A TRAGEDY, A FULL-SCALE FIRE EVACUATION DRILL, AN EMERGENCY EVACUATION SIMULATION.

SPEAKERS:
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A TRAGEDY, A FULL-SCALE FIRE EVACUATION DRILL, AN EMERGENCY EVACUATION SIMULATION

AGENDA

DESIGN

OPERATION

DECOMMISSIONING

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DESIGN

OPERATION

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AGENDA

INCIDENT

TRAINING

DESIGN

THE IMPORTANCE OF MARITIME TRANSPORTATION

Maritime transportation of people and goods has always been very important and in the last years its volume and therefore its importance has largely grown.

The recent Covid-19 pandemic and the blockade of ports that was experienced underlined the importance of maritime transportation around the world, that has been estimated to be the 80% of the global trade by volume.

In Europe, where the seaborne traffic represents 20% of the total transport, over 300 ports are very active in general cargo, bulk (liquid/dry), containers and "Ro-Ro" (Roll-on/Roll-off) ship.

THE ROLL-ON/ROLL-OFF SHIP

A "Ro-Ro" is a particular ferryboat designed for the transport of wheeled vehicles, and of loads, arranged on flatbeds or in containers, loaded and unloaded by means of wheeled vehicles in an autonomous manner and without the aid of external mechanical means. No cranes are used and all the content is moved by ramps to different decks, often connected by lifts.
Some ferries may carry passengers as well and they are referenced as "Ro-Pax".

"Ro-Ro" ships, and in particular "Ro-Pax", have always showed a great vulnerability to fires and a number of incidents. Even in the last decade, we recorded both severe fires and large number of victims among the passengers.
Majority of the fire started on-board without collision.

Francesca - Norman Atlantic - Moby Prince
Scandinavian Star - Sewol - Boccaccio

THE ROLL-ON/ROLL-OFF SHIP

Only in 2022 two Ro-Pax fires have been published in the international news:

- Olympia on the 18 February
- Stena Scandica on the 29 August.

"It looked like the apocalypse, a scene I hope in my life never to see again, people climbing on anything because their feet were burning, the soles of their shoes were melting on the hot metal sheets, a crowd gone mad" (Norman Atlantic disaster, [2022]).

Olympia fire (©Ansa)

Stena Scandica fire (©Il Mattino)

PATHS AND METHODS

Fire risk management aboard "Ro-Ro" ships can be managed considering a number of different insights, gained by different paths and with proper methods, as suggested by risk management standards such as ISO 31000 and IEC 31010:

- lessons learnt from real accidents;
- risk assessments;
- full-scale experiments and drills.

Methods may include simulations and modelling with specific tools, eventually used in combination, to investigate specific aspects.

An integral approach can ensure a better understanding of the issue

PATHS AND METHODS

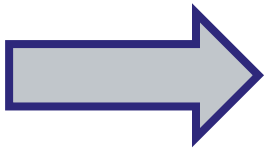
In fact, it is assumed that the issue may become even more urgent if one considers the increasing size of ferries, the expansion of fleets, the use of new fuels (LNG, ammonia, etc.), the indirect pressure of commercial needs, and the consequent desire to proceed as far as possible with the journey times and preparation times.

In particular, some insights will be presented and summarized related to:

- a root cause analysis of a real incident and the activities subsequently conducted to understand alternative scenarios as conditions change (Norman Atlantic);
- an evacuation full-scale drill in Messina with a Ro-Pax vessel;
- evacuation simulation activities performed by a specialized tool (Pathfinder).

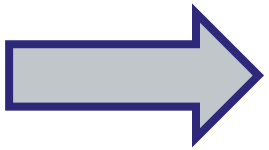
PATHS AND METHODS

LESSONS LEARNT FROM REAL ACCIDENTS



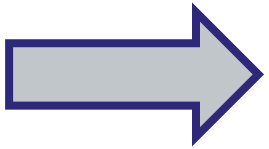
A root cause analysis of a real incident and the activities subsequently conducted to understand alternative scenarios as conditions change (reactive design).

RISK ASSESSMENTS



Evacuation simulation activities performed by a specialized tool (design).

FULL-SCALE EXPERIMENTS AND DRILLS.



An evacuation full-scale drill (training).

A REAL INCIDENT

THE NORMAN ATLANTIC FIRE

The ferryboat Norman Atlantic was an Italian ship rented by a Greek company for ferry crossing between the two countries. The cargo consisted of about 130 heavy vehicles, 417 passengers and 88 cars.

The night of the incident, the route Patras– Igoumenitsa – Ancona was planned, and 55 crew members were on board. Incident lasted for several hours, days in the inner decks, and showed, since the beginning a significant severity, resulting in emergency services difficulties and extensive damages

A REAL INCIDENT

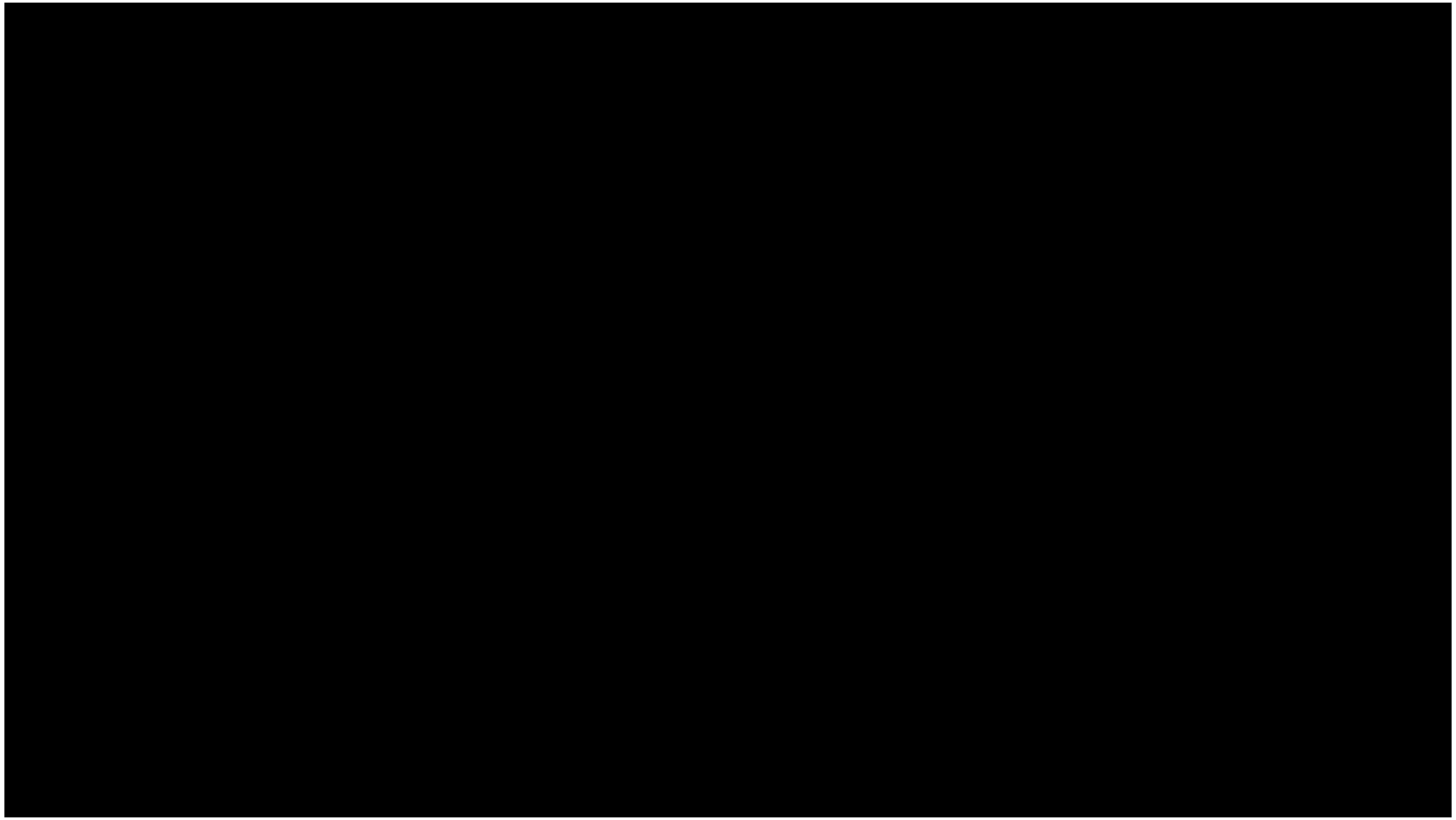
THE NORMAN ATLANTIC FIRE - Ship during the emergency

A REAL INCIDENT

THE NORMAN ATLANTIC FIRE – Resulting damages

A REAL INCIDENT

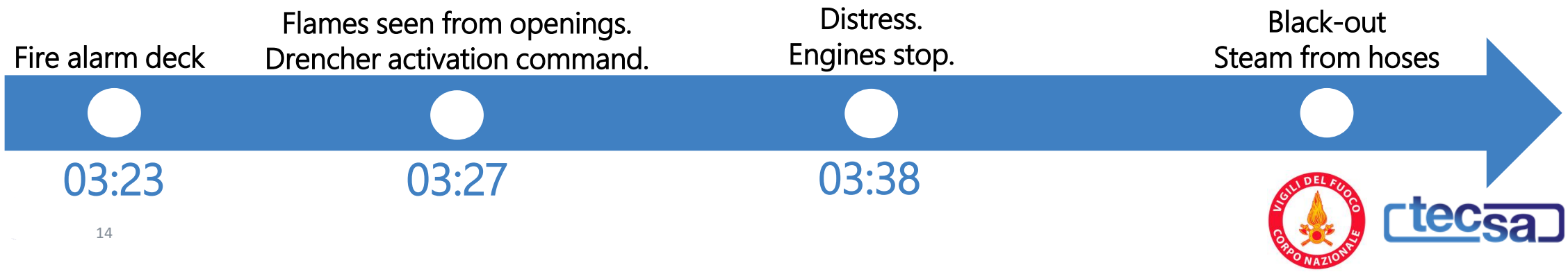
THE NORMAN ATLANTIC FIRE VIDEO



A REAL INCIDENT

THE NORMAN ATLANTIC FIRE

The cargo leaved from Igoumenitsa to Ancona, at 23:28 of 27/12/2014, the navigation was regular until 03.23 (UTC).
At 03:23 (near the frame #156) the fire alarm sprang into action on deck 4. Smoke sighting coming out from the lateral openings of the deck.
At 03.27 the Master observed flames coming out from the openings of deck 4.
Then the 1st Engineer Officer activated the manual deluge system ("drencher").
The Chief Engineer Officer and his personnel abandoned the Engine Room because of the excessive smoke. The two engines of the ship stopped definitively



A REAL INCIDENT

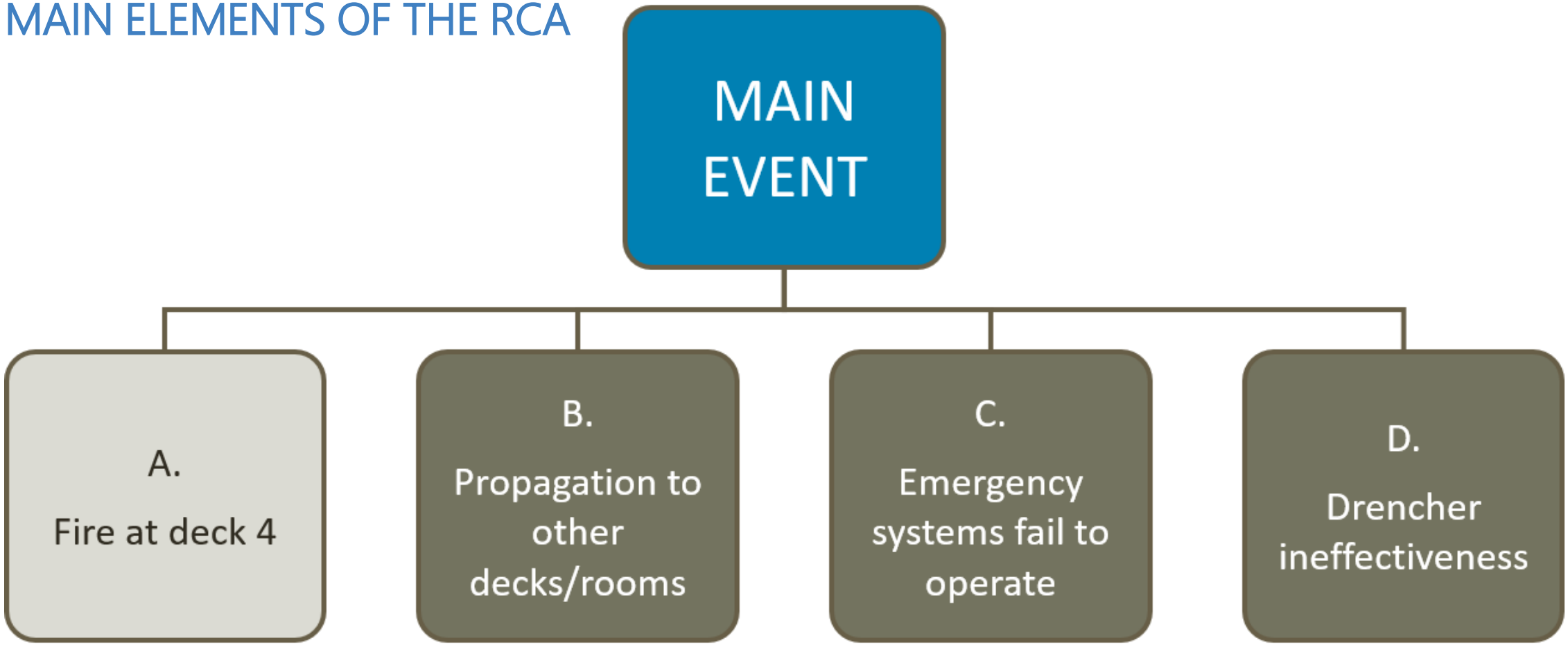
THE NORMAN ATLANTIC FIRE

The ship went in a black-out and the emergency generator, placed on deck 8, was incapable of providing energy to the emergency utilities, including the emergency pump.
The cooling team uselessly tried to cool the deck 5, but steam came from the fire hoses, instead of liquid water. The emergency management revealed as chaotic. Some passengers fell into the sea, others threw the remaining life rafts in the sea, with no possibility to properly use them.

At the end of the Search And Rescue operations, 452 people were rescued, including 3 illegal immigrants; 9 victims and 14 lost in the sea were also counted.

ROOT CAUSE ANALYSIS

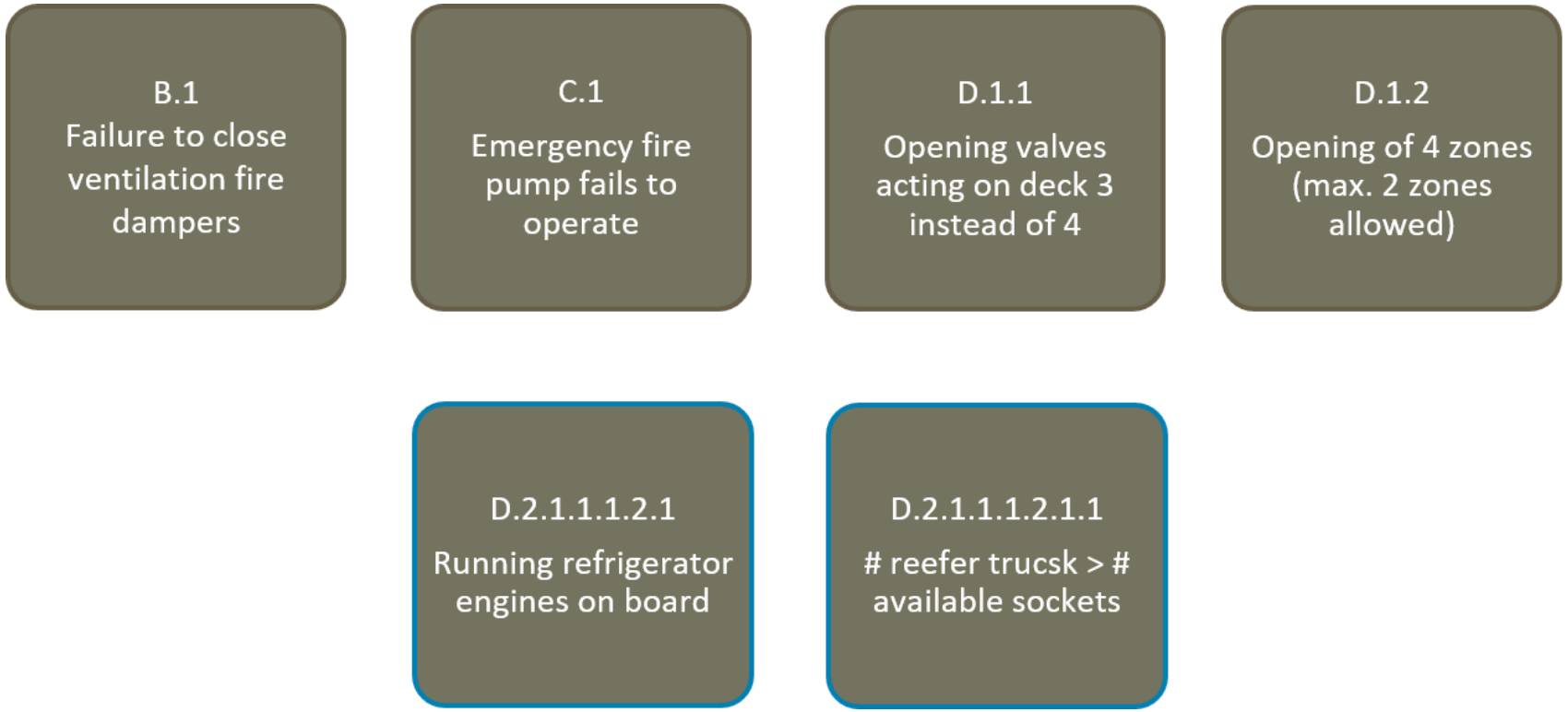
MAIN ELEMENTS OF THE RCA



ROOT CAUSE ANALYSIS

IMMEDIATE CAUSES

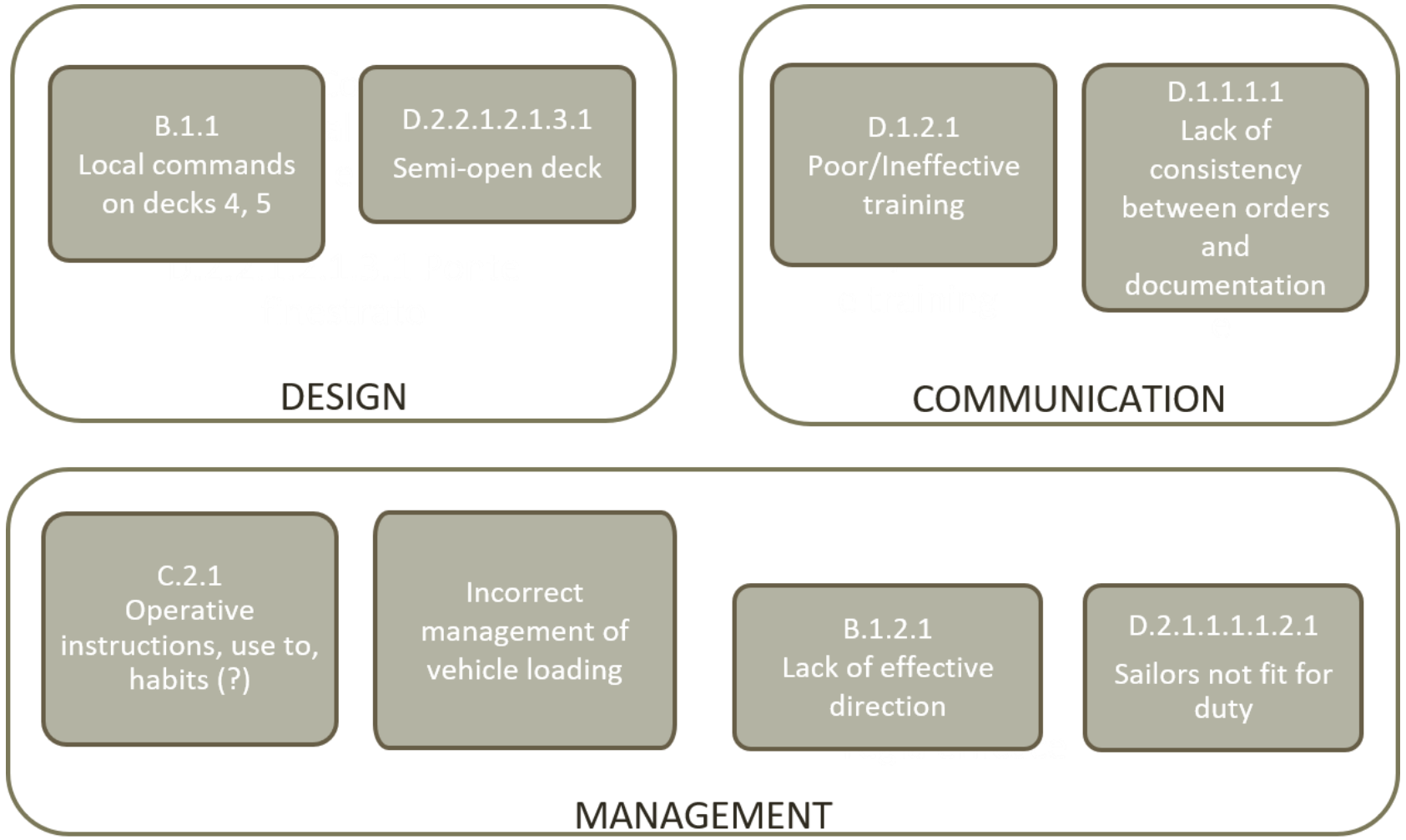
Root Cause Analysis led to a number of specific insights and, starting from identified immediate causes, it has been possible to select some important root causes.



ROOT CAUSE ANALYSIS

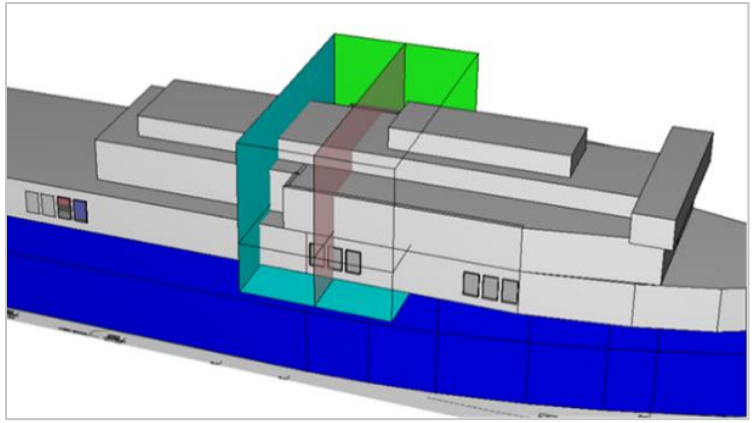
ROOT CAUSES

The complexity of the RCA underlines the applicability of the Reason's Swiss Cheese Model: safeguards are not reliable 100% and when their ineffectiveness align, then a hazard situation may become an incident.

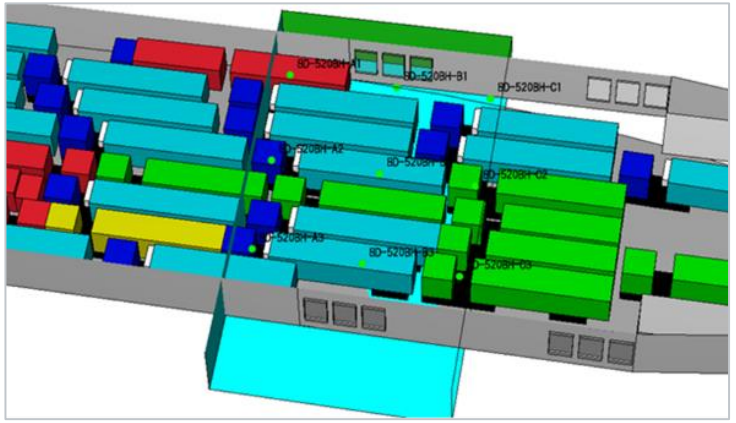


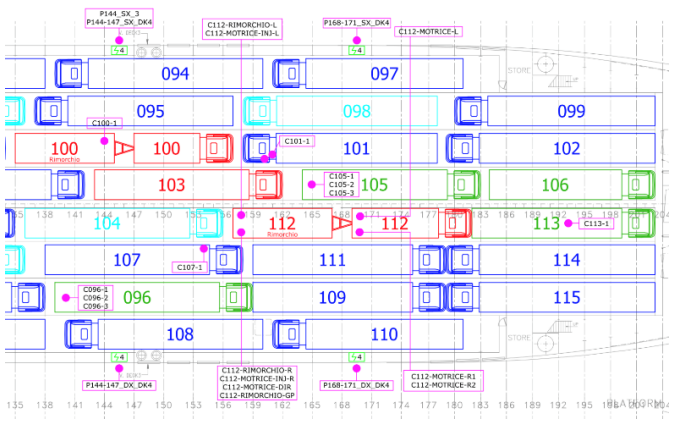
DEVELOPED RACCOMANDATIONS

The limited arc of time between the first alarm at deck 4 and the other decks is very short (e.g. 3 minutes between deck 4 and 5) but not incompatible with the extensive technical literature available.
Moreover, this rapidity also emerged from the numerical simulations, that have been carried out to validate the hypothesis advanced during the first stages of the investigation.



Simulation domain





Cargo load

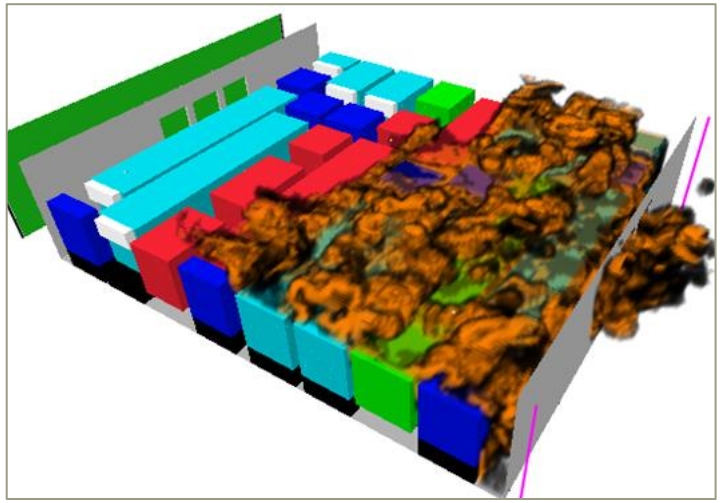
DEVELOPED RACCOMANDATIONS

Given the insights gained with the structured investigation (RCA), it has been possible to verify alternative conditions of fire and its physical effects through the development of different scenarios that the actual scenario shown recorded in the incident.

It has been verified the variation, from the incident recorded fire dynamic, in terms of HRR given different conditions (single and combined):

- fire protection deluge system activation in 120 s;
- absence of severe meteo conditions (no wind across the decks openings);
- increase fire water density discharge (up to 90 l/min).

Some cases showed up to a 60% mean reduction of the Heat Release Rate curve

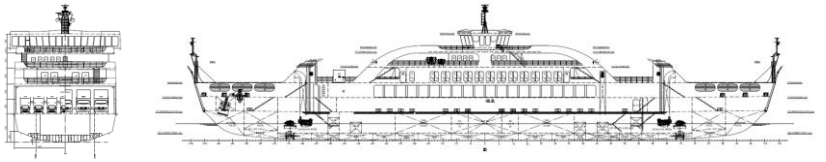


FULL SCALE FIRE EVACUATION DRILL

Messina, 17th of February 2022. Fire Brigade organized a fire event on a similar ship. The aim of the exercise was to test evacuation procedures for all passengers, with particular regard to people with special needs.

Goals of the drill:

- synergy/coordination in a multi-agency emergency context;
- overall assessment of people evacuation;
- rescuer's approach evacuation procedures for people with special needs.



Ro-Pax 'Trinacria'

Different meteo conditions in the Messina strait

FULL SCALE FIRE EVACUATION DRILL

THE RO-PAX TRINACRIA DRILL VIDEO

LESSON LEARNT

- Dangerous goods pose a severe threat to occupants and to the vessel.
- Importance of initial and prompt emergency management onboard due to the serious risk of fast escalation of an incipient fire.
- Crowding of passengers in specific areas of the ship can modify in a substantial way the evacuation to safe location, therefore specific training of the crew to manage high density areas is needed (areas to be identified)
- Triage activities in port are fundamental, while an initial level of priority should be defined onboard, before the arrival of external emergency services.
- Specific needs (eventually connected with disabilities) should be known in advance.

LESSON LEARNT

- Crew should be trained to understand physical and mental disabilities in order to assist passengers effectively before the arrival of specialized teams.
- Layout of the traditional ships may pose a severe threat to people having disabilities; those limitations should be known in order to guarantee a more effective emergency management
- It is strictly advisable that several emergency scenarios are considered in order to guarantee that variations will cover the majority of the possibilities.
- A ship evacuation due to a fire should be considered a large and complex emergency to be managed by a synergetic approach by authorities; specific drills, should be planned at periodic intervals involving all the stakeholders.

LESSON LEARNT

Large scale experiments may provide meaningful elements to improve ship evacuation models conducted using simulation, also taking advantage by collection evacuation data.

This is fundamental to understand how people behave in marine emergencies since still nowadays little data relating to passengers response time or full scale validation data in this environment exists.

This data could integrate the IMO recommendations, as anticipated in (Galea, Brown, Filippidis and Deere, 2010) and later on confirmed in (Park, Ham and Ha, 2015).

SIMULATION

The study of accidents that have occurred has shown how adoption of increasingly efficient and advanced technologies, crew training and application of procedures are keys in safeguarding human life and property.

The use of technology and specialized software allows for multiple simulations in advance that can highlight any critical issues and/or opportunities.

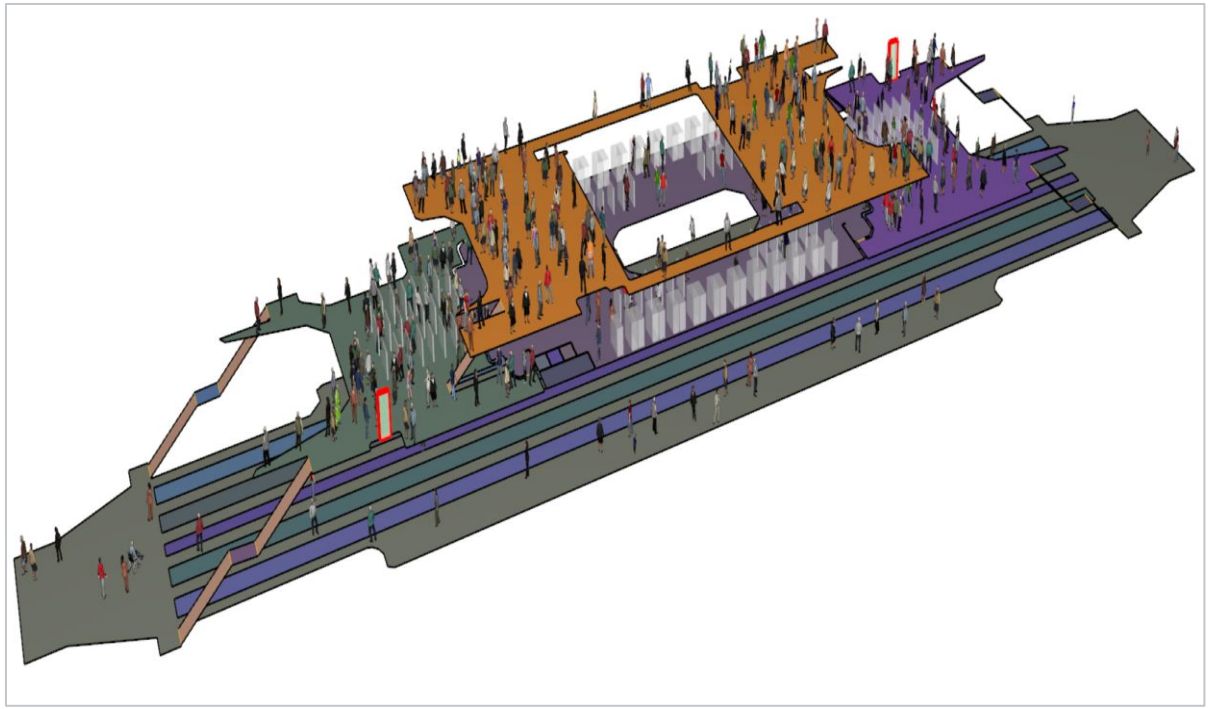
The guideline by IMO (2016) regulates evacuation analysis on ships through two distinct methods: simplified (relative simple and able to provide an approximation to expected evacuation performance) and advanced (suitable as the complexity of the ships increases). Advanced simulation may give some insights for existing ships too.

SIMULATION

The advanced methodology was applied using Pathfinder. The software uses an agent-based model (ABM) that allows capturing complex behaviors and interactions between occupants under the assumed emergency conditions.

The simulations were conducted by analyzing:

- modern hypothetical two-way ferry ship
- 399 passengers including 7 crew
- 150 cars or alternatively 23 TIRs
- passenger are distributed on 3 main decks
- a Marine Evacuation System (MES)



SIMULATION

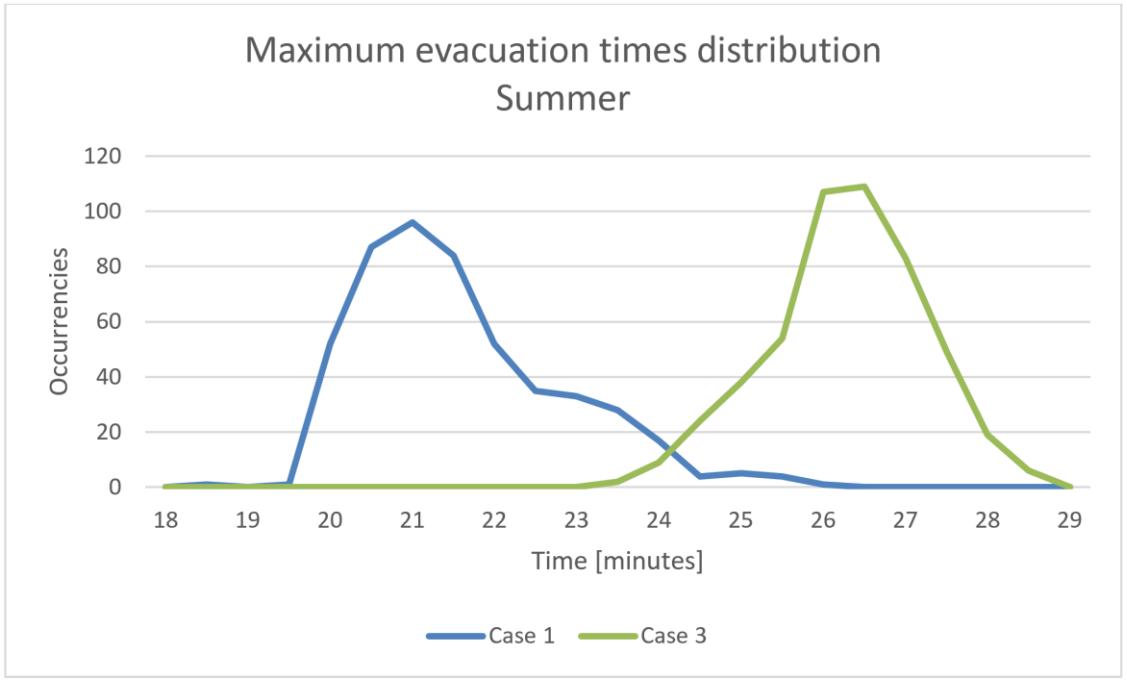
POPULATION GROUPS

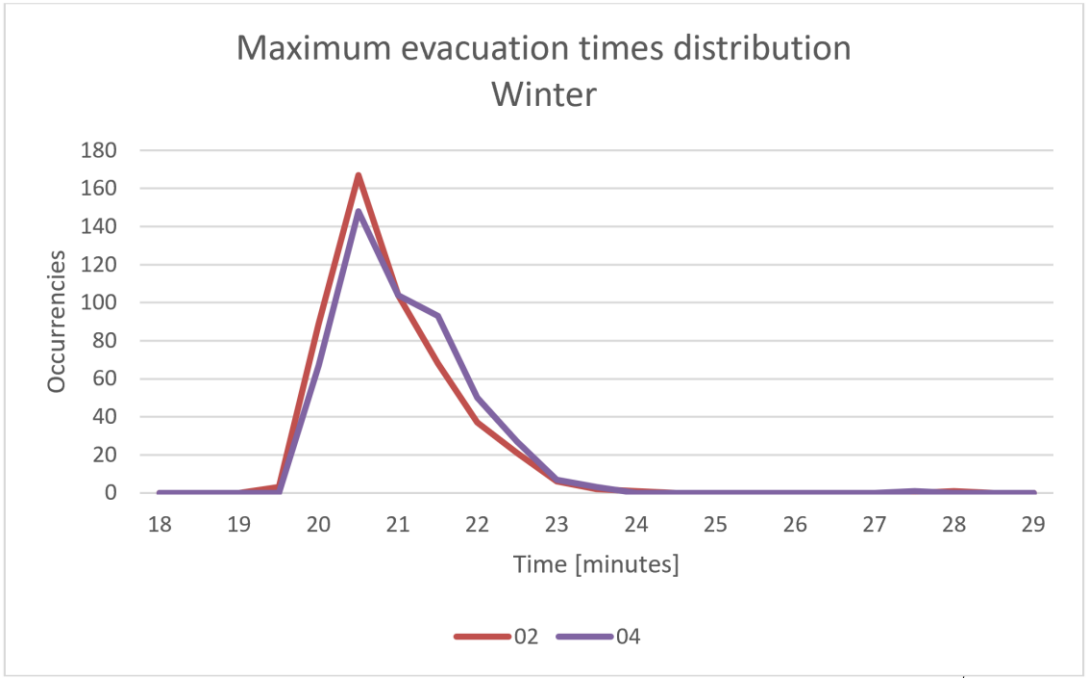
Population groups - PASSENGERS	Percentage of passengers (%)	Number passengers
FEMALES YOUNGER THAN 30 YEARS	7	27
FEMALES 30-50 YEARS OLD	7	27
FEMALES OLDER THAN 50 YEARS	16	63
FEMALES OLDER THAN 50 YEARS, MOBILITY IMPAIRED	10	39
FEMALES OLDER THAN 50 YEARS, MOBILITY IMPAIRED	10	39
MALES YOUNGER THAN 30 YEARS	7	27
MALES 30-50 YEARS OLD	7	27
MALES OLDER THAN 50 YEARS	16	63
MALES OLDER THAN 50 YEARS, MOBILITY IMPAIRED	10	39
MALES OLDER THAN 50 YEARS, MOBILITY IMPAIRED	10	39

Population groups - CREW	Percentage of passengers (%)	Number passengers
CREW FEMALES	50	3
CREW MALES	50	4

SIMULATION

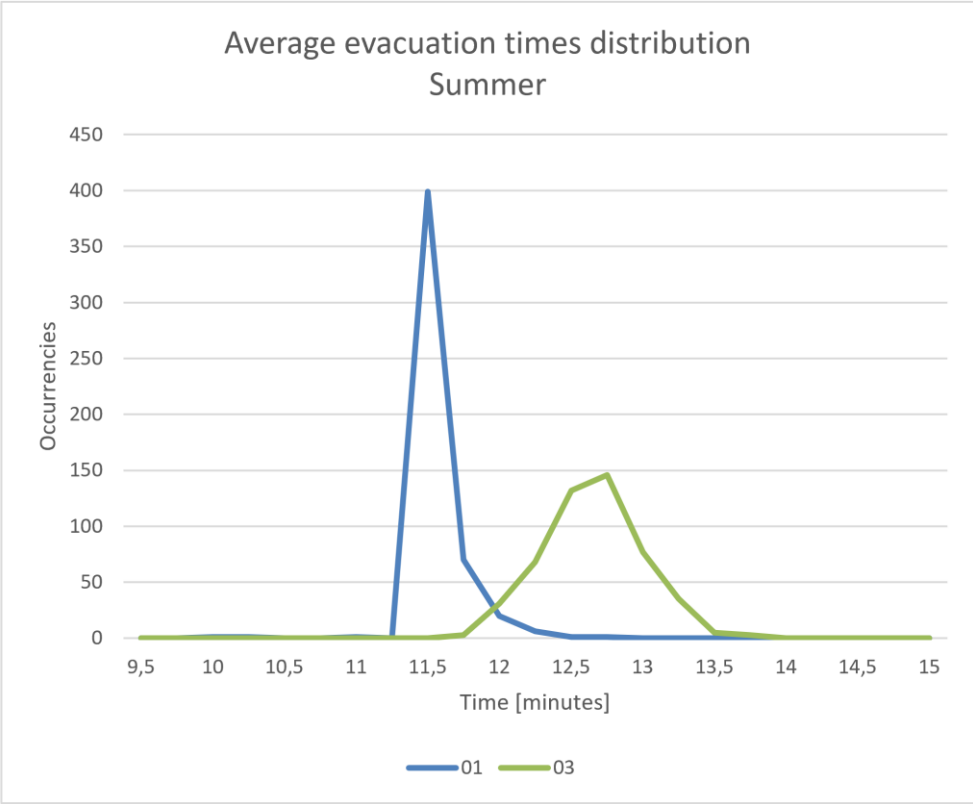
DIAGRAM MAXIMUM EVACUATION TIME

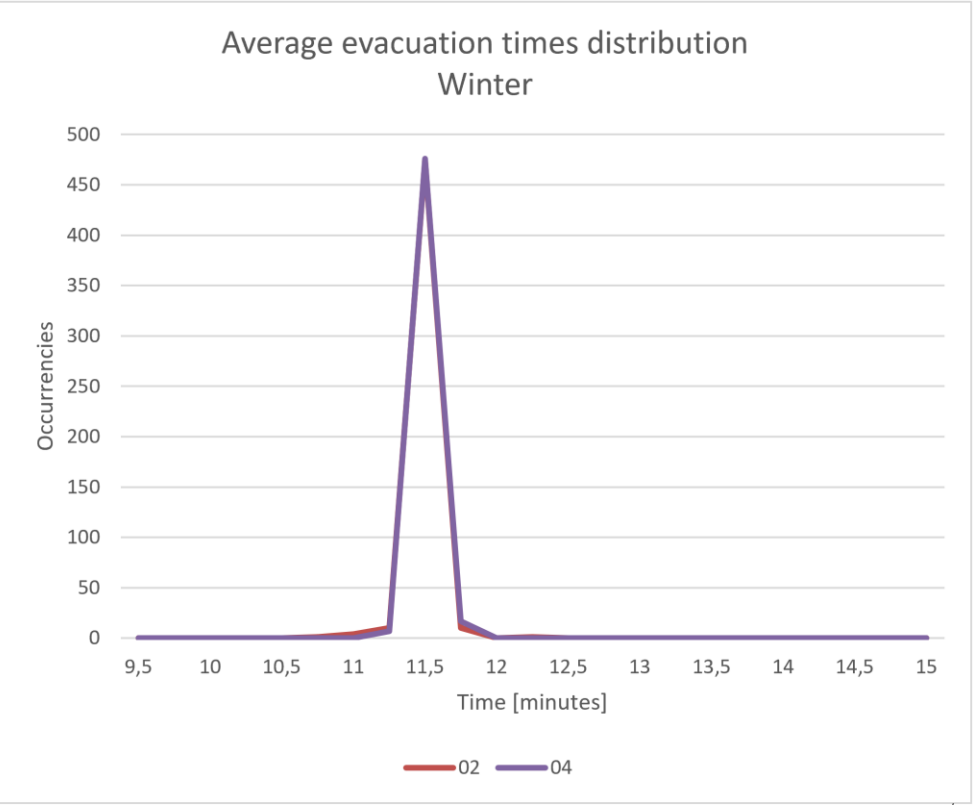




SIMULATION

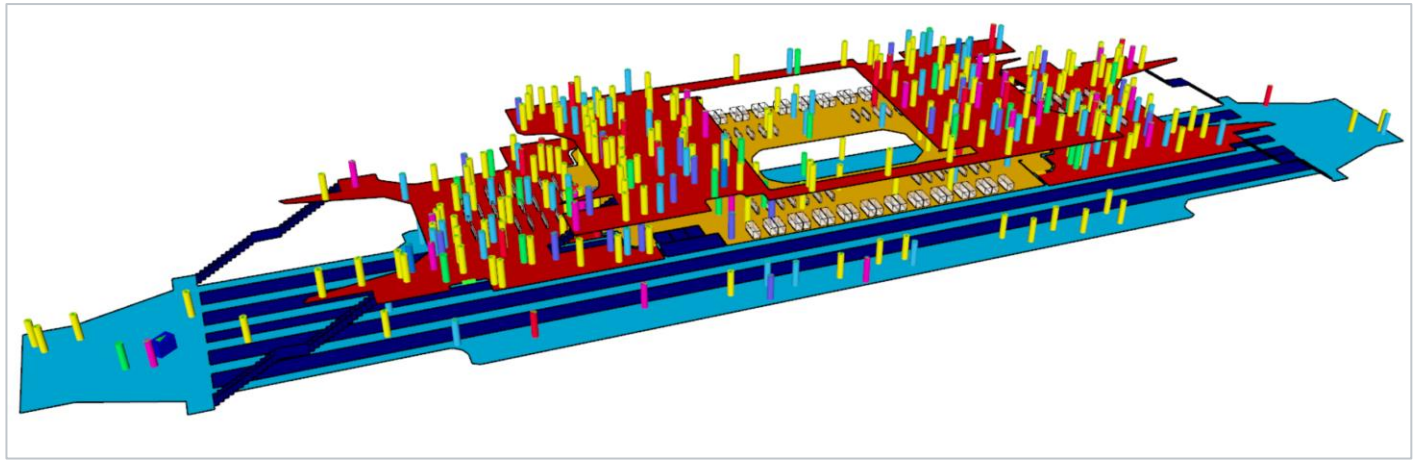
DIAGRAM AVERAGE EVACUATION TIME



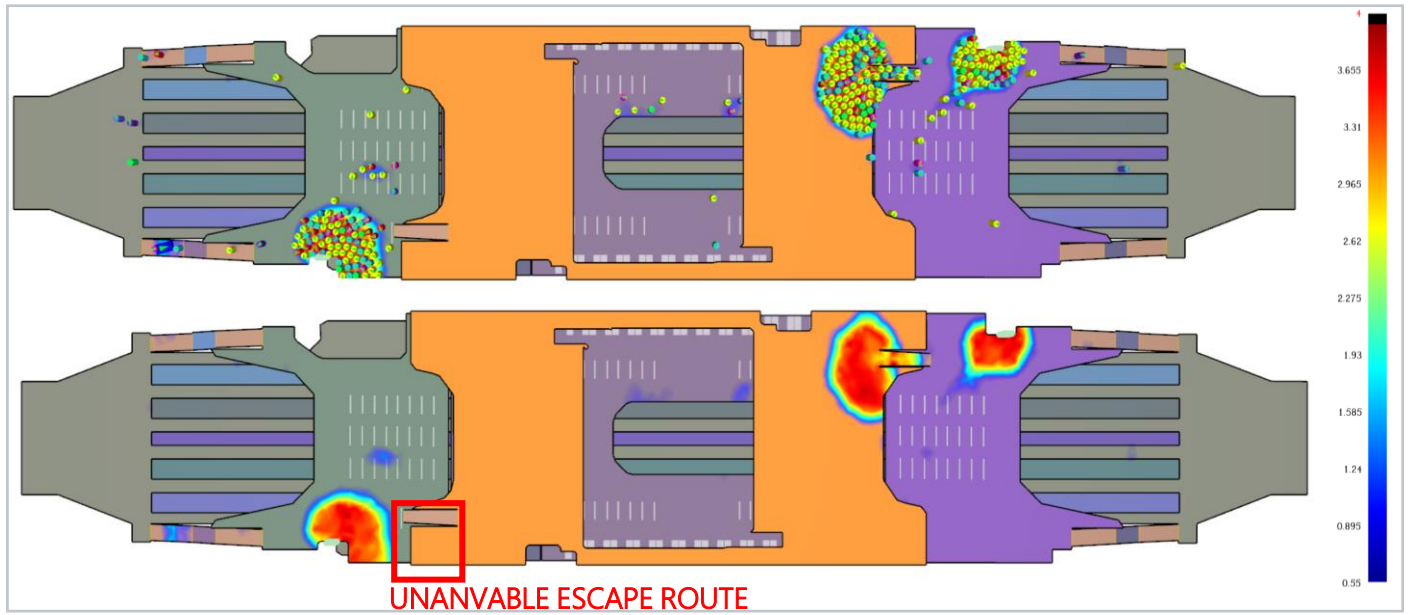


SIMULATION

An in-depth analysis of occupancy density carried out on the most unfavourable simulation made it possible to understand how, even if the maximum evacuation time fulfils its requirement, there is a problem related to the level of congestion in a specific area.



Ferry ship model (*Pathfinder software*)



Model of the ferry ship – Occupancy density *(Pathfinder software)*

CONCLUSIONS

Effective fire risk assessment and consequent management cannot be put in place with the support of a single approach or with a safety concern relegated to a single phase of the life-cycle (e.g. during design activities) and no single scenario.

Proper fire safety level can be achieved if fire risk is managed also during operation phases, including the reaction to real recorded events.

Technical safety, especially during design, is not enough while, technical safety insights may benefit from the availability and tools (as fire and pedestrian simulation) in order to understand specific threats and conditions, test different hypothesis, etc.

Human factor is a key element for the availability and the effectiveness of a number of different preventive and protective barriers, as well as the first cause of marine accidents involving ferries.

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Thank you!

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