Evacuation of passenger ships: challenges and research activities

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  - Statistical analysis of accidents on passenger ships leading to evacuation
  - Evacuation and rescue of passengers: a global process
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  - Risk analysis of the MAR process

► Conclusions
Background on evacuation and rescue of passengers

Statistical analysis of accidents on passenger ships leading to evacuation
General statistics on passenger ships

General statistics on passenger ships’ fleet

- Ro-Pax: 2/3 of the fleet, 65% of passenger transport capacity
- Cruise ships: 12% of the fleet, 22% of the passenger transport capacity
- “Others” includes non-SOLAS ships, High Speed Crafts etc. Most of them are less than 120m long.

The accident analysis concentrated on

- Ro-pax and other passenger ships having a length larger than 120m

LRFP and LMIU database

- Period analysed: last 10 years
- Keywords sought for such as “assembl”, “abandon”, “rescue”, “muster” etc: gave 171 accidents among which 135 pertinent cases
Accident statistics on passenger ships

Statistics showed that

- ~50% of casualties leading to abandonment are related to fire or grounding events
- ~50% of casualties lead to disembarkation at sea
- Fire at 50% of the time leads to disembarkation at sea
- Grounding leads (logically) to an evacuation at sea at 70% of the time
- Other events (collisions, steering, machinery problems) lead to disembarkation in port 70% to 90% of the time
- A mustering phase is not clearly stated in the database, but it is suspected in most of the cases (88%)
- 30% of the cases mustered had proven or suspected listing conditions
- 19% had proven or suspected smoke conditions

<table>
<thead>
<tr>
<th>Casualty Group</th>
<th>Basic Retrieval Abandon at sea (by any means)</th>
<th>Disembark at berth</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision</td>
<td>1%</td>
<td>10%</td>
<td>11%</td>
</tr>
<tr>
<td>Contact</td>
<td>2%</td>
<td>11%</td>
<td>13%</td>
</tr>
<tr>
<td>Fire / Explosion</td>
<td>12%</td>
<td>13%</td>
<td>25%</td>
</tr>
<tr>
<td>Foundered</td>
<td>4%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>Hull / Machinery damage</td>
<td>2%</td>
<td>15%</td>
<td>17%</td>
</tr>
<tr>
<td>Wrecked / Stranded</td>
<td>21%</td>
<td>8%</td>
<td>30%</td>
</tr>
<tr>
<td>Total</td>
<td>45%</td>
<td>55%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suspicion of list</th>
<th>MUSTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>64%</td>
</tr>
<tr>
<td>1</td>
<td>6%</td>
</tr>
<tr>
<td>2</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>20%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suspicion of smoke spread</th>
<th>MUSTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>78%</td>
</tr>
<tr>
<td>1</td>
<td>4%</td>
</tr>
<tr>
<td>2</td>
<td>7%</td>
</tr>
<tr>
<td>3</td>
<td>12%</td>
</tr>
</tbody>
</table>
Accident Analysis Reports

Lisco Gloria 2010

Vincenzo Florio 2004

Explorer 2007
Background on evacuation and rescue of passengers

*Evacuation and Rescue of passengers: a global process*
Mustering, Abandonment and Rescue route

1. Assembly to muster stations
2. Transfer to embarkation station
3. Embarkation in LSAs / launching of LSAs
4. Clearing off the vessel
5. Waiting for rescue
6. Rescue

Onboard vessel

At sea
Assembly to MS and transfer to embarkation station

Procedure

- Sweeping phase
- Group movement to assembly stations

- Regrouping into LSA groups
- Group transfer to LSAs
- In parallel: preparation of LSAs
- + various life-vest retrieving procedures (at MS, on way to LSA, go back in cabins)
Different life-vest retrieving procedures

Procedure A
- Public spaces
- Assembly Station

Procedure B
- Public spaces
- Cabins
- Assembly Station

Procedure C
- Assembly Station
- Cabins
- Public spaces
Embarkation in LSAs / launching of LSAs

Procedure

- Launching of LSA before or after embarkation depending on LSA type
- Davit launched Lifeboats:
  - Embarkation
  - Lowering
- Marine Evacuation Systems (MES)
  - Chutes & rafts deployment
  - Going down chutes
  - Transfer from platform to rafts
- Release LSAs
Clearing off the vessel and waiting for rescue

Procedure

- For rafts: attach towing line to lifeboats and/or rescue boats
- Sail away from abandoned vessel
- Wait for rescue

RNLI relief Severn class all-weather lifeboat towing the large 100-man liferaft in Portland Harbour. Photo credit RNLI

FASSMER partially-enclosed Lifeboat (FP6/SAFECRAFTS)
Rescue

Procedure

- No standardized procedure; depends on SAR appliances availability (so on location of evacuation zone)
- MRCC boats
- Helicopters
- Passing (re-routed) ships
Background on evacuation and rescue of passengers

*Regulatory framework: equipment and procedures*
Regulations / Life Saving Appliances

► LSA:
- SOLAS Ch III
- Life-Saving Appliances code
- A.689(17)
- A.520(13)
- MSC.81(70)

► Alternative design & arrangement for LSAs:
- SOLAS Ch III Reg.38
- MSC.1/Circ.1212

Guidelines on alternative design and arrangements for life-saving appliances

Guidance Note
NI 560 DR DIN E
January 2010
Regulations / Mustering & Abandonment

► Design:
- Means of escape SOLAS Ch II-2 Reg. 13:
  - 2 widely separated means of escape, door opened in the way of escape, direct access to stairway enclosure, lightings, locking systems of doors…
  - FSS Chap 13: design of handrails, width of escapes, landings, assembly stations…
  - ROPAX: Clear escapes, fixed furniture, max +/- 2 decks to climb, cabin safety instructions, load bearing handrails, evacuation analysis (MSC Circ. 1238 Guidelines for evacuation analysis)

► Procedures:
- Procedure, drills and exercises (ISM Code Sec. 7&8, IMO Resolution A.852(20), Circ. 1238)
- Passengers identified (number, gender, age, disabilities, …) SOLAS Ch.III Reg.27
- Safety instructions to passengers
  - Muster List (SOLAS Chapter III Reg. 37)
  - Muster for instructions must take place within 24h after embarkation (SOLAS Chapter III Reg. 8.2 and 8.4)
  - Drills weekly (SOLAS Chapter III Reg. 19)
  - Announcements (IMO A.691(17), Circ. 699
- Officers
  - Emergency procedures (STCW Code Section All, MERSAR)
  - Crisis management (STCW Code Section AV)
- Decision Support System (SOLAS Ch.III Reg. 29)
- Launching within 30 min from abandon ship signal (SOLAS Chapter III Reg. 21.1.3)
Regulations / Rescue

► Design:
  - No specific requirement

► Procedures:
  - Information on passengers to be readily available to SAR services in case of undesirable event (SOLAS Ch.III Reg.27)
  - Procedures for alerting SAR Authorities (MSC/Circ.892)
  - Crew should send daily report to their company (MSC/Circ.1043)
  - Helicopter onboard facilities and landing areas (IMO Res. A.855(20), MSC/Circ.895)
  - Co-operation plans between SAR and Passengers ships (IMO MSC/Circ.1079 COMSAR/Circ.31, IAMSAR Manual)
  - Recommendations to coastal states to provide SAR services (UNCLOS)
 Regulations / Safe Return to Port

Safe Return To Port

- SOLAS Chap II-2 Reg 21 - Casualty threshold, safe return to port and safe areas
- SOLAS Chap II-1 Reg 8-1 System capabilities after a flooding casualty on passenger ships
- MSC.1/Circ.1214 – Performance standards for the systems and services to remain operational on passenger ships for safe return to port and orderly evacuation and abandonment after a casualty

<table>
<thead>
<tr>
<th>Fire or flooding but casualty threshold not exceeded</th>
<th>Casualty but casualty threshold exceeded</th>
<th>Decision to start abandonment</th>
<th>Abandonment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pax directed to safe areas</td>
<td>Pax directed to Assembly Stations</td>
<td>Pax directed to LSA</td>
<td>LSA separated</td>
</tr>
</tbody>
</table>

Ship able to return to port:
1. the safe area(s)
2. providing all occupants with the basic services to ensure that the health of passengers and crew is maintained:
3. ventilation design shall reduce the risk that smoke and hot gases could affect the use of the safe area(s); and
4. means of access to life-saving appliances shall be provided from each area identified or used as a safe area, taking into account that a main vertical zone may not be available for internal transit.

Ship able to be evacuated and abandoned orderly. Emergency systems capable of operation > 3h in the remaining zones:
1. fire main;
2. internal communications (in support of fire-fighting and evacuation);
3. means of external communications;
4. bilge systems for removal of fire-fighting water;
5. lighting along escape routes, at assembly stations and at embarkation stations of life-saving appliances; and
6. guidance systems for evacuation shall be available.
Challenges and Bureau Veritas R&D activities

Risk analysis of the MAR process
Risks associated with the MAR process

► From start of mustering process until passengers are embarking LSAs:

- The critical issue is a time issue: people should evacuate before being harmed by fire heat and emissions or before the ship founders/capsizes.

- Performance standard = comparison of fire progression / ship stability degradation with the time required to embark all people from the start of the mustering (e.g. Required Safe Egress Time vs Available Safe Egress Time).

► From embarkation in LSA until rescue:

- A series of hazards can be identified, that will progressively degrade the health status of people along the rescue route.

- The duration of the process is less important, but still remains to be considered for the time of exposure to adverse climate/motion conditions.

- Performance standard = human health status
Risk Analysis / Mustering process and embarkation

- Fire and Evacuation simulations (FP6/MarNIS, FP7/SAFEGUARD):

- Enrichment of current Circ.1238 scenarii for evacuation simulations (FP7/SAFEGUARD):
  - Congestion criterion, degraded cases in accordance with SRTP concept
  - Life vest retrieval, group movement, disembarkation at berth, people demographics, simulation of assembly + embarkation in LSAs
## Identification of prioritised functions for an emergency response system to improve the mustering and embarkation process (FP6/MarNIS):

<table>
<thead>
<tr>
<th>Priority</th>
<th>Function</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gathering assembly station</td>
<td>Count and give name of passengers entering the Assembly Station.</td>
</tr>
<tr>
<td>2</td>
<td>Embarking LSA</td>
<td>Count and give name of passengers entering the LSA</td>
</tr>
<tr>
<td>3</td>
<td>Find people requiring care</td>
<td>Give name and location of people permanently identified as requiring specific care, as soon as danger is identified.</td>
</tr>
<tr>
<td>4</td>
<td>Ship sweeping phase</td>
<td>Detect presence of people in sweeping zones</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide detected persons locations (optional)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyse detected persons behaviour to detect abnormal behaviour (optional)</td>
</tr>
<tr>
<td>5</td>
<td>Travel from sweeping zone assembly point to AS</td>
<td>Provide pax and crew location and name</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyse individual pax and crew behaviour</td>
</tr>
<tr>
<td>6</td>
<td>Travel from AS to EA</td>
<td>Provide pax and crew location and name</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyse individual pax and crew behaviour</td>
</tr>
<tr>
<td>7</td>
<td>Normal safety groups gathering</td>
<td>Provide position and name of safety groups’ crewmembers anywhere on the ship</td>
</tr>
</tbody>
</table>
Risk Analysis / Mustering process and embarkation

► Time to embark

- mockup tests performed by FASSMER in FP6/SAFECRAFTS
- XXL-Series 250 persons
Risk Analysis / Abandonment and Rescue

- Risk based study performed in FP6/SAFECRAFTS (development of an engineering analysis method to demonstrate equivalency of Alternative Design and Arrangements of Life-saving Appliances)

- Rescue route divided in phases, elements and obstacles

- Degradation of “Human Health Status” assessed while passing each obstacle

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Related mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Health (GH)</td>
<td>Good physical and mental health</td>
<td>Good mobility</td>
</tr>
<tr>
<td>Moderate Injury (MI)</td>
<td>Superficial scratches Moderate bleeding</td>
<td>Mobility degraded</td>
</tr>
<tr>
<td>Severe Injury (SI)</td>
<td>Fractures and/or trauma</td>
<td>Mobility requiring assistance</td>
</tr>
<tr>
<td>Deceased (D)</td>
<td>Fatal injury</td>
<td>No mobility</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Phases</th>
<th>Elements</th>
<th>Obstacles</th>
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<tbody>
<tr>
<td>1</td>
<td>Deployment</td>
<td>Impossible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Malfunction</td>
</tr>
<tr>
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<td>Boarding</td>
<td>Mobility failure</td>
</tr>
<tr>
<td></td>
<td>Lowering</td>
<td>Premature release</td>
</tr>
<tr>
<td></td>
<td>Release</td>
<td>Impact hull / structural failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Impact hull / injuries</td>
</tr>
<tr>
<td></td>
<td>Clear ship</td>
<td>Fail manoeuvring</td>
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<tr>
<td>2</td>
<td>At sea</td>
<td>Capsizing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seasickness / hypothermia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Being tossed around</td>
</tr>
<tr>
<td>3</td>
<td>Recovery</td>
<td>Climbing pilot ladder</td>
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Risk Analysis / Abandonment and Rescue

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</tbody>
</table>
Risk Analysis / Abandonment and Rescue

- Relative contribution of individual obstacles to the overall degradation of the Success Rate = identification of critical areas for improvements

- Sea State 0-1, Abandoned vessel in beam seas with list 0° and trim 0°

- Davit launched lifeboat
Risk Analysis / Abandonment and Rescue

- Relative contribution of individual obstacles to the overall degradation of the Success Rate = identification of critical areas for improvements
- Sea State 6, Abandoned vessel in beam seas with list 20° and trim 10°
- Davit launched lifeboat

Critical areas for improvements

- Fall/maneuvering
- Premature release
- Fail to release
- Injuries, slamming
- Structural failure, impacts
- Fail to start engine
- Climbing, pilot ladder
- Capsizing
- Malfunction
- Injuries, impacts
- Seasickness
- Being tossed around
- Impossible
- Mobility failure
Risk Analysis / Abandonment and Rescue

► Project FP7/FLOODSTAND:

- Assessment of the risk level of the whole MAR process and comparison with the assessment of the risk associated with remaining onboard in case of flooding event

- Improvement of the rescue phase risk assessment: rescue phase duration simulation; example: Rescue of 1000 people in the Cap Gris-Nez region
Risk Analysis / Abandonment and Rescue

![Graph showing the number of people at sea, in transportation, and arrived onshore over time. The graph indicates that all people are recovered from LSAs by approximately 700 minutes.](image-url)
Conclusions
Conclusions

► MAR process risk analysis
  - Difficult exercise because of many components, phenomena, including Human Element
  - This can be an issue for risk based approval of LSA Alternative Design studies
  - Risk analysis shows that areas of improvement concern situations when LSAs are close to the abandoned or rescue ships:
    • LSA maneuvering/powering capabilities in adverse weather condition
    • LSA lowering and release
    • Transfer of people from LSA to rescuing ship (no standard for rescue equipment onboard all ships)

► Needs for future research activities:
  - Better consideration for procedures in evacuation models
  - Human behaviour in emergency situations ?
  - Decision Support Systems
  - Prediction of damaged (flooded) passenger vessels time-to-survive in sailing condition (Safe Return To Port)