IMO Information paper - RESPONSE TIME DATA FOR LARGE PASSENGER FERRIES AND CRUISE SHIPS

Robert Brown[1,2], Edwin Richard Galea[1], Steven Deere[1] & Lazaros Filippidis[1]
[1]Fire Safety Engineering Group, University of Greenwich, London, UK
[2]Offshore Safety & Survival Centre, Marine Institute, Memorial University, St. John's, Canada

1.0 Introduction

Understanding how people behave in emergency situations within maritime settings is vital if we are to design evacuation efficient vessels and evacuation procedures for crew to follow. An essential component of this understanding is the collection and characterisation of data for human performance when responding to alarms and moving to assembly stations. Unfortunately, little data exists relating to passenger response time or for full-scale validation of evacuation models specific to maritime environments. As part of the EU FP7 project SAFEGUARD, a series of five semi-unannounced full-scale assemblies were conducted at sea on three different types of passenger vessel. From these trials two full-scale validation data-sets[1] and five passenger response time data-sets were collected. The five response time data-sets, consisting of 2366 response time data points, represents the largest response time data-sets ever collected – on land or sea. One of the objectives of the SAFEGUARD project was to develop a series of passenger response time distributions that can be used in passenger ship evacuation analysis. Response time is defined as the time between the sounding of the alarm and the moment when passengers start purposeful movement to an assembly station.

In one of the first International Maritime Organization (IMO) documents to specify protocols for the use of ship evacuation models for the analysis and certification of passenger ship design, IMO MSC/Circ.1033[2], an arbitrary uniform random distribution was set to represent the response time behaviour of passengers. This has been shown to be unrepresentative of actual passenger response time and liable to produce incorrect or misleading conclusions concerning the suitability of ship design for evacuation[3] . As part of the EU FP5 project FIRE EXIT, passenger response time data was collected for a passenger ship at sea[4]. This data was accepted by the IMO and used in the formulation of IMO MSC.1/Circ.1238[5], the modified protocols for passenger ship evacuation analysis and certification. However, the response time data produced by FIRE EXIT related to only a single class of passenger vessel (RO-PAX with cabins) and only a single example of that class (Eurostar Roma (ER)). As such, the data cannot be considered representative of passenger ships as a whole. The IMO Fire Protection (FP) Sub-Committee in their modification of IMO MSC/Circ.1033 at the FP51 meeting in February 2007[6] invited member governments to provide, "...further information on additional scenarios for evacuation analysis and full scale data to be used for validation and calibration purposes of the draft revised interim guideline". The SAFEGUARD project was developed to meet this requirement by measuring passenger behaviour during planned assembly trials at sea on three different types of vessels – a ferry with cabins, a ferry without cabins and a cruise ship.

Here we present a summary of the findings and recommendations from the SAFEGUARD project relating to the Response Time Distributions (RTD) proposed for adoption in a modified version of IMO MSC.1/Circ 1238[5]. A full paper describing this work will be presented at the "SAFEGUARD Passenger Evacuation Seminar" hosted by RINA on 30 November 2012. The full paper will be available shortly after the seminar on the SAFEGUARD website at http://www.safeguardproject.info/downloads/.

1.1 Ship and Trials Details

The data that is suggested for adoption is derived from two vessels. The first (RP1) is a RO-PAX vessel operated by ColorLine and can carry approximately 2000 passengers and crew and over 700 vehicles. The route taken by the vessel during the data collection trials was from Kristiansand in Norway to Hirtshals in Denmark, a trip of 3 hours and 15 minutes. The ship contains a mixture of public passenger spaces spread over three decks including; business and traveller class seating areas (airline style seating), large retail and restaurant/catering areas, bar areas, indoor and outdoor general seating areas and general circulation spaces.
The second vessel (CS) is a cruise ship operated by Royal Caribbean Cruise Lines International and has a capacity of 2500 passengers and 842 crew. The route taken by the vessel during the data collection trial was from Harwich (UK) to St Petersburg (Russia) via Copenhagen (Denmark), a total voyage of about 7 days. The trial was conducted on the leg of the voyage to Copenhagen. The ship contains a variety of spaces spread over 12

passenger decks including; staterooms (cabins), restaurant areas, bar areas, large retail areas, theatre, cinema, gym, sports facilities, casino, indoor and outdoor general seating areas and general circulation spaces. The precise timing for each assembly drill was unannounced but for ethical reasons, the passengers were informed that at some time on their voyage an assembly drill would take place. It is worth noting that these assembly trials were conducted while the vessels were at sea; this is unusual as almost all ship assembly drills are conducted while the vessel is along side in port. It was important to undertake the drills while at sea as this added to the realism of the exercise and hence the collected data. Two assembly drills were conducted on RP1. The first took place on 4 September 2009 at 08:20 and the second on 5 September 2009 at 08:19 approximately 30 minutes after the vessel departed from Kristiansand enroute to Hirtshals. It is important to note that the trials took place on the same leg of the ship's regular route and that different passengers were onboard each day. A total of 1431 and 1349 passengers were onboard for the first and second trial, respectively. One assembly drill was conducted on the CS on 31 July 2010 at 09:01 on the morning after departure from the UK. A total of 2292 passengers were on board.

2.0 Data Collection and Analysis Methodology

In order to collect the response time for a passenger, one must observe the passenger's behaviour following the alarm and record the time that has elapsed to the point when the passenger is deemed to have started purposeful movement to the assembly station. In order to do this for as many passengers as possible in as many regions of the ships as possible, the team mounted battery-powered video cameras in strategic locations or made use of the ship's own CCTV camera system. Before each trial, the team ensured that cameras were synchronised to a known, pre-recorded trial time standard or that they were capable of recording audio so that the audible alarm could be used as a reference point for synchronisation. In total, 30 video cameras were installed on RP1, while on CS 106 cameras were used (94 of the ship's own CCTV cameras and 12 digital video cameras). A considerable amount of video data was collected during the five trials, approximately 14 GB of video data (6 hours of footage) during the first RP1 trial and 11.7 GB (5 hours of footage) on the second trial; approximately 37 GB of video data (53 hours of footage) during the CS trial. Given the vast amount of video collected and the large number of passengers to be analysed, a team of three people was trained to extract response times from the video footage. To ensure reliability and consistency in their results, the analysts had to pass an inter-rater testing process in which they each analysed the same set of passengers and compared their results. Analysis was undertaken using commercially available software - Adobe Premiere Pro. In total, 533 and 470 response time data points (trial 1 and trial 2 respectively) were collected from the RP1 trials (1003 in total) and 1228 data points were collected from the CS trial.

3.0 Proposed Modifications to RTDs used in IMO Evacuation Guidelines

The RTD currently used in the IMO guidelines governing ship evacuation analysis[5] are based on two assembly trials conducted on the ER. In total 194 unique response time data points were collected on ER from which two RTDs were generated, one for the Day Case, and one for the Night Case. In the following we propose modifications to these RTDs based on the SAFEGUARD data collected from three trials on two vessels (a RO-PAX vessel (RP1) and a Cruise Ship (CS)) which consists of 2231 response time data points in total – significantly more than were used to construct the RTDs currently used in IMO MSC. 1/Circ 1238[5] guidelines.

3.1 Cruise Ship and RO-PAX RTDs

The RTDs currently used for evacuation analysis of passenger ships within IMO MSC. 1/Circ 1238[5] is used for all types of passenger ships including RO-PAX and cruise ships. The data generated as part of the SAFEGUARD project clearly shows that the RTDs for RO-PAX vessels are significantly different to that for cruise ships. RTDs for cruise ships generally have longer and more significant tails compared to RTDs for RO-PAX vessels. It is thus suggested that the guidelines be modified so that different RTDs are used for RO-PAX and Cruise Ships. RTDs for both types of vessels are presented below based on data generated from the SAFEGUARD project.

3.2 Proposed RTD for RO-PAX Vessels.

The RTDs derived from the two SAFEGUARD trials on RP1 were found to be statistically identical and so they can be combined to produce a single RTD comprised of 1003 data points. Furthermore, this RTD is statistically almost identical to the existing Day Case RTD within the current guidelines governing ship evacuation analysis which is based on 67 response time data points derived from the earlier ER trials. Thus, a new Day Case RTD is proposed for the IMO guidelines to replace the existing RTD for RO-PAX vessels. This is based on combining the 1003 response time data points collected from the SAFEGUARD RP1 trials with the 67 response time data points that comprise the RTD currently used within the IMO evacuation analysis guidelines. While the proposed Day Case RTD for RO-PAX vessels is statistically similar to the existing Day Case RTD it is considered to be a more representative, robust and reliable RTD as it is based on significantly more data points (15 times more) than is currently used and is based on data from four trials from two different RO-PAX vessels.

The combined RTD is truncated at 300 s, removing the tail of the distribution, as is currently done for the IMO Day Case RTD. Since truncating the distribution represents 99.2% of the overall distribution, a scale factor must be applied so that the area under the curve equals 1.0. The new Day Case RTD is presented in Figure 1 and is described using Equation 1. Appropriate data to modify the Night Case RTD for RO-PAX vessels was not collected and so it is suggested that the RTD currently used for the Night Case within the IMO evacuation guidelines remains unaltered.

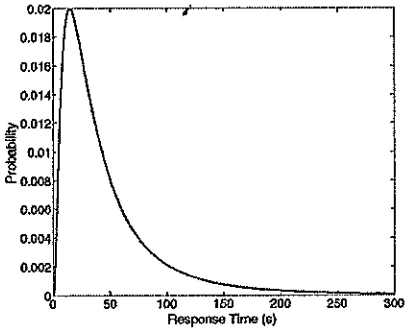

Figure 1. Suggested new IMO Day Case RTD for RO-PAX ferries

$$y = \frac{1.0076}{\sqrt{2\pi} \cdot 0.903x} exp\left[-\frac{(\ln(x) - 3.511)^2}{2 \times 0.903^2}\right] \qquad [1]$$

3.3 Proposed RTD for Cruise Ships.

It is suggested that the RTD derived from CS for public spaces should be used to represent the new Day Case RTD for Cruise Ships. The RTD is truncated at 300 s, removing the tail of the distribution, as is currently done for the IMO Day Case RTD. Since truncating the distribution represents 94.8% of the overall distribution, a scale factor must be applied so that the area under the curve equals 1.0. The new Day Case RTD for Cruise Ships is presented in Figure 2 and is described using Equation 2. The new Day Case RTD is based on 633 data points, considerably more than the 67 data points used in the existing IMO evacuation analysis guidelines.

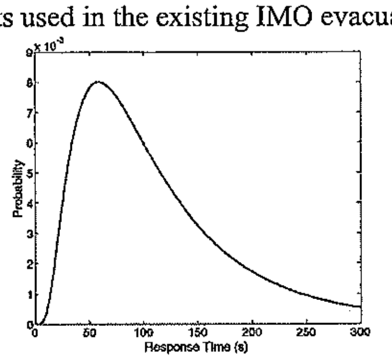

Figure 2. Suggested new IMO Day Case RTD for Cruise Ships

$$y = \frac{1.0548}{\sqrt{2\pi} \cdot 0.702x} exp\left[-\frac{(\ln(x) - 4.562)^2}{2 \times 0.702^2}\right] \qquad [2]$$

It is suggested that the RTD derived from the trial on CS for cabin areas should be used to represent the new Night Case RTD for cruise ships. Truncating the RTD at 300 s, which is done in the current IMO evacuation guidelines, results in only 60.3% of the data-set being included. Clearly, as a significant proportion of the data is represented in the tail, truncating the RTD at 300 s is not appropriate. It is suggested that the truncation point be extended to 700 s, which would include 90.3% of the original data-set and require the use of a smaller scaling factor to ensure the area under the curve equals 1.0. Furthermore, in keeping with the approach IMO uses to represent the night case RTD, this curve should also be shifted by 400 s to account for the fact that passengers would be sleeping (which is typically not the case for the trials conducted). This truncated, shifted and scaled curve is presented in Figure 3 and described using Equation 3. The new Night Case RTD is based on 598 data points, considerably more than the 127 data points used in the existing IMO evacuation analysis guidelines.

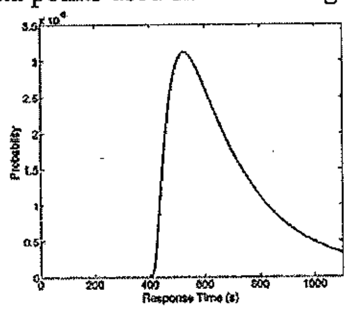

Figure 3. Suggested new IMO Night Case RTD for Cruise Ships

$$y = \frac{1.1074}{\sqrt{2\pi}\cdot 0.817(x-400)} exp\left[-\frac{(\ln(x-400)-5.49)^2}{2\times 0.817^2}\right] \quad [3]$$

4.0 Assessing the Impact of the New RTDs on Passenger Ship Assembly Times

Three new RTD are proposed for adoption by IMO to replace the existing RTD in IMO MSC. 1/Circ 1238[5]. The impact of these proposed RTDs on the assembly process is assessed using the maritimeEXODUS[3,4] software and two ship geometries, one for a RO-PAX vessel and one for a cruise ship.

A new Day Case RTD is suggested for RO-PAX vessels which is essentially similar to the existing RTD within IMO MSC. 1/Circ 1238[5] (Figure 1 and Equation 1). To assess the impact of the new RTD on the assembly process a Day assembly scenario, as specified by IMO MSC.1/Circ 1238[5], is investigated. The test geometry used in this analysis is the same RO-PAX ship geometry that was used in the original analysis of the IMO MSC. 1/Circ 1238 RTD[4]. This was a hypothetical RO-PAX vessel consisting of three main vertical zones across 10 decks, of which five decks could be occupied by passengers. The vessel has a capacity of 1650 passengers and has 150 crew. The software was run (50 times) using the IMO MSC. 1/Circ 1238[5] specified RTD and this process was repeated using the SAFEGUARD RO-PAX Day Case RTD (see Equation 1). The analysis of this case shows that the maximum difference between the assembly times for the two cases is 3.5%, with the 95th percentile cases differing by 3.2%. It is also noted that the total assembly time using both RTDs easily satisfies the IMO requirement for overall assembly times. There were also no significant differences between the two cases in terms of congestion generated during the assembly process. All the differences in values between the two models are considered insignificant (i.e. less than 10%) and as such it can be said that the two RTDs have the same impact on the simulations.

The proposed Day and Night RTDs for cruise ships (see Equations 2 and 3) are significantly different to those specified in IMO MSC. 1/Circ 1238[5] and so it is necessary to identify the likely impact these will have on the assembly process of a cruise ship. This is assessed by undertaking the Day and Night assembly scenarios as specified by IMO MSC. 1Circ 1238[5] for a cruise ship geometry. The test geometry used in this analysis is the same cruise ship geometry used in the SAFEGUARD validation analysis[7]. The vessel consists of 12 passenger decks, of which seven decks are accommodation spaces consisting of passenger cabins. The vessel has a maximum berthing capacity of 3001 passengers, which is the size of the population during the IMO Night scenario and a 2501 capacity during the IMO Day scenario.

The model parameters used in the simulations are compliant with those specified in IMO MSC. 1/Circ 1238[5] with the exception of the RTD. As is required by IMO MSC. 1/Circ 1238[5] a total of 50 repeat simulations were produced for each scenario and the 95th percentile case is selected to represent the prediction of the assembly process. Four different scenarios were run, the standard Day and Night scenarios (which utilise the RTDs specified in IMO MSC. 1/Circ 1238[5]) and the Day and Night scenarios using the SAFEGUARD RTDs (Equations 2 and 3 respectively). The proposed Day Case RTD was found to increase the predicted total assembly time for the 95th percentile case by an insignificant (0.1%) amount compared to the existing analysis. The proposed Night Case RTD was found to increase the predicted total assembly time for the 95th percentile case by a moderate amount (21.2%) compared to the existing analysis. The moderate increase in the assembly times is due to the significantly longer tail in the newly proposed cruise ship Night Case RTD which extends to 1100 s - beyond the upper limit of 700 s in the current night RTD specified in IMO MSC. 1/Circ 1238[5]. It is also noted that the total assembly time using both proposed new RTDs easily satisfy the IMO requirement for overall assembly times. There were also no significant differences between the two cases in terms of congestion generated during the assembly process.

5.0 Further Work

While the response time data collected in this work has been comprehensive, additional data is required to:

- Quantify the RTD for passengers in cabins on RO-PAX vessels. Sufficient high quality, reliable response time data is required to characterise the response times for passengers in cabins.
- Better quantify the impact of sleeping passengers on the night time RTD. Currently, the cabin space RTD is arbitrarily shifted by 400 s to represent sleeping passengers. A more reliable data set based on actual experimental data is required to characterise how long sleeping passengers will require to respond to the call to assemble.
- Explore the dependence of population demographics on the RTD. Passenger vessels may have very different populations based on the nature of the voyage. This may vary from significant numbers of young people to significant numbers of elderly people. The impact that this will have on passenger response times should be characterised.

6.0 Acknowledgement

The SAFEGUARD project (contract 218493) is funded under the European Union Framework 7 Transport initiative and Transport Canada Marine Safety and the Newfoundland and Labrador Research and Development Corporation.

7.0 References

[1] Galea, E.R., Deere, S., Brown, R., and Filippidis, L, An Evacuation Validation Data-set for Large Passenger Ships, To appear in the proceedings of PED2012 conference, Zurich, 2012.

[2] IMO, "Interim Guidelines for Evacuation Analyses for New and Existing Passenger Ships", IMO MSC/Circ 1033, 6 June 2002.

[3] Deere, S., Galea, E.R., Lawrence, P., Filippidis, L. and Gwynne, S., "The impact of the passenger response time distribution on ship evacuation performance", Trans of the RINA, Part A – Int Journal of Maritime Engineering, ISSN 14798751, Vol 148, Part A1, 2006, pp 35-44.

[4] Galea, E.R., Deere, S., Sharp, G., Filippidis, L., Lawrence, P., and Gwynne, S., "Recommendations on the nature of the passenger response time distribution to be used in the MSC 1033 assembly time analysis based on data derived from sea trials." International Journal of Maritime Engineering, Vol 149, Part A1, ISSN 1479-8751, pp 15-29, 2007.

[5] IMO MSC.1/Circ 1238, 2007.

[6] FP 51/WP.3, 8 Feb 2007.

[7] Galea, E.R., Filippidis, L., Deere, S., Brown, R., Nicholls, I., Hifi, Y., Besnard, N., Proposed Ship Evacuation Model Validation Data-Sets and Acceptance Criteria with Application to Three Ship Evacuation Models, In Preparation, To be submitted to RINA International Journal of Maritime Engineering, 2012.

SAFEGUARD

Passenger Evacuation Seminar

30 November 2012
London, UK

PAPERS

THE ROYAL INSTITUTION OF NAVAL ARCHITECTS
10 UPPER BELGRAVE STREET, LONDON, SW1X 8BQ Telephone: +44 (0)20 7235 4622