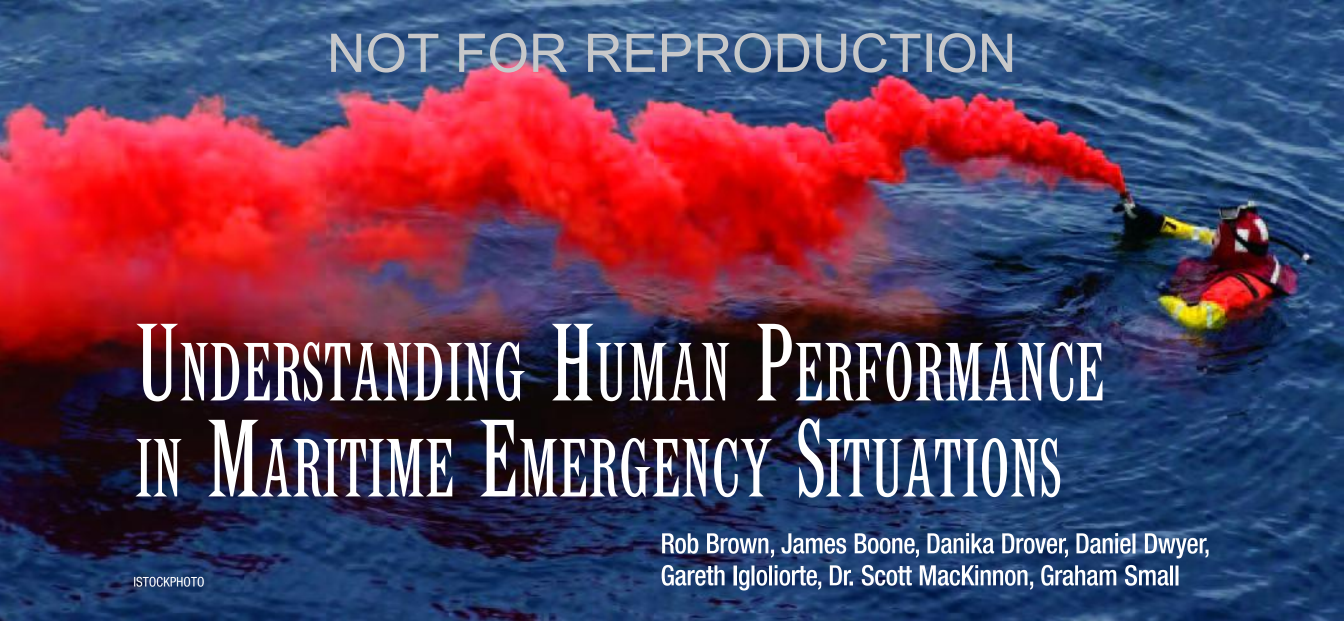

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Understanding Human Performance in Maritime Emergency Situations

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Computer-based simulation can provide ship designers and evacuation planners with a reliable means to study passenger movement during the evacuation of passenger vessels. Controlled experiments are used to quantify abandonment times for passengers of differing age, sex, mobility and experience as they use a wide array of different life saving appliances in varying weather conditions. The results of such experiments represent critical input for computer-based simulation.

Introduction

The development of models that simulate complex human behaviour in emergency situations has been the subject of numerous studies covering a wide variety of evacuations from buildings and airlines to passenger ships. Ship evacuations pose numerous additional difficulties in emergency situations as passengers are often unfamiliar with the marine and motion environment, specialized equipment and general marine procedures. The International Maritime Organization (IMO) has recently introduced a regulation that all newly built ships must have undergone a formal evacuation assessment to determine if changes at the design stage might improve a ship's ability to be evacuated. Currently, more than 20 evacuation models are available (Kim et al., 2004) to designers in the shipbuilding industry.

Due to the inherent variability of human behaviour, especially in stressful situations, models that predict evacuability of ships are generally probabilistic in nature (Vassalos et al., 2002). These probabilistic models typically predict a range of evacuation outcomes given a set of input distributions for human behaviour. This is an advantage over deterministic models, which would predict the same result every time with the same given set of input parameters. Still, input distributions for human behaviour during evacuation must be properly quantified in order to provide a realistic basis from which to carry out probabilistic modeling.

This paper provides a summary of several collaborative projects between the Marine Institute Offshore Safety and Survival Centre (OSSC), the School of Human Kinetics and Recreation at Memorial University, and BMT Fleet Technology Ltd. in an effort to quantify human performance related to passenger movement during ship evacuation. It represents a good start at quantifying basic aspects of the evacuation process in a way that can be used in probabilistic modeling for ship evacuation assessment.

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General Setup for Testing

Four different full-scale life saving appliances (LSAs) were utilized throughout the work outlined in this paper (Figure 1) - a vertical escape chute, a single track marine slide (both installed 6m above the water), a davit launched liferaft and a totally enclosed motor propelled survival craft (TEMPSC). All equipment was set up in a controlled, well-lit lab-type environment with calm water and generally dry conditions. This setup represents the base-case situation - controlled abandonment. Personnel acting as crew during the tests were experienced mariners and provided realistic, consistent instructions and guidance to subjects where required. Subjects were identified by unique numbers allowing researchers to determine if correlations existed between personal characteristics and performance.

For passenger vessel setups, subjects were untrained personnel wearing normal street clothes and SOLAS approved lifejackets. For offshore platform or commercial vessel setups, subjects were trained personnel wearing only immersion suits. For non-ambulatory person abandonment setups, articulated mannequins were weighted to published anthropometric guidelines and secured in stretchers.

Acquisition of Data

Elapsed time through or into the various LSA components was the main independent variable measured in the tests described. Data acquisition was primarily by video recording. Cameras were mounted (Figure 2) at the start of different zones for each of the LSAs and synchronized to facilitate continuous monitoring of each subject throughout the abandonment process. The zones were further grouped as either translational or action (depending on the LSA) to permit modeling of more general cases when the equipment modeled is not exactly the same as that in the lab. Questionnaires were also completed by subjects to determine a variety of detailed information relating to age, gender and their previous experience with similar situations.

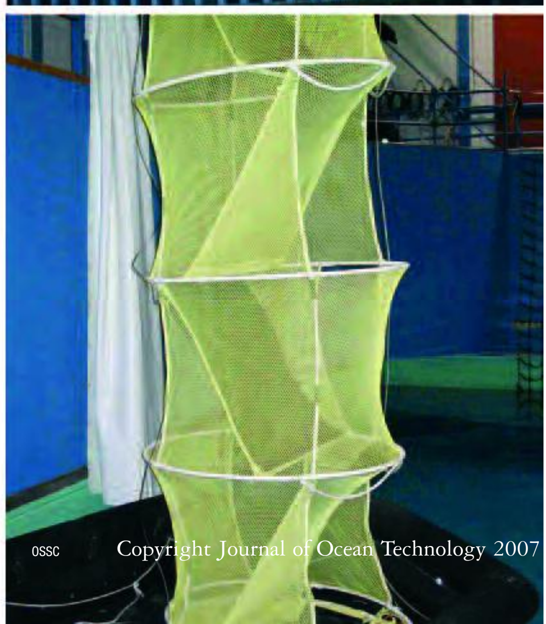

Figure 1 Life saving appliances used in the studies quoted: davit launched liferaft (top left), single-track marine slide (bottom left), TEMPSC (top right) and vertical chute (bottom right)

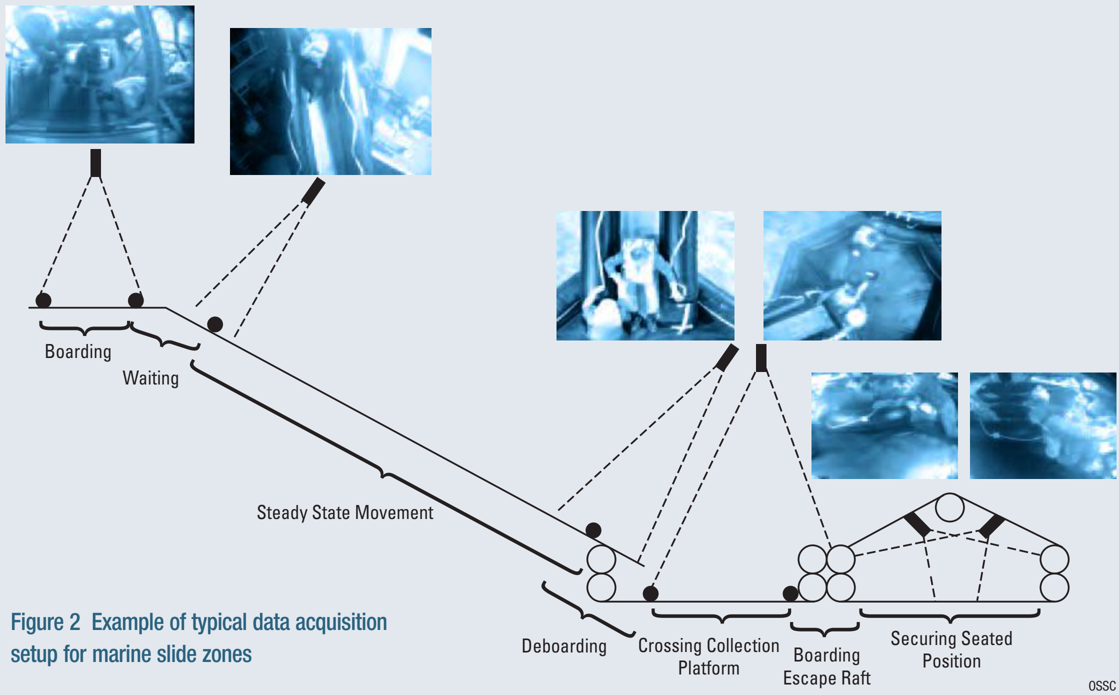

Figure 2 Example of typical data acquisition setup for marine slide zones

Results

Except where noted, results from the trials reported below are for untrained personnel - assumed representative of those onboard passenger vessels.

Lifejacket Donning

SOLAS approved lifejackets were utilized throughout these tests. Subjects were assembled into groups of not more than 50 persons and given brief instruction on the proper donning method. Each group was videotaped throughout the donning process, which began when the researchers called start and ended with each subject raising his/her hand when finished. Times were tabulated for those subjects that could clearly be seen raising a hand. For the 180 subjects tested, the average time required to don a lifejacket was 38.5 seconds (Figure 3).

Untrained Personnel in Four Different LSAs

A total of 275 subjects (40% male, 60% female, with an average age of 37, an average height of 1.7 metres and an average weight of 75 kilograms) were involved in these trials which represent abandonment under controlled baseline conditions. Results indicate that, in general, males are faster than females and that overall abandonment time tends to increase with age on all

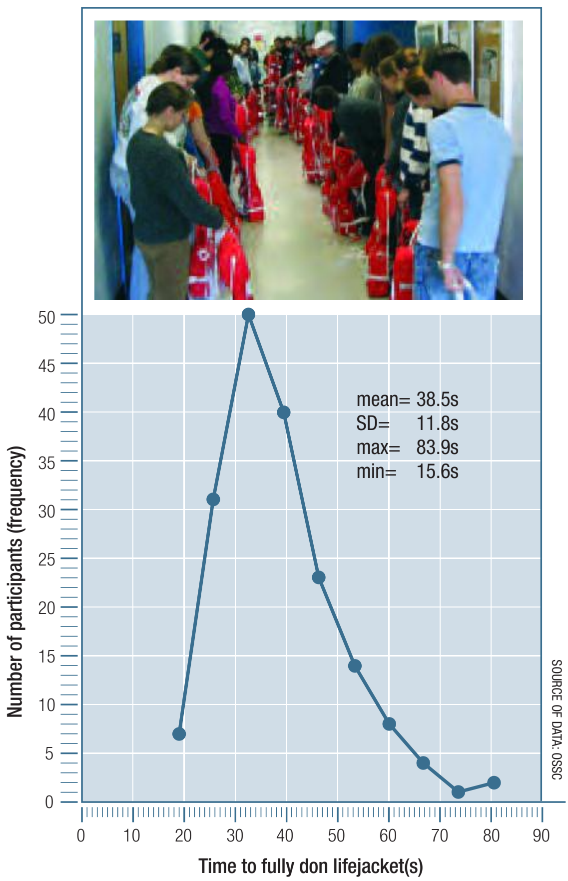

Figure 3 Distribution of lifejacket donning times

four LSAs utilized. However, little variation is seen in abandonment time for lifeboats and davit launched liferafts, regardless of age or sex.

An analysis was also made of the time required to move into a seating position in a floating liferaft as a function of liferaft fullness. Results indicate that the time required to become seated decreases from roughly 10 seconds to roughly 5 seconds as the liferaft fills to capacity.

Trained and Untrained Personnel in a Vertical Chute

Eighty-two (82) subjects were involved in trials to compare abandonment time under controlled baseline conditions for trained and untrained subjects using a chute system. Results indicate that, on average, trained subjects were able to abandon using the chute in less than half the time required by untrained personnel. The age range for both groups was very similar (trained: 38 years; untrained: 41 years), however the proportion of male to female subjects was much higher for the trained group (males:females - 36:5) than for the untrained group (males:females - 21:20).

Abandonment for Non-Ambulatory (Stretcher) Cases

A series of tests was carried-out to determine the efficacy of abandonment for non-ambulatory personnel using the slide and chute LSAs. It was assumed that the stretchers arrived at the LSAs ready for abandonment (i.e. times recorded did not include stretcher loading). Three types of stretchers (Table 1) and three mannequin masses (Table 2) were tested to determine if efficacy of evacuation depended on any combination of these factors.

Results for the slide tests indicate that the mass of the stretcher did not affect the time required for abandonment, however abandonment times did vary with stretcher type. Times for the rigid solid plastic basket litter were, on average, 1.3 seconds faster than the collapsible plastic litter and 5.3 seconds faster that the rigid mesh basket litter. Overall results indicate that it will take on average 89.3 seconds and a maximum of 129.8 seconds for a loaded stretcher to descend the slide and be placed into its final position in the liferaft.

Results for chute tests indicate that rigid basket litters cannot be used in some chutes. It was not possible to move either of the rigid litters through the chute. It was possible to move a loaded collapsible plastic litter through the chute due to its flexible nature. However, doing so took more than 30 minutes and required two personnel to travel with the mannequin in the litter at all times. Throughout the trial, the handlers were required to turn the litter in a specific manner in order to move from one cell to the next and prevent striking or scraping the face of the mannequin (Figure 4).

Table 1: Stretcher types tested

	Stretcher Type:	Construction Material:	Mass (kg):
	Rigid solid plastic basket litter	Rigid plastic construction	11.0
	Collapsible plastic litter	Flexible plastic construction	5.9
	Rigid mesh basket litter	Stainless steel construction with moulded plastic basket	20.0

Mass Category	Demographic	Target Mass (kg) (Pheasant, 2003)	Actual Mass (kg)
Light	50th Percentile, 12 year old British male	40.0	39.7
Medium	50th Percentile British Female	63.0	62.7
Heavy	95th Percentile British Male	94.0	86.2

Table 2: Mannequin masses tested

In an effort to determine if the required turns would actually be possible to perform with a real human, one of the investigators volunteered to be evacuated through the chute in the collapsible plastic litter (Figure 4). The mass of the volunteer was 89kg. The time required to perform this task again exceeded 30min. The subject indicated considerable concern for his safety at each turn in the chute and general discomfort resulting from the forces applied by the elastic members at the bottom of each cell in the chute - as direct result of his being constrained in a litter. Based on the inability to move rigid litters through the chute and the difficulty of moving a collapsible litter safely through the chute, the project team assessment was that some chutes may be inappropriate for the evacuation of stretcher cases.

Figure 4 Attempts at abandonment through the vertical chute

Proper belay and rope systems were used for each trial of this study and operated by instructors trained in technical rope rescue. If such equipment is to be made available to a ship's crew, training and regular drills must be provided to ensure correct usage. These results identify several issues that should be of interest to regulatory bodies. In a mass casualty situation, the number of injured personnel could easily exceed the number of uninjured and trained personnel (Coleshaw et al., 1998). In this study all evacuation personnel were in good health.

Using Test Results in Simulation

A simulation was setup with commercially available marine evacuation simulation software, maritime EXODUS, developed by the Fire Safety Engineering Group at the University of Greenwich (http://fseg.gre.ac.uk/exodus/air.html). (See profile on p. 98)

The flow rates into the collection platform and the liferafts are defined as attributes of the equipment. Findings from the research trials described in this paper were incorporated within maritimeEXODUS by appropriate definition of each attribute.

The simulation of evacuating stretcher cases may require an analysis separate from the main body of a ship evacuation simulation, unless an MES dedicated to the evacuation of only injured or physically impaired individuals is assumed. The main body of simulations would focus on the evacuation of able-bodied personnel, supplemented by stretcher case simulations. These results would represent a situation in which 10 individuals would require evacuation via stretcher using a 30m slide. Simulation results indicated that these 10 stretcher cases would increase the evacuation time of a ship by 12 to 23.5 minutes (Figure 5).

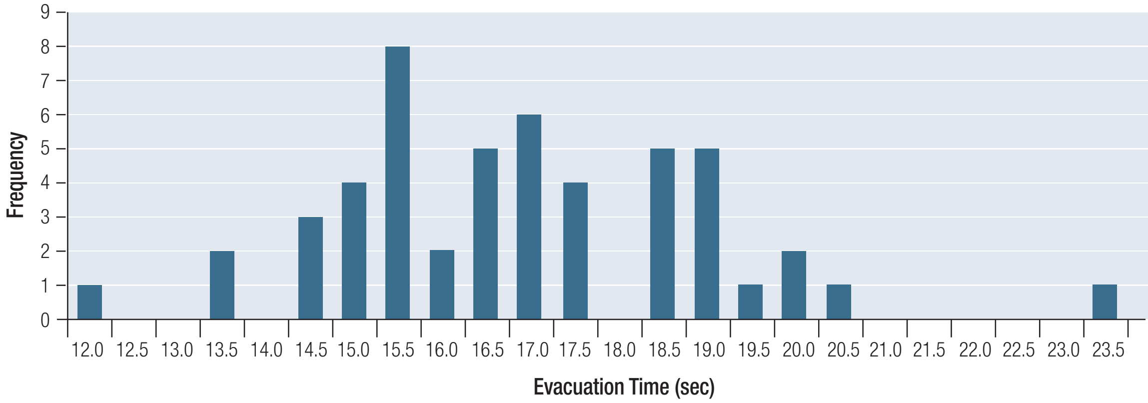

Figure 5 Distribution of simulated evacuation time for 10 stretcher cases on a slide

Summary and Future Work

With a focus on abandonment of passenger vessels, the research discussed in this paper represents a significant step forward in quantifying human performance during ship evacuation. Results from the research have quantified that males are generally faster than females and that abandonment time increases with age for untrained persons. The research indicates that with training, subjects are able to egress through vertical chute systems roughly twice as fast as subjects without training in the same chute.

While the research with non-ambulatory subjects indicates some difficulty in abandonment for slides and chutes, further effort is required to more fully investigate the evacuation of non-ambulatory personnel. In addition, further planned research will aid in properly defining potential scenarios and to quantify human abandonment performance for a wider spectrum of LSAs and environmental conditions.

Such efforts will permit accurate simulation of ship evacuation and suggest areas for improvement of ship design and crewing requirements, including training to ensure safe, effective and efficient response to emergencies at sea and ultimately save lives.

Acknowledgement

The authors would like to acknowledge the support of Marine Atlantic, Viking Lifesaving Equipment, the Atlantic Innovation Fund, Precarn Inc. and Transport Canada in conducting the work outlined in this paper.

References

Brown, R. (2005). Deliverable D6.4 Abandonment Trials Report. Technical Report to FIRE EXIT Project Consortium by Memorial University of Newfoundland's Offshore Safety and Survival Centre, March, 2005

Brown, R., S.N. MacKinnon (2005). Measurement of Egress Time for Injured or Physically challenged Users of Marine Evacuation Systems. Technical Report to Transport Canada, Marine Safety by Memorial University of Newfoundland's Offshore Safety and Survival Centre and School of Human Kinetics and Recreation, September, 2005.

Dwyer, D. and R. Brown (2006). A Comparison of Time Required for Evacuation of Trained Versus Untrained Personnel using a Marine Evacuation Chute. Technical Report by Memorial University of Newfoundland's Offshore Safety and Survival Centre, March, 2006.

Coleshaw, S., Mills, F. (1998). Evacuation of Casualties. Safety at Sea International, March, 21-24.

Drover, D.J., S.N. MacKinnon, R.C. Brown, J. Boone, G. Small (2005). Measurement of Egress Time for Injured or Physically Challenged Users of Marine Evacuation Systems. 36th Annual Conference of the Association for Canadian Ergonomists, Halifax, NS.

IMO (2002). Interim guidelines for evacuation analyses for new and existing passenger ships. MSC/circ.1033, June 6.

IMO (2003). Life-Saving Appliances Code. United Kingdom:IMO.

Kim, Hongtae, D. Lee, J. Park, J. Lee, B. Park, S. Lee (2004). Establishing the Methodologies for Human Evacuation Simulation in Marine Accidents. Computers and Industrial Engineering 46 (4): 725-740

Pheasant, S. (2003). Bodyspace. London: Taylor & Francis.

Vassalos, D., G. Christiansen, H. Kim, M. Bole, J. Majumder (2002). Evacuability of Passenger Ships at Sea. Safety at Sea and Marine Equipment Exhibition (SASMEX) 2002.