IMO INF PAPER SUMMARY TO THE ENHANCED SCENARIOS PAPER

This paper details the work undertaken as part of the EU FP7 project SAFEGUARD to develop representative scenarios. It is recommended that the scenarios relating to fire, heel and trim are considered to replace the current secondary cases. A comprehensive list of possible scenarios relevant to the operation of the ship is also considered. Finally it is recommended that the congestion criteria is based on the maximum allowable evacuation time and becomes a pass/fail criterion.

FIRE - The aim was to create a benchmark fire case which modelled the impact of a severe fire without requiring a full fire simulation. To do this the change in evacuation procedures and the reduction in travel speeds of passengers due to smoke obscuration were both tested.. Several ways to define the affected (degraded) main vertical zone (MVZ) are discussed.

It is recommended to modify the assembly procedure for the fire case as follows:

1. Identify the MVZ to be degraded. This zone is considered to contain the fire;
2. Agents within the affected MVZ exit the zone horizontally moving to their nearest neighbouring MVZ. If the affected MVZ is an end zone then all agents move horizontally to the nearest neighbouring MVZ.

Examples of the fire scenario were tested on a cruise vessel geometry. The assembly time for the 95th percentile case in the fire benchmark day case was found to increase by 34% (310 s) compared to the standard day case. For the fire benchmark night case, the assembly time for the 95th percentile case is increased by 30% (470 s). For this vessel, the total assembly time for the fire benchmark day and night cases are 20.3 min and 33.5 min respectively, both well within the maximum allowed.

HEEL AND TRIM - Additional scenarios have been developed involving conditions of adverse heel, trim and motions. Three potential scenarios were identified: Scenario (a) static heel of 20° and trim of 10°. (b) Static heel with roll motion superimposed from t = 0, static heel: 15°, roll amplitude: 5° and roll period: 20 s. (c) Time-varying heel with roll motion superimposed from t = 0, heel: linearly varying from 0° at t = 0 to 15° at t = 60 minutes and then held steady, roll amplitude: 5° and roll period: 20 s.

Scenario (a) was tested. The basis assembly times (95%-ile) were estimated to be 25.7min and 16.5min (night and day cases, respectively). In both cases, the impact of the heel and trim conditions was to increase the assembly time. The extent of the increase was shown to be scenario- and ship layout-specific. For the night case, the increase in assembly time was of up to 11% for both heel and trim cases. For the day case, the increase was up to 24% and 13% for heel and trim cases, respectively.

CONGESTION CRITERIA – It is further recommended that the congestion criterion becomes a pass/fail requirement. It is also recommended that the time component is dependent on the maximum assembly time allowed for the ship rather than the predicted assembly time.

SCENARIOS RELEVANT TO THE PURPOSE OF THE SAFE OPERATION OF THE SHIP – One of the key observations made by the project team was that the application of pre-defined benchmark scenarios to different designs and classes was not straightforward. A list of further, potential scenarios is outlined that could be tested as part of the evacuation analysis, these include: a hybrid case; public spaces to 100% capacity, emergency disembarkation to shore etc. These additional scenarios are not intended to be compulsory scenarios but are examples of additional scenarios that an Administration could consider to be sufficiently important to be analysed, as is possible within the current Guideline document. The choice of scenario would need to be justified and a minimum from the list required.

IMO INF PAPER SUMMARY – THE ENHANCED SCENARIOS PAPER

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DISCLAMER: The opinions expressed are solely those of the authors.

1. Background

The Sub-Committee on Fire Protection, at its fifty-fourth session, took note of the results (FP 54/9 and FP 54/INF.6) of the correspondence group established at FP 53 to consider this matter. Among other tasks, the correspondence group agreed that amending circular MSC.1/Circ.1238 with relevant scenarios should be considered. Thus, FP 54 invited Member Governments and international organizations to submit detailed proposals to FP 55.

The Sub-Committee on Fire Protection, at its fifty-fifth session, took note of the detailed proposal FP 55/7 and requested a presentation of EU project SAFEGUARD scenarios at the next session. In addition three full journal papers describing this work will soon be available at the RINA website.

2. Executive summary

This paper details the research and testing undertaken through project SAFEGUARD to develop additional scenarios for possible adoption in a modified set of guidelines for the evacuation of passenger vessels. Through research a set of representative scenarios have been identified, some of which have been tested. It is recommended that scenarios relating to fire, heel and trim are considered to replace the current secondary cases and a more comprehensive list of possible scenarios relevant to the operation of the vessel are considered.

3. Enhanced secondary fire benchmark scenarios

An attempt has been made to develop a fire benchmark scenario that could be included in a modified form of the IMO evacuation analysis guidelines. The aim was to create a benchmark scenario which in some way modelled the impact of a severe fire on the evacuating passengers without introducing the need to undertake a full fire simulation.

Fire generates hazardous gases known as fire hazards. The two primary impacts of fire hazards are;

- The reduction in travel speeds of passengers due to smoke obscuration
- Change in the evacuation procedures associated with the main vertical zone (MVZ) containing the fire, referred to as the degraded MVZ.

In the SAFEGUARD study only a single degraded MVZ was identified at any one time.

Two fire scenarios were considered, one in which all the decks within the affected MVZ are considered to be affected by fire hazards (in line with the fire casualty scenario implicit in Regulation 22.3 of SOLAS Chapter II-2) and a scenario in which only a single deck within the degraded MVZ is affected. In the former there is only a single case that must be examined; while in the latter each deck within the degraded MVZ must be examined in turn resulting in a case for each deck in the degraded MVZ. The analysis suggested both scenarios result in identical conclusions and as the former requires less effort it is selected as the fire scenario to examine.
Several possible ways to define the degraded MVZ include:

- The MVZ having the maximum person load at the time of the alarm: MVZ_{load}
- The MVZ from which the last passenger to assemble starts in the respective primary case: MVZ_{time}.
- The adjacent zone to MVZ_{time} which, when degraded, makes a maximum number of additional persons evacuates through MVZ_{time}: $MVZ_{adja/time}$
- The adjacent zone to MVZ_{load} which, when degraded, makes a maximum number of additional persons evacuates through MVZ_{load}: $MVZ_{adja/load}$

To identify the MVZ_{time} it is suggested to perform a batch of simulations of the primary case and either:

1. Select the zone based on the 95th percentile run and retain the muster station and the population assignment in the degraded cases.
2. Assess across the batch and use the zone which appears the most times.

The method of selection must be stated in the analysis report.

Each of the different approaches to selecting the degraded MVZ generates a scenario which is challenging and tests the evacuation capabilities of the vessel in different ways:

- The degraded case where MVZ_{load} is selected (degradation 1) has merits as it moves the single largest population of any one zone to adjacent zones, thus challenging the adjacent zones escape routes.
- The degraded case where MVZ_{time} is selected (degradation 2) means some persons will take longer to reach their muster station.
- The degraded case where $MVZ_{adja/time}$ is selected (degradation 3) increases the load on MVZ_{time}. This should slow down further the last person to assemble.
- The degraded case where $MVZ_{adja/load}$ is selected (degradation 4) increases the load on $MVZ_{load.}$ This further challenges its escape route.

All degradations are considered to have merit for investigation; however assessing all would constitute a significant amount of work therefore the following is proposed.

- In all cases degradations 2 and 3 are assessed
- In cases where the passengers may have to cross one or more MVZs to assemble (cruise type vessels, day case) all four degradations are assessed.

Whilst the above proposals are seen as one way of considering the degradations, further discussion could alter the manner in which they are included in the final requirement.

Upon investigation, the reduction in agent travel speeds within the degraded zone was not found to have a significant impact on the time to assemble; even when the travel speeds of the affected agents were reduced to 0.3 m/s. Thus, there is no need to include a speed reduction in the proposed fire benchmark scenario. The modified evacuation procedures were found to have a significant impact on the time to assemble.

The modified assembly procedure for the fire case is as follows:

- Identify the MVZ to be degraded. This zone is considered to contain the fire;
- Agents within the affected MVZ exit the zone horizontally moving to their nearest neighbouring MVZ. If the affected MVZ is an end zone then all agents move horizontally to the nearest neighbouring MVZ.

The following assumptions should be made:

- Any assembly stations within the affected MVZ are considered viable and agents may pass through the affected MVZ, including any open decks, only on the decks containing the assembly stations;
- All stairs within the affected MVZ are considered non-viable. Crew and passengers may only use stairs in the unaffected zones;
- Crew involved in searching tasks are assumed to have the lowest response time associated with the scenario.

This procedure and assumptions are illustrated in Figure 1.

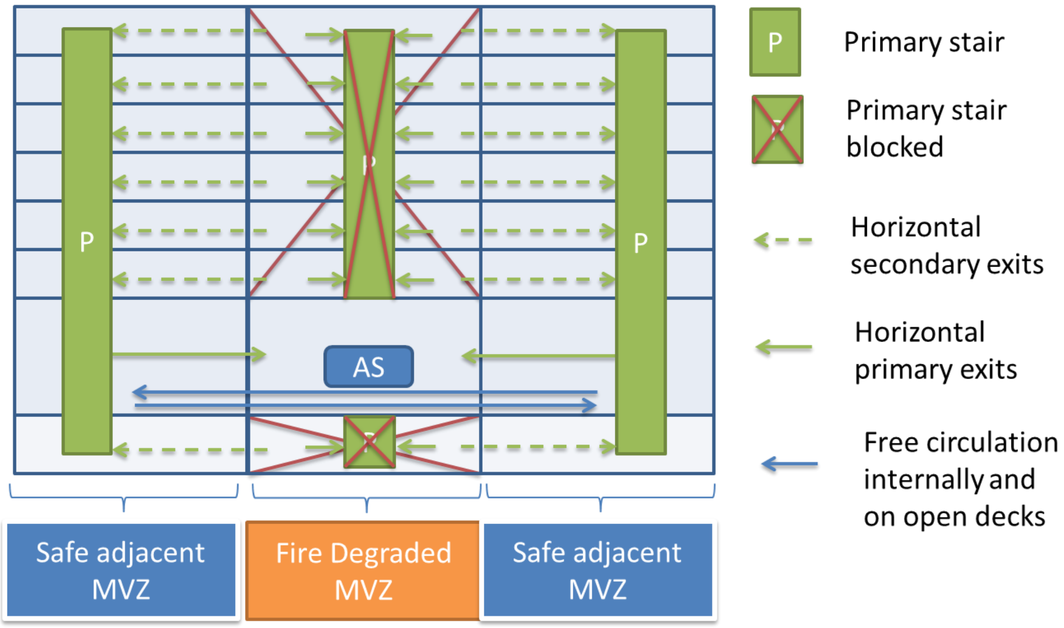

Figure 1: Illustration of procedures for the degraded cases.

As an example of the impact of the suggested fire degraded benchmark scenarios, degraded case 3 (day and night) was assessed as part of SAFEGUARD for a large cruise ship configuration consisting of seven MVZ and 2502 passengers and 668 crew members in the day case and 3001 passengers and 801 crew members in the night case. The assembly time for the 95th percentile case in the fire benchmark day case was found to increase by 34% (310 s) compared to the standard day case. For the fire benchmark night case, the assembly time for the 95th percentile case is increased by 30% (470 s). For this vessel, the total assembly time for the fire benchmark day and night cases are 20.3 min and 33.5 min respectively, both well within the maximum allowed.

It is however noted that the suggested approach does not produce a prediction of possible fire related fatalities or injury levels, nor does it provide an assessment of the fire safety provision afforded by the design. To do this requires a detailed fire simulation for a prescribed fire scenario coupled with an evacuation simulation. While this approach is currently possible and normally used in the land based building industry, it has the disadvantage of currently being expensive in terms of time, resources and computational power.

4. Heel and trim scenarios

From the starting point of developing a *heel scenario*, additional scenarios have been developed involving conditions of adverse heel, trim and motions. The aim was to develop sensible, representative scenarios and the means to implement them within software. Development was completed through an extensive review process of current legislation, accident reports, damage calculations and model tests. Various factors were identified which could effect the evacuation of a vessel. The additional scenarios were simplified to those which involve inclinations and rotational motions of the decks.

Three potential scenarios were identified:

(a) Static heel or trim from the start of the assembly process (t = 0)

- heel: 20°
- trim: 10°

(b) Static heel with roll motion superimposed from t = 0

- static heel: 15°
- roll amplitude: 5°
- roll period: 20 s

(c) Time-varying heel with roll motion superimposed from t = 0

- heel: linearly varying from 0° at t = 0 to 15° at t = 60 minutes and then held steady
- roll amplitude: 5°
- roll period: 20 s

Due to limited research on the subject of how motions effect the ability of passenger and crew to evacuate a vessel, only scenario (a) was investigated as part of SAFEGUARD.

Available data was reviewed on the effect of vessel trim and heel on persons walking on flat and even environments and whilst ascending or descending stairs. Changes to travel speed were found to be of primary influence. On this basis and because only limited trial data is available a simplified approach was adopted and look up tables defining speed variation factors were developed for software implementation. The following scenarios were evaluated:

- case 1H: Night case with 20° heel
- case 1T: Night case with 10° trim
- case 2H: Day case with 20° heel
- case 2T: Day case with 10° trim

Utilising geometry from a cruise vessel the scenarios were tested. The basis assembly times (95%-ile) were estimated to be 25.7min and 16.5min (night and day cases, respectively). In both cases, the impact of the heel and trim conditions was to increase the assembly time. The extent of the increase was shown to be scenario- and ship layout-specific. For the night case, the increase in assembly time was of up to 11% for both heel and trim cases. For the day case, the increase was up to 24% and 13% for heel and trim cases, respectively.

5. Congestion criterion

A further suggested modification to all scenarios involves taking into account the congestion criteria as a pass/fail requirement that the ship must comply with in addition to the final evacuation time criterion. The congestion areas are currently identified as those areas where the density of people exceeded a density threshold (4p/m²) for longer than 10% of their assembly time (exceeding the time criterion). It is further suggested that rather than the time component being dependent on the predicted assembly time for the ship, it is based on the maximum assembly time.

Thus for all RO-PAX ships and other passenger ships with three MVZs or less the critical time component is given by 10% of the maximum assembly time, i.e. 10% of [(60’-20’)/1.25=32’] or 3’12’’ while for a ship of more than three MVZ’s, the critical time component is given by 10% of [(80’-20’)/1.25=48’], or 4’48’’. The modified requirement is a more stringent congestion threshold than used in the current guidelines as it is a pass/fail criterion. The congestion criterion is considered to be reached when a density of 4p/m² or more is observed continuously for a time greater than the critical time.

The modified congestion criterion guaranties that even if the assembly phase is short, there is no critical congestion area that persists for more than 10% of the maximum allowed assembly time. This additional mandatory criterion ensures that the dynamic of the evacuation is acceptable and not only the final assembly time. Within detailed analysis conducted as part of the SAFEGUARD project the density criteria challenged the ship designs considered while the evacuation time was considered acceptable, in particular during Day case scenarios.

6. Scenarios relevant to the purpose of safe operation of the ship

Identifying correct, relevant, fit for purpose scenarios that allow understanding as well as compliance should be the aim of the guidelines. Within the SAFEGUARD project, analysis of historical data, statistics and expert judgement were used to identify a range of additional possible scenarios that would be relevant for particular phases of ship operations. These scenarios may in fact be more relevant and demanding than the currently accepted Day and Night Scenarios. These included:

- Hybrid case (50% capacity in cabin, 50% capacity in public spaces) representing a morning or an evening situation and using specific passenger response times appropriate for the location.
- Enhancing the day case to populate the outer decks as well as the public spaces.
- Outer decks, theatres, main restaurants, filled to 100% capacity in complementary day cases.
- Emergency disembarkation to shore when the ship is at berth.
- Modelling of actual procedures on-board including the procedures relating to life vest management.
- Modelling of launching and abandonment in line with procedures and equipment.
- Crew management in emergency planning.
- Initial distribution of person on board as per working shifts (for Special Purpose Ships, SPS)

One of the key observations made by the project team was that the application of pre-defined benchmark scenarios to different designs and classes was not straightforward. Some different scenarios have been tested by the project team. Any one of these (or others not tested) could be the worst case.

These additional scenarios are not intended to be compulsory scenarios but are examples of additional scenarios that an Administration could consider to be sufficiently important to be analysed, as is possible within the current Guideline document. The choice of scenario would need to be justified and a minimum from the list required.

Within SAFEGUARD, the Hybrid and the enhanced day case have been tested. They showed different evacuation dynamics (different congestion spots), and sometimes increase in evacuation times (from 10% to 16%).

The advantages of using appropriate, justified, fit for purpose scenarios over prescribed scenarios are numerous; Theoretical worst cases are identified, vessels are tested to these theoretical worst cases, having guidelines and scenarios with more flexibility would mean developments in ship design trends would more easily be accommodated, developments in software could be utilised to allow for more realistic testing of scenarios, real areas of concern identified by the owner/operator/flag administration could be identified and tested. However, before an additional scenario is considered for analysis, it is essential that sufficient realistic data is available to correctly configure the evacuation model. For example, while it may be interesting to examine scenarios involving retrieval of life vests, unless appropriate and robust data sets characterising the amount of time required to retrieve the life vest, don the life vest and appropriate walking rates on the flat and stairs for people wearing (or carrying) life vests is available the scenario will be unrepresentative and potentially misleading.

7. Actions requested

It is recommended that:

.1 The IMO 1238 should include the fire and heel degraded scenarios to replace the current case 3 and 4; and

.2 A fixed congestion criterion should be added to all cases;

.3 The sub-committee consider SAFEGUARD scenarios relevant for the purpose of safe operation of the ship.

8. Acknowledgement

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