessel types, the peak is observed at the range of 10 to 19 years of age.

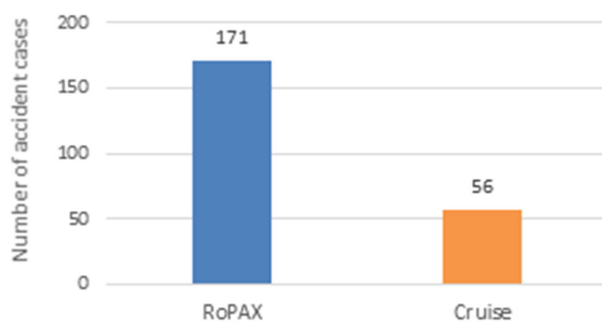


Figure 12. Breakdown of fire & explosion accident based on ship type

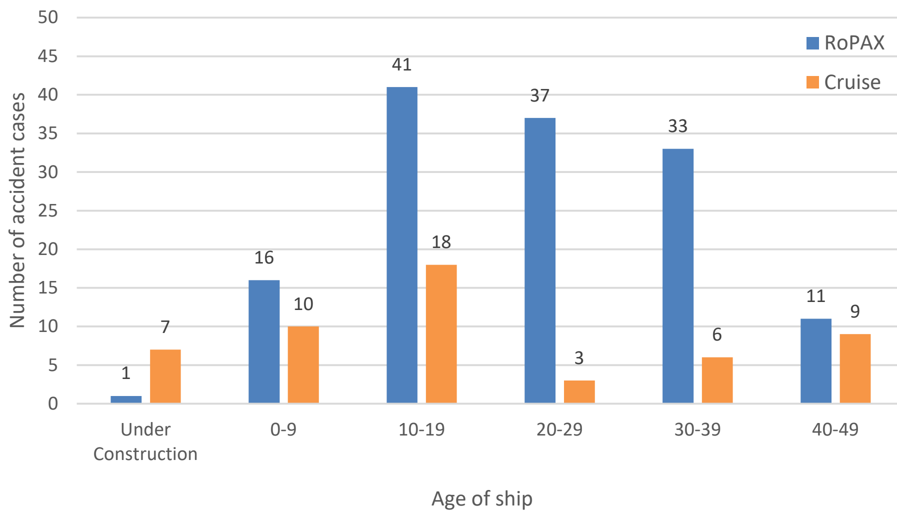


Figure 13 Distribution of the ship age of Cruise and RoPAX ships

Concerning the natural light at the time of the accident, the statistical distribution is shown in Figure 14, daylight and night accounted for the same 44%, and twilight accounted for 12%.

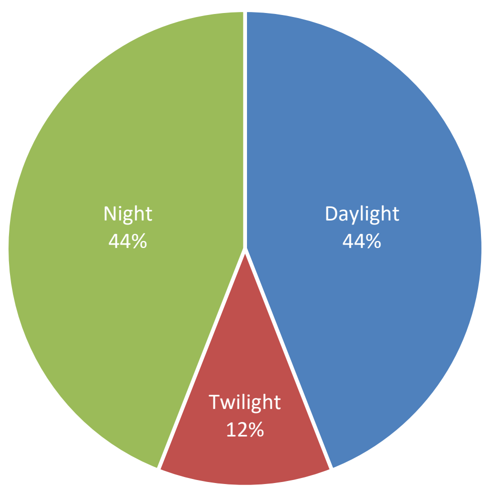
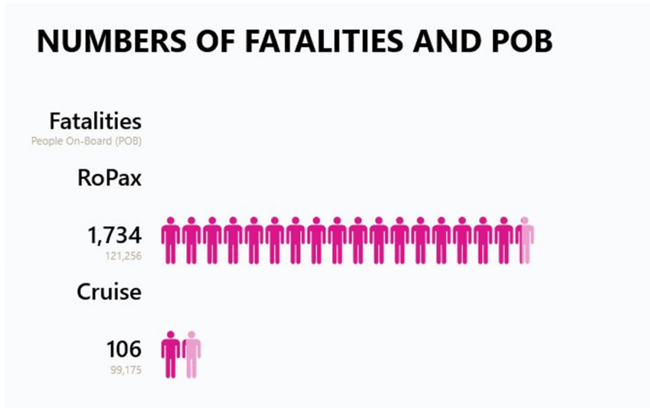


Figure 14. Distribution of natural light during the fire & explosion accidents

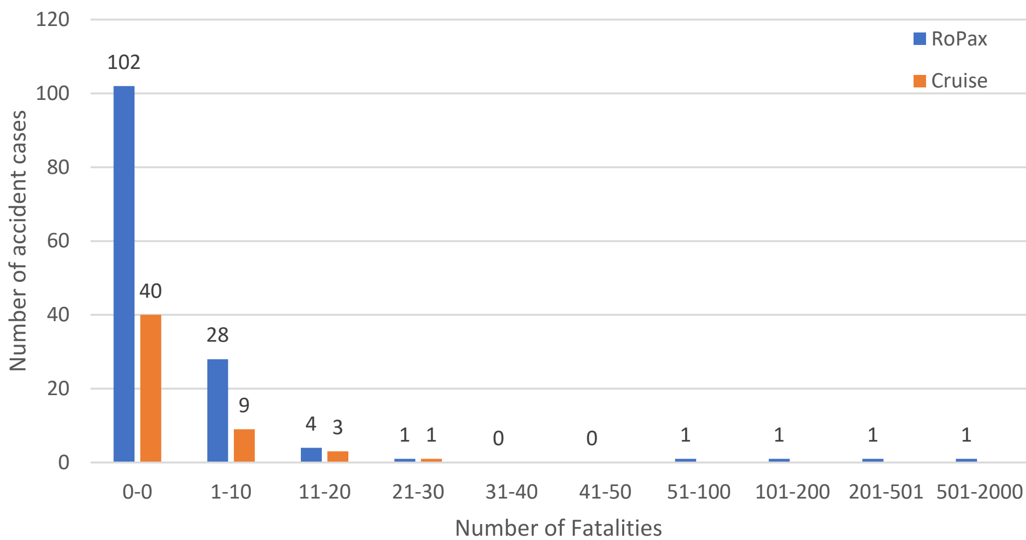
Figure 15 (a) shows the total fatalities and people on board registered in the database (POB) for each RoPAX and Cruise ship. The fatalities include those killed, injured or missing during the fire & explosion accidents. The ratio of no fatalities due to the fire & explosion accidents on RoPAX and Cruise ships, as seen in Figure 15 (b), respectively, is 73% and 75%.

The largest fatalities are the explosion of 'AL SALAM BOCCACCIO 98' (RoPAX), where fatalities including killed, injured and missing occurred with 43 Crew and 988 passengers. In addition, the most serious fire accident that occurred on the ship named 'DA SHUN' (RoPAX) showed 90.38% of the fatality ratio (282 fatalities out of 312 POB).

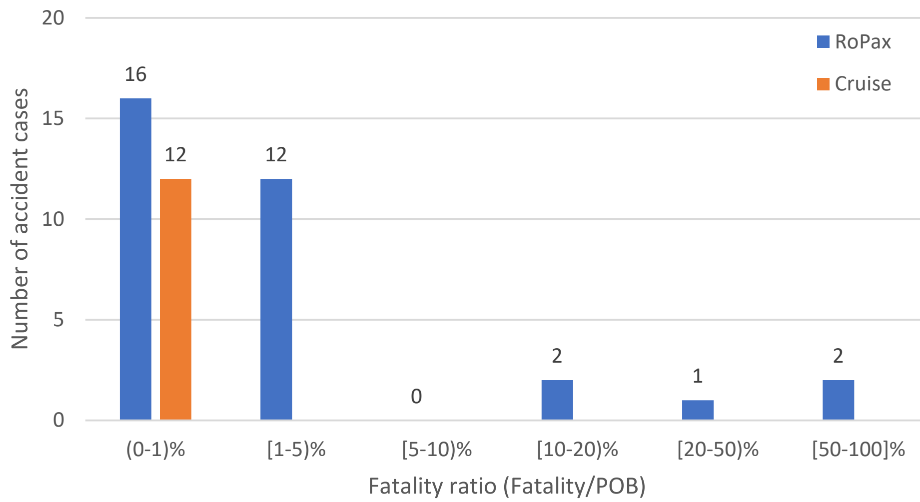
According to Figure 15 (c), the proportions of cases where the fatality ratio exceeds 0 and less than 1% amongst fire and explosion accidents with fatalities are 84.8% for RoPAX ship and 100% for the Cruise ship.


NUMBERS OF FATALITIES AND POB
Fatalities
People On-Board (POB)
RoPax
1,734
121,256
Cruise
106
99,175

(a)


120
100
80
60
40
20
0
Number of accident cases
102
40
28
9
4
3
1
1
0
0
1
1
1
1
0-0
1-10
11-20
21-30
31-40
41-50
51-100
101-200
201-501
501-2000
Number of Fatalities
RoPax
Cruise

(b)



(c)

Figure 15. Number of fatalities and people on board (POB) recorded during fire & explosion accidents

3. SafePASS Risk Model

The SafePASS Risk Model attempts to identify the critical parameters that can influence the evacuation and abandonment performance and provide risk estimates for the persons onboard during the various phases of that process. The Risk Model will be based on the results of the historical accident analysis presented in the previous section, some underlying assumptions and expert judgments as well as data from the literature review in the field. The risk will be determined by associating the potential consequences, at each stage of the evacuation and abandonment process, with the likelihood of occurrence, thus adapting the same risk definition as in ISO 2009 [1]. Both the probabilities of occurrence and the consequences will be informed based on the fusion of the data from the SafePASS Accident Database and the data gathered from simulation tools.

The proposed model is found on well-established previous studies such as GOALDS [2], EMSA III [3, 4], eSAFE [5] and the more recent submission in IMO, SSE 7/INF.3 [6]. Nevertheless, the purpose of the SafePASS Risk Model is to assess the situation as it develops. In this respect, the risk estimations are related to an event's given occurrence and the conditional probability of the events to come. The model should update continuously as the emergency situation is unfolding, gathering information regarding the evacuation status, counting any reported casualties and estimating the potential casualties due to the actual unveiling situation onboard.

The hazards considered under the SafePASS Risk Model are those pertaining to the accident database, namely:

- Collision
- Grounding
- Fire & Explosion

3.1. Event Sequence

Generally, risk models are developed based on decision sequences that specify major ramifications in the sequence between accident and consequences. Past examples of such generic models, which look into the evacuation and abandonment process and the performance of Life-Saving Appliances (LSAs), are the FSA for bulk carrier submitted to IMO in 2001 [7] and the EU research project SAFECRAFT [8, 9].

The SafePASS Risk Model and its associated Event Tree follows the widely acceptable high-level emergency event sequence proposed in IMO SSE 4/3 [10].

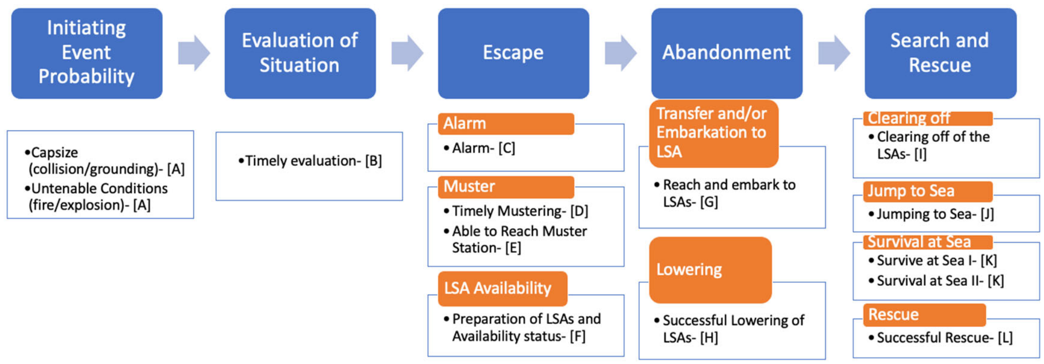


Figure 16. Sequential events of ET and the conditional dichotomy events

Figure 16 shows the sequence of the top events and the conditional dichotomy events under each phase, starting from the Initiating Event to Search and Rescue.

3.2. Influence Diagrams

The high-level events and their corresponding conditional events, presented in the previous subsection (Figure 16), were investigated further to examine and pinpoint the major influences that can reduce the probability of a successful evacuation and abandonment and can increase the number of fatalities. The influences that correspond to each event were clustered together and lead to the development of a series of influence diagrams, which encapsulate the major influences in each stage of the emergency. In the cases where the influences were depended on whether the emergency was related to fire or flooding, two separate influence diagram models were generated.

The influence diagrams that will determine the fatality calculations were in accordance with SSE 7/INF.3 [6] and cover the following fatality causes:

- Fatality due to evacuating due to reaching early an unattainable situation (capsized, foundering, early uncontrolled fire), i.e., Time To Capsize (TTC) < Time To Evacuate (TTE).
    - Any delays in evaluation, mustering, abandonment due to rolling, heeling, trimming of the vessel, fast fire propagation etc.
- Fatality due to faulty evaluation of the situation
    - Abandonment necessary but not initiated
    - Abandonment not necessary but initiated
- Fatality due to failing to muster, e.g.:
    - Technical problems
    - Human error (crew, passenger)

    - Unable to reach muster station (e.g. blocked routes, accident)
- Fatality due to missing/inaccessible life-saving means (survival craft), e.g.:
    - Not functioning
    - Ship condition prohibits the use
    - Unable to prepare survival craft (access obstructed, launched before boarded)
    - Damaged in accident
    - Inaccessible
- Fatality in the embarkation and clear-off process, e.g.:
    - Accident in onboard evacuation
    - Accident with survival craft
    - Unable to clear-off
- Fatality during waiting for rescue, e.g.:
    - Missing habitable environment
    - Missing supplies (water, calories)
    - Loss/failure of survival craft

Examples of the influence diagrams can be seen in Figure 17 and Figure 18. Both diagrams refer to the influencing parameters for a ‘fatality due to missing/ inaccessible survival crafts’ but Figure 17 is assuming a fire scenario whereas Figure 18 corresponds to a flooding case.

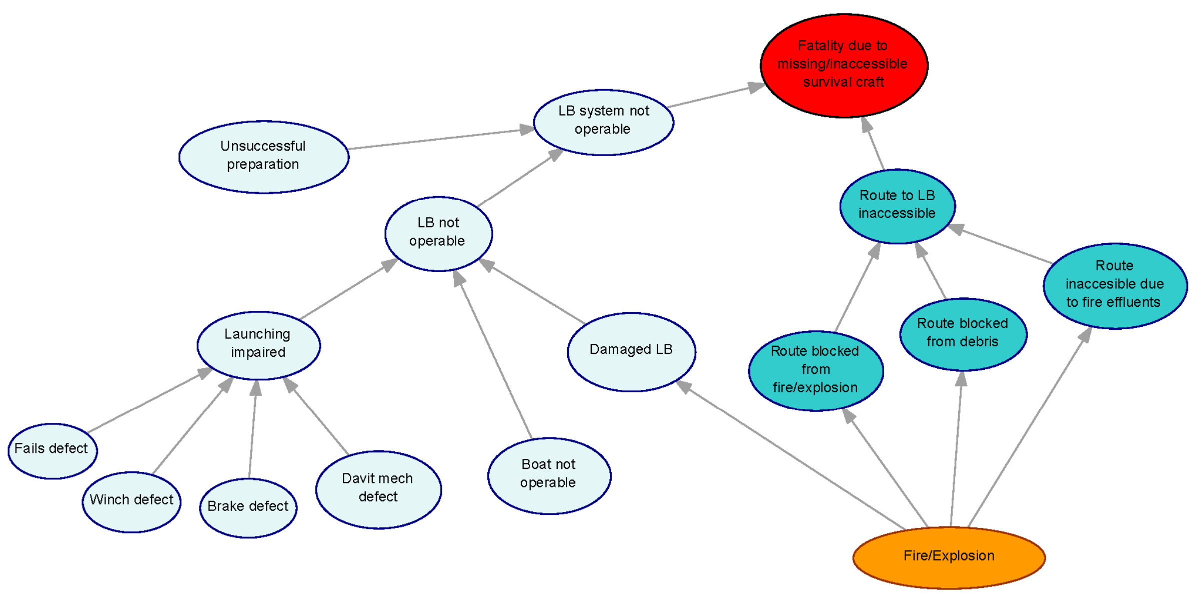


Figure 17. Influence diagram for a “fatality due to missing/inaccessible survival craft – fire & explosion”

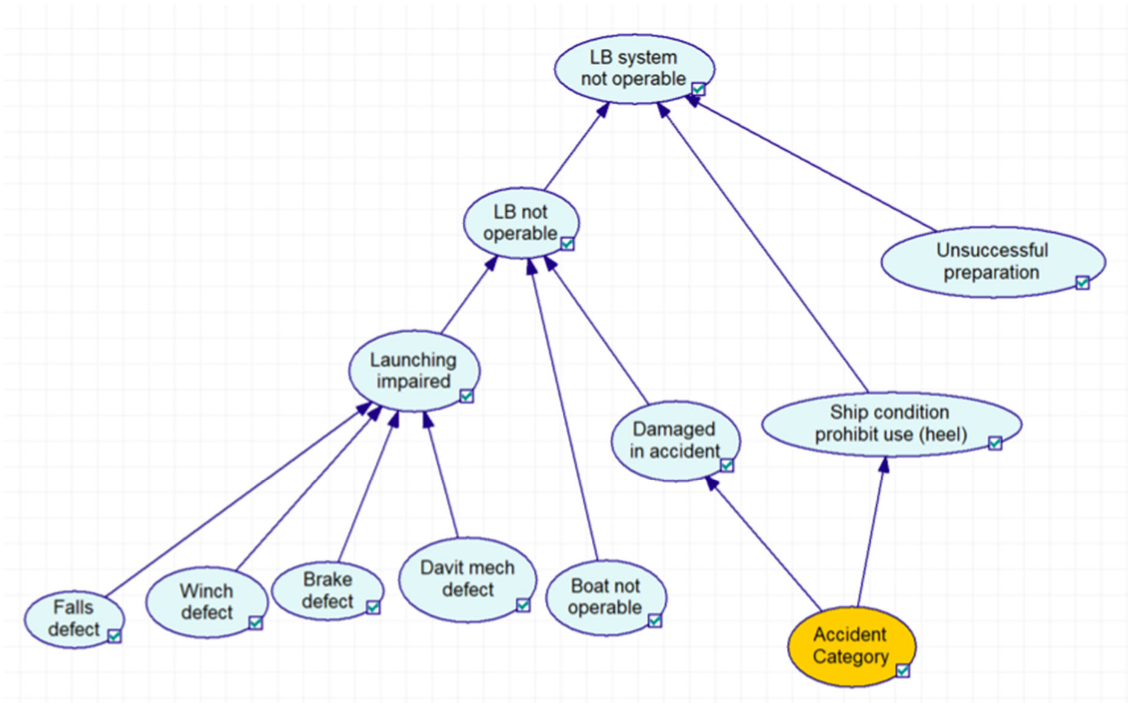


Figure 18. Influence diagram for a "fatality due to missing/inaccessible survival craft - flooding" [6]

3.3. Event Tree

Event Trees allow for a structure of the possible consequences based on an initiating event. Figure 16 depicts the overall structure of the event tree based on the overarching sequential stages of the evacuation, abandonment, and rescue process, whereas Figure 19 shows an overview of the flow of information between the Event Tree gates, the influence diagrams and other SafePASS Components

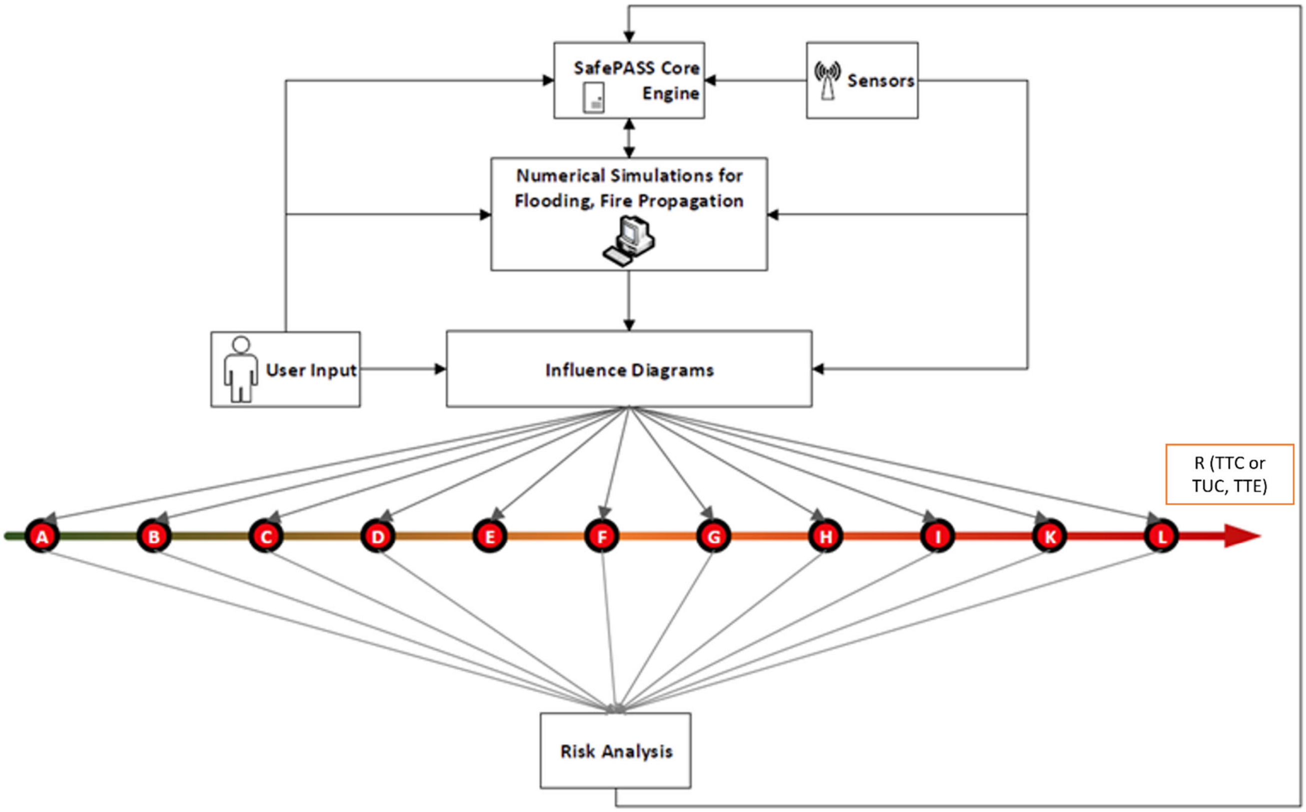


Figure 19. SafePASS Dynamic ET Information Flow

The conditional dichotomy events, denoted in red circles, are input points that allow for the transformation of the static and binary event tree to a dynamic process of quantifying any potential outcomes. This is achieved by altering, in any dichotomy point (gate), the distribution of the probabilities based on the information for each individual or stage of the evacuation and abandonment process. This information will influence the variables of the corresponding influence diagrams, which will, in turn, determine the distribution of the probabilities on each side of the dichotomy. More specifically, the influence diagrams will act as functions that determine the probability distribution along the various paths of the event tree based on input from both users and sensors alike.

3.3.1. SafePASS ET Part 1: Timely Evaluation 'YES' Branch

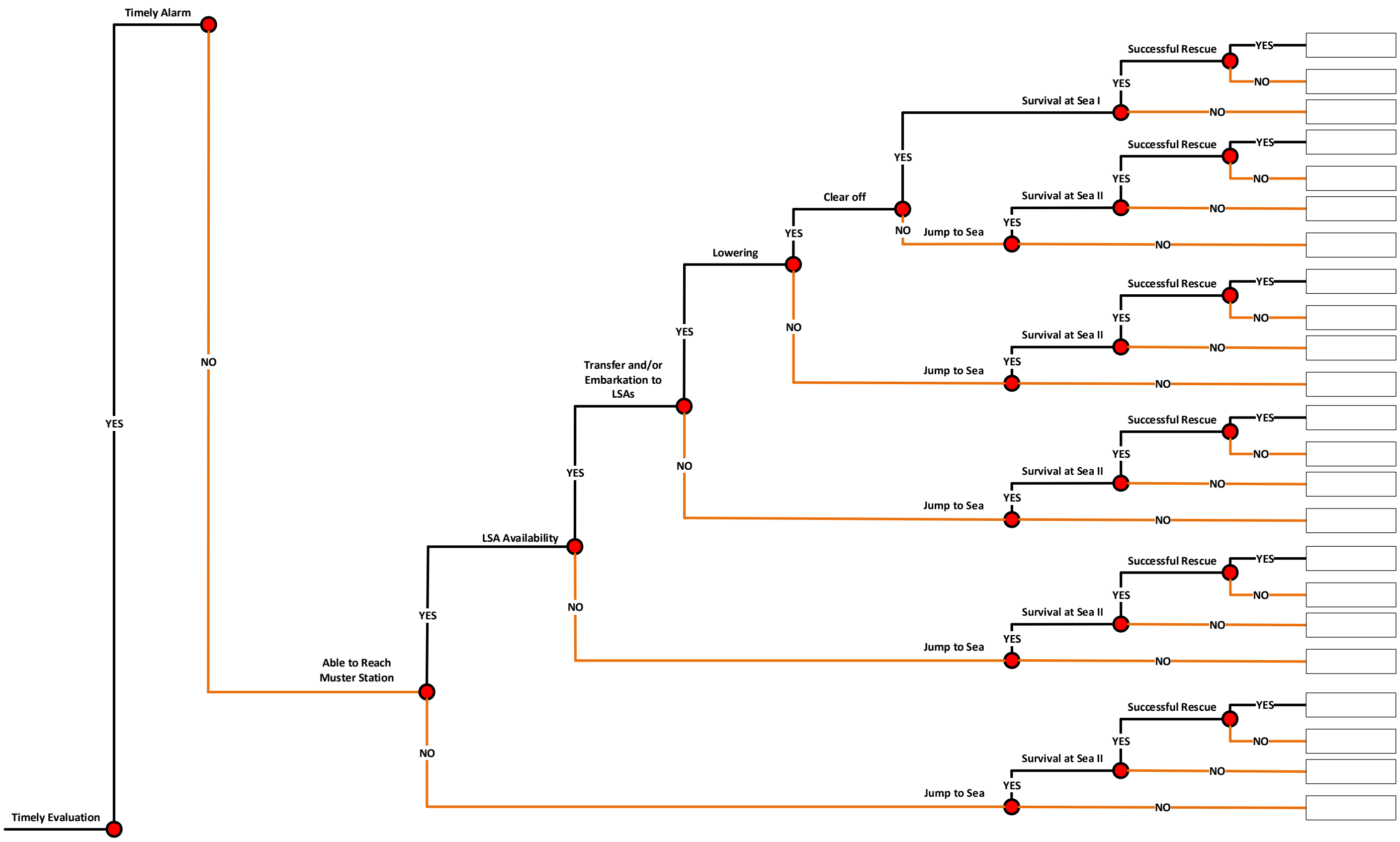


Figure 20. SafePASS ET Part 1: Timely Evaluation 'YES' Branch

3.3.2. SafePASS ET Part 2: Timely Evaluation 'NO' Branch

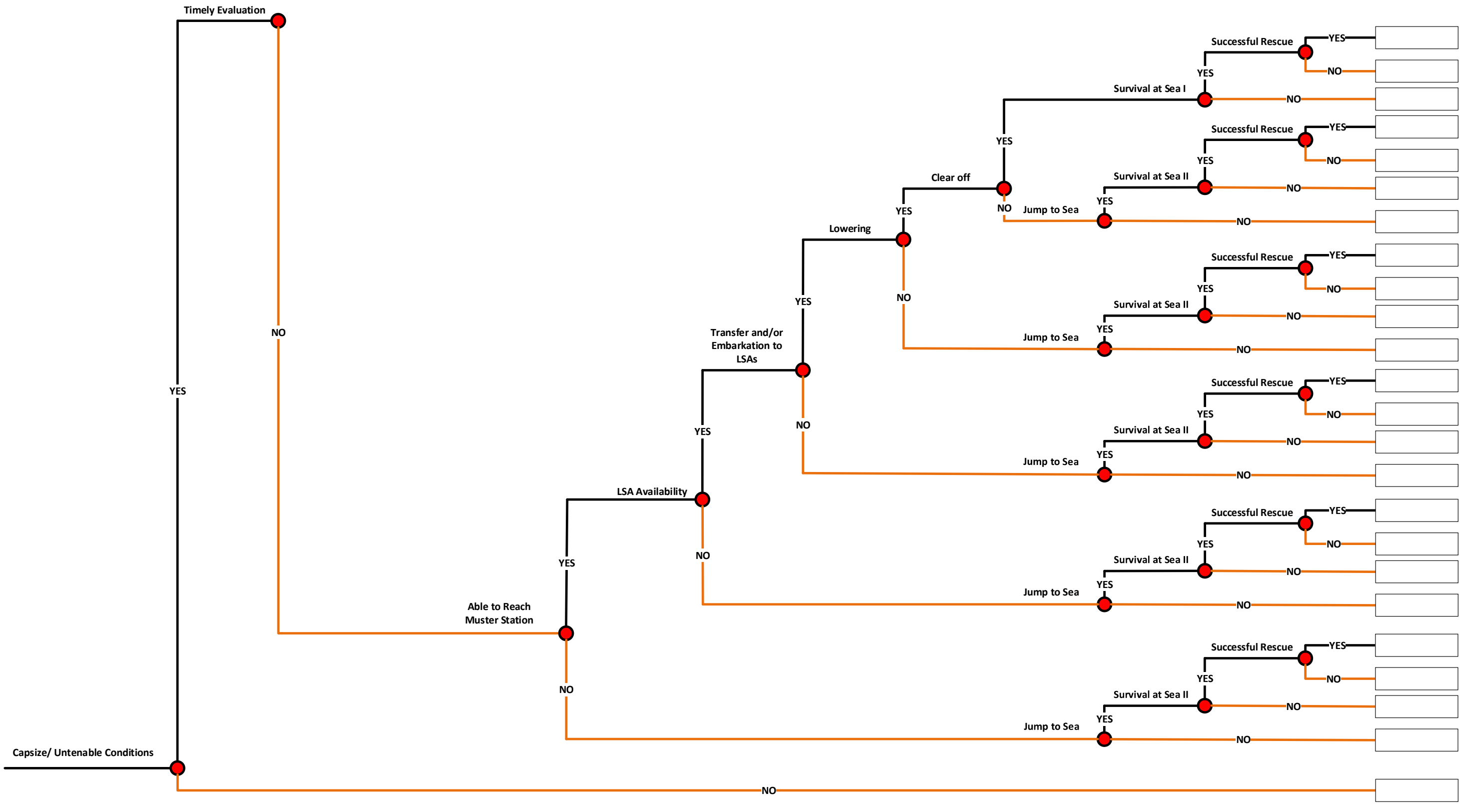


Figure 21. SafePASS ET Part 2: Timely Evaluation 'NO' Branch

3.3.3. SafePASS ET Part 3: Timely Mustering 'YES' Branch

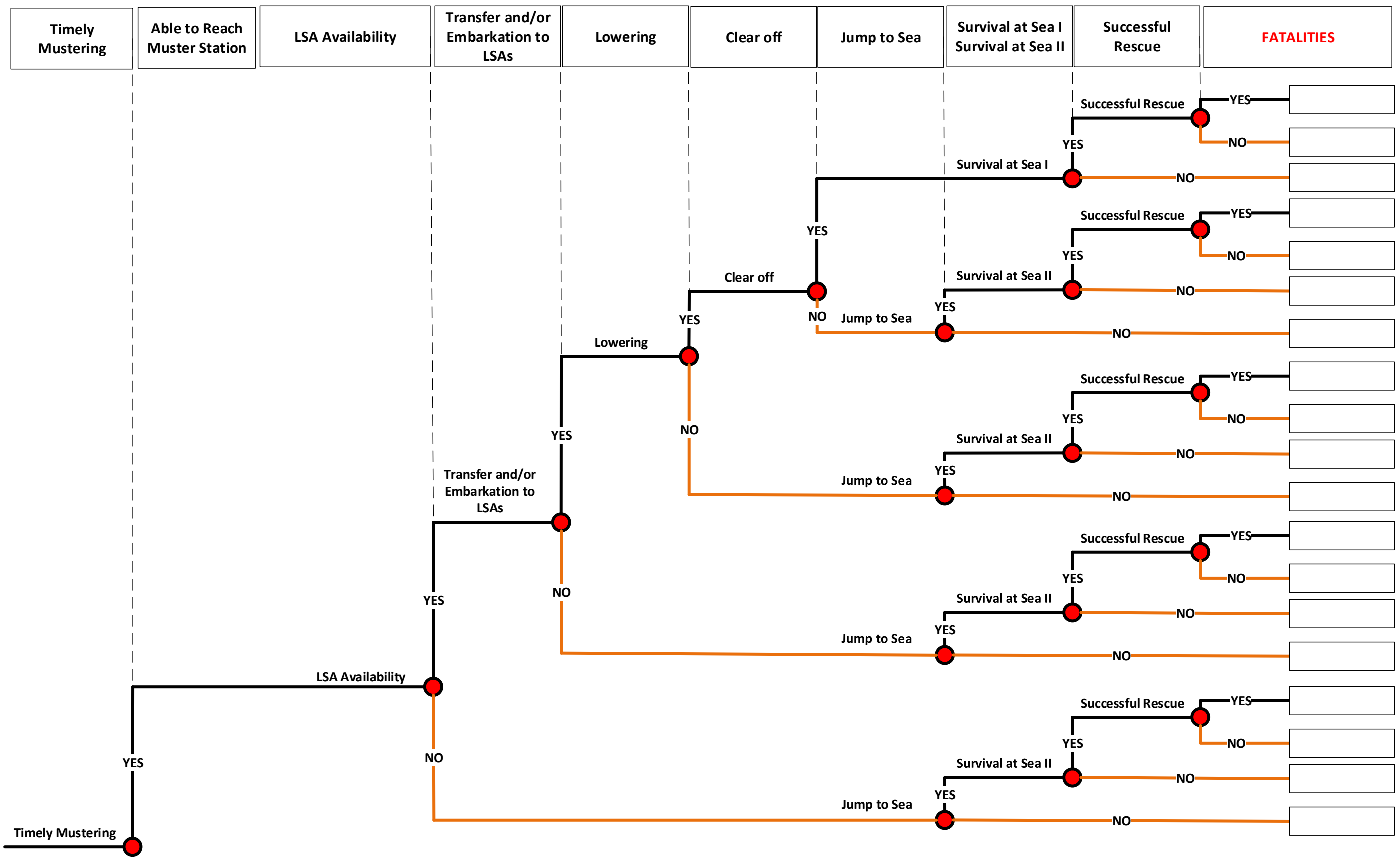


Figure 22. SafePASS ET Part 3: Timely Mustering 'YES' Branch

3.3.4. SafePASS ET Part 4: Timely Mustering 'NO' Branch

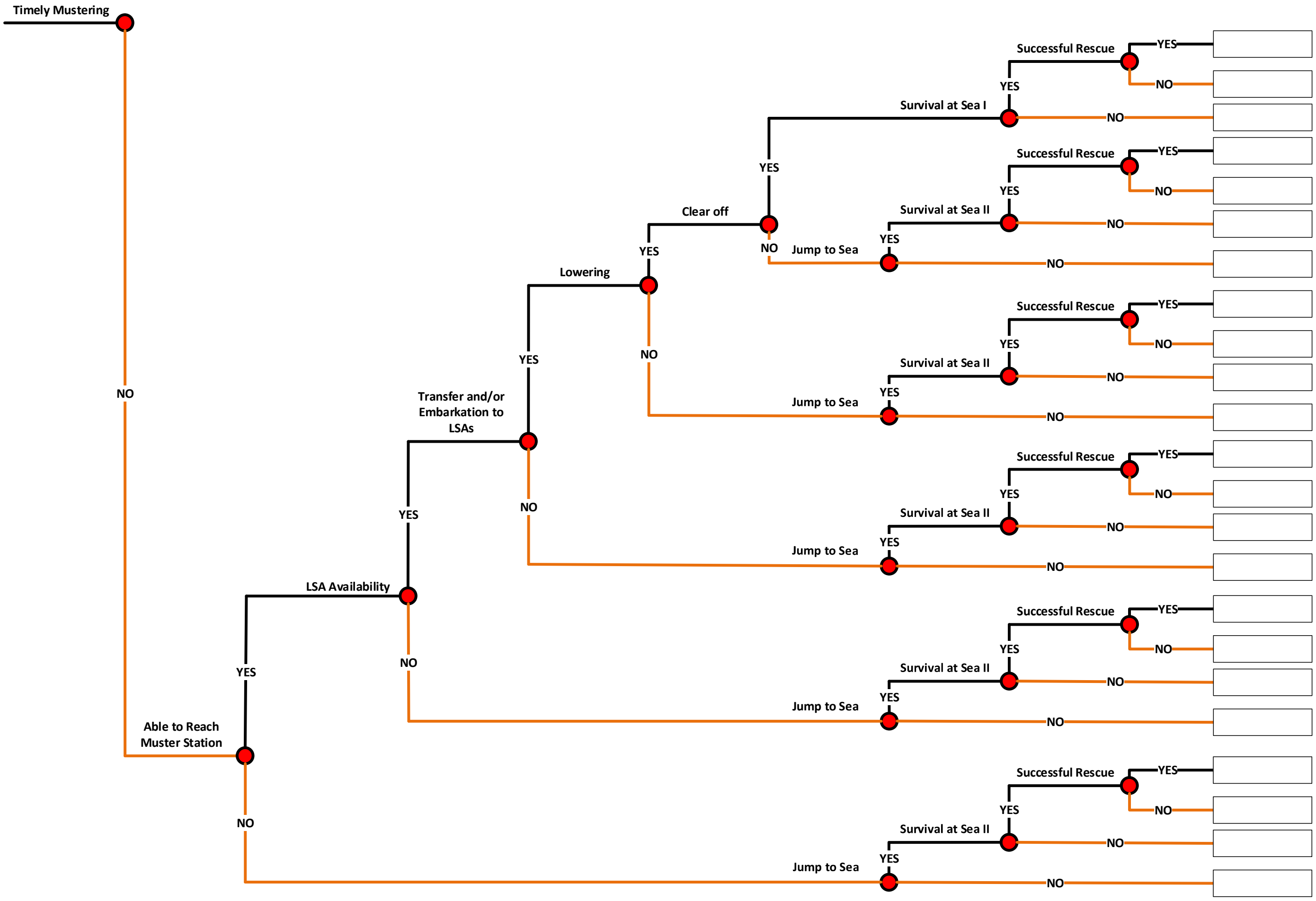


Figure 23. SafePASS ET Part 4: Timely Mustering 'NO' Branch

Initiating Event: Capsize/ Untenable Conditions

The initiating event probability is conditional to the type of accident (collision, grounding or fire & explosion). The numerical simulations provide an initial estimate of the propagation of the flooding and fire damage. If the Capsize/Untenable Condition gate is 'Yes' then the path continues to the next event gate (timely evaluation). If it is 'No', then the path leads straight to the Fatalities section. In this case, it is assumed that there are no fatalities associated with the mustering/abandonment phase since evacuation was not required.

Event 2: Timely Evaluation

The probability distribution on the Timely Evaluation gate will be based on the influence model proposed on [6], outlining the parameters for a faulty evaluation of a situation. The most important of those are: a) Wrong/ Insufficient Information, b) Human Performance/Error. In the case of the 'No' path, on the presumption that there will be no Timely Alarm and hence no Timely mustering, the next two events are skipped, and the next gate is the 'Able to reach Muster Station' node.

Event 3: Timely Alarm

Similarly, as in the preceding event, in case of a technical failure to alarm or failure to respond to the alarm, the timely mustering branch is deemed unnecessary, and the path leads to the 'Able to reach Muster Station' gate. It is, therefore, possible to account for the consequences of no orderly or timely mustering.

Event 4: Timely Mustering

The Timely Mustering branch is relevant only if the preceding events are true and the probability distribution among its branches is regulated by the corresponding influence diagram.

Event 5: Able to reach Muster Station

This gate is meant to capture the cases where due to blocked/inaccessible pathways the passengers are unable to reach the muster stations. If the 'No' path is followed, then we assume that the passengers haven't managed to reach the LSA embarkation area and the next available gate is the 'Jump to Sea'. The 'yes' path, in turn, accounts for the possible cases where passengers, although unable to muster timely, were able to reach the embarkation deck.

Event 6: LSA Availability

The LSA availability factors have been analysed on and in the case of no availability, the next node is the 'Jump to Sea'.

Event 7: Transfer and/or Embarkation to LSAs

This step is meant to capture any problems during the embarkation stage and also include any potential delays in the case where the muster station is not close to the embarkation area.

Event 8: Lowering & Event 9: Clearing

The potential consequences of a technical or human error during the lowering and the influencing factors for 'Clearing' of the LSAs can be captured on the gates for the 'Lowering' event and 'Clearing' event respectively. The probabilities of each branch are determined according to their corresponding influence diagram.

Event 10: Jump to Sea

The ‘Jump to Sea’ node can help us distinguish between the cases of people that are at sea and those who are trapped on-board (if the ‘No’ path is followed).

Event 11: Survival at Sea

The Survival at Sea stage has two distinctly different gates. Survival at Sea I is related to the cases where the passengers are on-board an LSA whereas the Survival at Sea II is related to ‘individual’ survival parameters for those who have ‘jumped at sea’. For each scenario, there is a different influence model that is being used.

Event 12: Successful Rescue

The last event gate tries to determine the probability of Rescue based on the SAR options available.

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