DISCUSSION

PASSENGER RESPONSE TIME DATA-SETS FOR LARGE PASSENGER FERRIES AND CRUISE SHIPS DERIVED FROM SEA TRIALS

R Brown Marine Institute, Canada and University of Greenwich, UK
E R Galea, S Deere and **L Filippidis** University of Greenwich, UK
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COMMENT

Dr S Bonsall; Liverpool John Moore University, UK

The paper consists of 27 figures; numerous equations and 12 notes/ references, many of which are written by the authors of this paper. Whilst this may indicate a lack of “reading around the subject” it also indicates the unique nature of the topic and that little exists at present in the public domain about this topic. Indeed the authors and the research group they represent are the main contributors to the IMOs discussions and circulars on this subject. Given that background the paper is very detailed and consists of comparisons between the evacuation times of 3 passenger ships, 2 being Ro-Pax vessels and 1 a cruise liner. On board evacuation time statistics have been gathered from significant populations enabling the authors to draw significant conclusions relating to evacuation times in the presented scenarios. The paper is therefore a useful addition to the debates on this subject which is of major relevance to the understanding of evacuation times in passenger vessels. Data and research in this area is difficult to obtain thus the authors should be congratulated for their work.

Professor D Andrews, FREng (Fellow), University College London, UK

This is a valuable piece of work in that it clearly demonstrates the IMO rules are somewhat arbitrary in assuming all passenger carrying ships are similar with regard to emergency evacuation. However, the investigation presented shows for the example ROPAX and Cruise vessels quite different evacuation performances. The paper also reveals Cabin and Airline like seating give quite different evacuation performances, as indeed do the effects of passenger demographics on personnel movement results.

As the authors conclude the results have been assembled from "semi-announced assembly trials" which provokes the obvious question as to whether there would be any different conclusions for the real life situation of emergency assembly and evacuation from the range of ship types, seating arrangements and passenger demographics? To some degree this is answered in the subsection below that comment by saying the results obtained would seem to be "in a similar manner in the built environment," but it would help if the authors could provide some quantification in this regard both between the two sectors and the spread of results for the differences explored in this work

The authors are numeric when talking of the Cruise Ship Night Case 95th percentile with "a 21.2% amount" which they consider "moderate" but 21.2% increase in RTD sounds quite significant?

Finally in considering where additional data is required, investigation of "very different populations" is highlighted. Do the authors have any proposals to address this observing that the EU Project, whose work they are reporting upon, is now complete?

Mr A Carran, P.Eng, C.Eng, MIMechE, 3GA Marine Associates, Canada

Having been involved with the authors in the Eurostar Roma trials for EU FP5 research project FIRE EXIT [ref 4], and other experiments to determine passenger movement speed in evacuation scenarios, I am pleased to see this valuable additional data set. The authors are to be commended and so are the ship owners/operators who were prepared to accept the customer relations risks in allowing these trials to be performed.

In 4.3 Proposed RTD for Cruise Ships, the authors observe that 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. The 400 second allowance has always seemed arbitrary: have the authors learned anything from the new data that might support (or otherwise) the 400s night case allowance?

In 3.2(b), the authors compare the differing data for RTDs of passengers in Cabin Spaces in the cruise ship and the overnight ferry, noting slower responses from cruise ship passengers. They speculate that cruise ship passengers are more settled in their cabins, and therefore more reluctant to leave. Is there any analogous work to support this, perhaps comparing apartment buildings to hotels?

Dr T Morrall, Eur Eng, FRINA, UK.

The authors should be congratulated for their excellent work in establishing a set of comprehensive passenger response time data-sets for large passenger ferries and cruise ships. The recommendations to modify the IMO guidelines governing ship evacuation analysis is fully supported by their key findings. As the authors have pointed out, there is still a need for additional data to explore the dependence of population demographics on board the ship, e.g. distribution of age, gender, and the more complex human behaviours, (e.g. disabilities, passengers in wheelchairs or needing the assistance of crew members etc., and family or group bindings etc.). This data would be needed to obtain realistic qualitative effects on the evacuations simulations. The question is how can this additional data be obtained? Although ship trials are undoubtedly the best option, could this data be obtained by simulation, or from land based trials in other environments?

The evacuation from passenger ships can either be considered as precautionary, with no imminent threats to the passengers and crew, or for an emergency, where failure to evacuate the ship in good time will be crucial. I would assume that the data-sets obtained by the authors are for the former. However, as the characteristics of an emergency evacuation are likely to be very different from a precautionary evacuation, what data-sets or modifications are needed for an emergency evacuation, for example, for grounding or a collision, where the vessel may sink or heel to a large angle in the time taken to muster? This leads to the consideration of additional evacuation scenarios for emergency evacuation, as well as the simulation of abandonment in ship's lifeboat etc. If a more holistic approach is considered desirable for more realism, what further steps are needed to achieve this objective?

Dr E Ronchi, Lund University, Sweden

This paper presents useful data on response time distributions during semi-unannounced, full-scale assemblies conducted at sea on three different types of passenger vessels. This paper increases the understanding on response times on passenger ships given the little experimental data currently available. The large effort made within the SAFEGUARD project in the collection and analysis of data about response time distributions is a significant contribution to the understanding of pre-evacuation behaviours in different types of passenger ships.

The use of the proposed log-normal response time distributions based on experimental data is an important step towards a more accurate assessment of the predictive capabilities of evacuation models for the analysis and certification of passenger ships.

There is one particular finding of the paper that can generate a debate within the evacuation research community: "if the response times and demographics of sufficient people are characterised for a given type of structure, then if the assembly exercise is repeated under similar notification conditions, a similar RTD will be generated". It would be interesting to further discuss this statement in the context of the evacuation conditions, i.e., what are the boundary conditions that permit the prediction of repeatable response time distributions? For example, the interpretation of this type of data can be made with an emphasis on the possible impact on the evacuation process of factors other than demographics, i.e. the impact of staff and level of training on passenger response times. The authors may further discuss the potential differences in the response time behaviours of the populations in relation to the actions of the crew members or the level of training of the evacuating population. The trials were performed at sea, thus increasing the reliability of the data collected. Nevertheless, the trials were semi-unannounced due to ethical reasons, so it would be useful to discuss the possible sources of different response times in a fully unannounced scenario, possibly comparing the observed behaviours with actual evacuation events (e.g. including the recent ship evacuation cases which have appeared in the media). Previous studies of the authors have also discussed the impact of culture on evacuation behaviours (i.e. the EU FP7 BeSeCu project http://www.besecu.de). The paper can be a useful starting point to discuss the possible impact of those factors and the subsequent solutions to implement them in evacuation models, e.g., to which extent conservative assumptions should be considered in light of their possible impact.

An additional point of discussion arises from the authors' application of the validation procedure presented in the IMO MSC.1/Circ.1238. The use of log-normal distributions of response times, based on the data presented in the paper, contributes to a more accurate representation of human pre-evacuation activities. The aim is to capture the variability of possible pre-evacuation behaviours using distributions that are representative of the actual response times. In this context, the current methodology suggested by the IMO MSC.1/Circ.1238 (and adopted by the authors) prescribes a minimum of 50 repeat simulations for each of the benchmark cases. The use of a fixed number of simulations (50) for the assessment of the predictive capabilities of evacuation models is an assumption employed to test the impact of stochastic human behaviours on the evacuation process (e.g., response time distributions). To address the probabilistic nature of human behaviour, evacuation models are evolving towards the inclusion of ever more stochastic variables and algorithms. For this reason, the evacuation research community should open a discussion on the need to investigate a more systematic approach for the assessment of uncertainty associated with human behaviours. For instance, the use of convergence criteria instead of a fixed number of runs (50) would be useful to assess the variability of the evacuation simulation results of the same scenario in relation to the number of simulated runs. This would permit an increased understanding on the impact of the use of distributions/stochastic variables (e.g. response time distributions) on the representation of the behaviours of the occupants and a better assessment of the predictive capabilities of evacuation models.

AUTHORS' RESPONSE

The authors greatly appreciate **Dr Bonsall's** comments regarding our paper and our work. We agree that data in this area is extremely rare. This is primarily due to the difficulty in collecting representative data. To be truly representative, evacuation data that is intended for use in evacuation analysis relating to large passenger ships should be; collected on vessels at sea, using representative populations who are as unaware as possible that they are participating in an experiment. This clearly creates a number of ethical and practical issues which makes collecting the data difficult. It should come as no surprise that the trials we undertook required many months of planning and preparation. I would also like to add that the passenger ship companies (Color Line, Royal Caribbean Cruise Lines International and Minoan Lines) and the officers and crew of the ships involved are to be commended for their participation. It is not an easy decision for a ship company, Master and senior officers to hold a semi-unannounced assembly drill part way during a cruise. In addition, the 5582 passengers who participated – without complaint - in this work are to be commended for their cooperation.

The authors appreciate **Professor Andrews** insightful comments on our work. To address the first point raised by Professor Andrews, the response time distributions generated from the semi-unannounced sea trials performed as part of this work and the earlier Fire-Exit project can all be considered to be log-normal in appearance. This is in agreement with the response time distributions derived for fully-unannounced evacuation experiments within the built environment. The authors and other researchers have run a number of fully-unannounced evacuation experiments in many different types of buildings and all such experiments generate response time distributions which have the characteristic log-normal shape. Furthermore, where it has been possible to determine response time distributions from real emergency incidents, such as the World Trade Centre 9/11 disaster [1], these response time distributions have also been log-normal in appearance. So we can expect this aspect of the response time distribution to be the same in real situations, fully-unannounced and semi-unannounced situations.

However, determining the precise nature of the log-normal response time distribution is more complex. Research has shown that response times are dependent on a range of factors such as; the nature of the notification (alarm) system, nature of addition incident cues, whether individuals within the population are alone or are in groups, the presence of trained staff, familiarity with the environment, the nature of the activity that the population is engaged in at the time of the alarm, experience of previous alarms, the frequency of previous alarms, perception of risk, population demographics and as this research has shown, for those on passenger ships, the nature of the voyage. As part of another EU funded research project (BeSeCu), Prof Galea and his colleagues has also demonstrated that social culture may even influence how rapidly a group of people respond to an alarm – so a population made up of people from, for example Turkey may respond more or less rapidly to a population made up of people from a different culture, such as for example, the UK under identical circumstances [2,3]. All of these factors may influence the precise nature of the log-normal distribution, changing the mean and standard deviation of the distribution. However, at present there is no theoretical model that can accurately predict the precise nature of the response time distribution and so design engineers are reliant on experimental data and engineering judgement (informed "guesses") to define the response time distribution that is used in design calculations – which is why data of this type is so important.

This poses a number of interesting questions as suggested by Prof Andrews. The first being, will a group of people in a similar functional environment on land and at sea e.g. a restaurant in a building and on a cruise ship, have the same response time distribution? This would be an interesting experiment to undertake, as many of the parameters that influence response time would be the same in both cases. It is reasonable to assume that while both response time distributions would be log-normal in appearance, there would be differences between the two distributions. Unfortunately, it is too difficult to quantify the differences and too difficult to even suggest which one would have the greater mean response time! However, if we further constrain the problem and subject both populations to the same type of alarm e.g. a fire alarm (either a voice or simple bell) and the same type of other incident cues, I would expect that the response time distribution in both cases would be very similar. Another question is: will the response time distribution for passengers on a large passenger ship be different for a real incident and a fully-unannounced or semi-unannounced trial? This again is a difficult question to answer. As already stated, we would expect in all three cases to produce log-normal response time distributions, but how would they differ, if at all? If we further constrain the problem and suggest that similar incident cues are imposed on the population in each case, it would be reasonable to assume that the real incident and the fully-unannounced trial would produce very similar distributions. However, the response time distribution produced in the semi-unannounced trial could be different to the other two, but it is difficult to determine if it would have a longer or shorter mean and standard deviation. In the semi-unannounced case, some people may take longer to respond, as they are expecting a drill to occur (albeit at an unknown time) so do not feel the need to react quickly, others may react more rapidly as they are expecting a drill and want to get the exercise over as quickly as possible so that they can return to their leisure activities, while others will be uncertain whether or not it is a drill and react in the same way they would in a real incident.

Concerning the differences between the proposed SAFEGUARD response time distributions and the existing IMO response time distributions for day and night scenarios as applied to cruise ships, our work has shown that there are statistically significant differences between the proposed and existing response time distributions. Because of these significant differences, we recommend that IMO should adopt the suggested response time distributions [4]. However, how much impact will these different response time distributions have on the overall predicted vessel assembly time? Clearly, this will be dependent on the precise layout of the vessel and the procedures employed. In order to gauge the impact we applied the existing and suggested response time distributions to a particular cruise ship layout with a given set of procedures. We found very little increase in the predicted 95th percentile assembly time using the proposed day time response time distribution, and a 21.2% increase in the predicted 95th percentile assembly time for the night case. While the night case shows a relatively large increase in assembly time, we do not consider it to be significant as the vessel is still considered to have satisfied the assembly time criteria.

Finally, we have suggested that the EU should continue to address passenger ship evacuation issues in the next Framework Programme which begins in 2014 called Horizon 2020. We have made a number of recommendations for further research, including issues associated with passenger demographics and response time. We hope that the EU will include these issues within the next research call.

The authors thank **Andrew Carran** for his comments on our work and join him in acknowledging the invaluable contribution of the ship owners/operators. Indeed, we also acknowledge the great support we had from the ship's officers and crew and of course the passengers.

We agree with Mr Carran that the 400 second off-set to the response time distribution to account for sleeping passengers is completely arbitrary. Prof Galea was a member of the committee that framed the original IMO MSC Circ 1033 guidelines and recalls the discussion concerning the night scenario. While it was agreed that the response time of sleeping passengers was longer than that of passengers who were awake, no data was available at that time to quantify the difference. The arbitrary value of 400 seconds was eventually agreed between the various interest groups with the suggestion that more research was needed to quantify impact of sleep on response time. It is believed that some of the very long response times observed in the SAFEGUARD trials for passengers in cabins were the result of sleeping passengers. However, while some of the passengers commented that they were asleep in their cabins when the alarm sounded, it is difficult to attribute the observed long response times to sleeping passengers. It is hoped that in the next EU Framework Programme (Horizon 2020 starting in 2014) there will be a call for appropriate research to address this issue.

The differences between the response time distributions for passengers in cabins on overnight ferries and Cruise Ships is difficult to explain. We have suggested several reasons, including that on the Cruise Ship, the cabins were essentially temporary homes with passengers "moving in", unpacking their belongings and personal effects while in contrast cabins on the ferry were places for a few hours sleep and so passengers were less likely to move in. Mr Carran suggestion to compare this to apartment buildings and hotels is reasonable. There is evidence to suggest that people in domestic dwellings take longer to respond and begin the evacuation process than people in other types of accommodation. These differences are due to a range of factors such as; a greater sense of affiliation with the property and possessions within the property thus being more likely to investigate and confront the hazard, and stronger social bonds between the people at risk within the property thereby being more likely to warn other people, all of which delays the start of the evacuation process. The later may not be relevant to passenger ship situations as family groups could be present in both types of ship cabins. However, there may be similarities between the contrasting behaviours observed in apartments/hotels and cruise ship cabins/ferry cabins.

The authors greatly appreciate **Dr Morall's** comments regarding our paper and our work. Dr Morall has raised two questions which will be addressed in turn.

As indicated in our response to Prof Andrew's questions, we have indicated that there is a need for more data to quantify how people respond to the call to assemble. In particular, data relating to how population demographics influences passenger response time and how sleeping passengers respond to the assembly alarm is required. In addition, data relating to how passengers with disabilities and family groups respond to the call to assemble is essential if we are to reliably simulate the assembly process. I believe that this type of data must be collected in real life situations on board vessels and in as unannounced a way as can be accepted by ethics committees, ship owners/operators and off course passengers. Once again, as indicated in our response to Prof Andrew's questions, at present there is no theoretical model that can reliably predict the precise nature of the response time distribution and so it is not possible to derive this type of data from simulation. Furthermore, collecting the data from other environments, such as a similar land based facility, is unlikely to provide a reliable indication of the nature of ship based response time distributions. Indeed, this work has demonstrated that even different types of passenger vessels e.g. cruise ship and passenger ferry are likely to lead to different types of response time distribution being generated under similar conditions. Having said this, I believe that some types of data required by evacuation simulation can be collected from land based facilities. For example, as part of the FIRE-EXIT project the Canadian SHEBA facility was used to collect passenger movement speeds along corridors and up/down stairs at different static angles of heel and under a limited range of dynamic motions and under conditions of visual obscuration caused by smoke. Unfortunately, the SHEBA facility is no longer available, but similar types of facility could be constructed to obtain movement speed data for a range of population demographics (including people in wheel chairs) and a range of static heel/trim conditions and dynamic conditions. This type of data could also be collected from actual vessels at sea through recording the normal movement of passengers along corridors and up/down stairs subjected to different sea states. Already installed CCTV cameras could be used to collect the movement data and bridge instrumentation used to continuously record the sea state. In this way the data could be collected without the need to run a specially contrived experiment.

Concerning the issue of precautionary and imminent threat evacuations, the IMO MSC Circ 1238 guidelines are intended to provide an indication of how long it may take to assemble a vessel under ideal conditions. The vessel is upright and there is no fire and smoke impacting the movement and behaviour of the passengers. The analysis is intended to provide insight into how the vessel is likely to perform under hypothetical (ideal) benchmark conditions. It also provides a means of comparing the performance of one vessel design with another. The data collected as part of the SAFEGUARD project addresses this type of scenario.

In realistic situations, I would hope that if the passenger vessel was in a state of distress, with potential to threaten the safety of passengers, that the Master of the vessel would start the assembly process before conditions deteriorated to the extent that would make assembly difficult e.g. before the vessel took on an adverse angle of heel. Under these conditions, the data that was collected in project SAFEGUARD is likely to be appropriate and representative. If the assembly process is started after the vessel has taken on an adverse angle of heel or after smoke has entered the passenger space, then the SAFEGUARD response time data may not be appropriate. Under these conditions, passengers may take longer or shorter to respond than suggested by the SAFEGUARD data. I do not believe it is possible to reliably extrapolate human performance under these adverse conditions from the SAFEGUARD data. Collecting such data is challenging, but the data could be derived from real situations, if video data from CCTV or passenger video footage is available. For example, video footage from the Costa Concordia incident may provide valuable data concerning how passengers respond to a real emergency situation. In addition, it may be possible to device experimental protocols that would represent these conditions, but this is extremely difficult for parameters such as response time and group bonding due to practical constraints associated with ethics.

Concerning the nature of the IMO MSC Circ 1238, as part of project SAFEGUARD a range of additional, more challenging scenarios were proposed – the so called degradation scenarios. These included a benchmark scenario where the vessel was heeled over at 20 degrees and another scenario involving smoke spread throughout a main vertical zone. These scenarios have been proposed to IMO to augment the current scenarios [18]. However, a limitation of these scenarios is the lack of reliable data concerning how passengers move under these conditions. While some data is available concerning the impact of heel and smoke on movement speeds e.g. FIRE-EXIT data, more data is needed if our models are to produce reliable simulations under these adverse conditions. SAFEGUARD also considered other scenarios such as an abandonment scenario however, it was felt that there was even less reliable data for these scenarios and so it was not appropriate to adopt these cases as part of the suite of benchmark cases. For the abandonment scenario to be reliably simulated, data relating to passenger movement speeds wearing lifejackets and passenger boarding rates into lifeboats (as a function of passenger demographics) are required.

The authors greatly appreciate **Dr Rochi's** comments regarding our paper and our work. Dr Ronchi raises a number of interesting questions which will be addressed in turn.

First let us consider the comments concerning the repeatability of the response time data. The observations from the SAFEGUARD project are indeed important and have implications beyond passenger ship applications to any situation involving people responding to an alarm. Our assertion is that for a given structure type and a given notification system, and a given population demographic and provided that the population is sufficiently large, the response time distribution generated for one population will be similar to that generated for another population. This suggests that if an evacuation experiment is conducted with a given population, if it were repeated with a different population with similar demographics, we would expect to find the same response time distribution generated. Essentially, the only difference between the two evacuations is the population. All other factors that influence the response time distribution are the same in both cases. However, while the population in both cases are different, it is essential that the demographic is the same in both cases. This means that the age and gender distribution in both cases should be reasonably similar. In addition, it is important that the population is reasonably large in order to capture differences in specific population characteristics such as the presence of social groups. So if we repeated an evacuation with all things being the same in both cases except for the population, and if the population demographics was the same in both cases, but it consisted of a small number of people, say 10 people, we would not expect the response time distribution to be the same in both cases. However, if the population was large, say consisting of 100+ people, we would expect the response time distribution to be more similar. Other factors, such as the level of staff intervention will also impact response time, but I would expect this to be one of the controlled parameters. For example if for one case there is no staff intervention, while in the other case there is considerable staff intervention, the response time distributions generated by these two scenarios would not necessarily be the same. This is because the conditions in both cases were not the same. In the SAFEGUARD Superspeed trials, the vessel was clearly identical in both cases, the alarm system was the same, the staff and staff intervention was the same, the population demographics was the same, the nationality mix was very similar and the evacuation even took place at the same time of day. The only difference between the two evacuations was the passengers, and both populations were large.

The issues concerning response time data generated from semi-unannounced, unannounced and real incidents has already been discussed in reply to the comments from Prof Andrews and so will not be repeated here. Furthermore, the potential impact of social culture on response phase behaviour has also been discussed in response to Prof Andrews comments. As previously discussed, based on our work in the EU project BeSeCu, we now believe that social culture may influence the manner in which a population responds to an alarm, including how rapidly they respond [19,20]. While the link between social culture and response time has not been definitively proven, if correct, then we would expect a passenger ship populated predominately with one national group to generate a response time distribution which is different to that generated by a similar sized population predominately made up of a different national group. If correct, then social culture would need to be added to the set of control parameters.

Next, let us consider the issues associated with the analysis procedure presented in IMO MSC.1/Circ. 1238. The evacuation guideline procedures described in IMO MSC.1/Circ. 1238 requires that a minimum of 50 repeat simulations are undertaken as part of the assembly analysis for a given benchmark scenario and the 95th percentile case taken as the representative assembly time for the scenario. The reason for repeating the analysis a number of times is due to two factors. First is the inherent variability in the human behaviour algorithms used in many of the more sophisticated evacuation models. This variability is to be expected as people will not necessarily behave in exactly the same way if they were to repeat the evacuation under identical conditions – evacuation is inherently a stochastic process. Indeed, if the evacuation model was deterministic and produced the exact same results each time the simulation is repeated without any changes to the initial or boundary conditions, I would argue that the model is not very realistic. The second reason is that when the simulation is repeated, the population distribution is also different. While the same number of agents are present in each region of the geometry and the demographic range of the population is fixed, the precise nature of the agents may be different, including movement rates and response time. Furthermore, the precise starting location of the agents in each region may also be different. These differences may result in very different assembly times being generated for each repeat simulation. Indeed, our analysis, as part of the SAFEGUARD project has suggested that 50 repeat simulations is not sufficient to fully cover the range of assembly times that could be generated for a given scenario. Our analysis suggests that several hundred simulations may be required to correctly describe the distribution of possible assembly times. Unfortunately, the guidelines do not specify on what basis more than 50 repeat simulations may be required, only that it is a minimum. Our suggestion is that if a fixed number of repeat simulations are specified it should be considerably larger than 50, of the order of several hundred. Alternatively, a methodology could be developed which determined key parameters for the predicted assembly time distribution, such as mean assembly time, assembly time standard deviation, 95th percentile assembly time. The number of required repeat simulations could be based on demonstrating that these key parameters converged to some predetermined level of tolerance. Given the speed of modern computers, the additional simulations would not prove too onerous.

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