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A systematic methodology to assess the impact of human factors in ship design

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Abstract

Evaluating ship layout for human factors (HF) issues using simulation software such as maritimeEXODUS can be a long and complex process. The analysis requires the identification of relevant evaluation scenarios; encompassing evacuation and normal operations; the development of appropriate measures which can be used to gauge the performance of crew and vessel and finally; the interpretation of considerable simulation data. Currently, the only agreed guidelines for evaluating HFs performance of ship design relate to evacuation and so conclusions drawn concerning the overall suitability of a ship design by one naval architect can be quite different from those of another. The complexity of the task grows as the size and complexity of the vessel increases and as the number and type of evaluation scenarios considered increases. Equally, it can be extremely difficult for fleet operators to set HFs design objectives for new vessel concepts. The challenge for naval architects is to develop a procedure that allows both accurate and rapid assessment of HFs issues associated with vessel layout and crew operating procedures. In this paper we present a systematic and transparent methodology for assessing the HF performance of ship design which is both discriminating and diagnostic. The methodology is demonstrated using two variants of a hypothetical naval ship.

Keywords: Evacuation analysis; Evacuation simulation; Human factors; Naval architecture; Ship design; Pedestrian dynamics

1. Introduction

Modifications to ship configuration such as hull form, length, beam, size and location of internal compartments have a direct impact on ship performance in terms of stability, powering, seakeeping and strength. These traditional design parameters are well understood and can be determined in a relatively straight forward manner. Equally, when modifying the internal configuration of a ship, it is also important to determine what, if any, human factors (HF) benefits or disbenefits may result. How these aspects can be assessed is less well defined. In this paper we present a novel mathematical procedure, based on computer simulation of evacuation and normal operations (NOP), for assessing the HF performance of ship design.

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Making modifications to the internal layout of a ship or its operating procedures will have HF implications for crew and passengers, which in turn will have an impact on overall levels of safety under emergency conditions and efficiency of operation in normal conditions. The procedures employed to undertake a specific task such as evacuation or preparing the vessel for action may be modified to improve the efficiency in undertaking these tasks. Equally, changing the location of cabins, public facilities, corridor systems, stairs, assembly locations etc will have a direct impact on the ability of crew and passengers to safely and efficiently evacuate the vessel under emergency conditions. Furthermore, for passenger vessels, size, location and configuration of public spaces such as restaurants, cinemas, bars, etc will influence the ease with which they can be accessed, filled and emptied under NOP. This will in turn impact the operational characteristics of the vessel. For naval vessels, the location and distribution of compartments may have an impact on the time required by crew to go from one state to another, it may also have an impact on the minimum number of crew required to safely and efficiently operate the vessel under a variety of different conditions. These factors will have an impact on the vessels overall operating efficiency, ability to fulfil the assigned mission and lifetime costs associated with crewing requirements.

It should also be noted that changes to configuration that lead to improvements in one aspect of human performance e.g. assembly time, may have a negative impact on other aspects of human performance e.g. ease of access of public spaces.

Advanced ship evacuation models such as maritimeEXODUS can be used to determine the performance of personnel under emergency conditions for both passenger [1–4] and naval vessels [5] as well as the normal circulation of personnel for both passenger and naval vessels [5,6]. Common to this type of model is the capability to represent the population as a collection of unique interacting individuals, the ability to represent the detail of the space in which the individuals interact (i.e. the model should have a discretised representation of space) and the ability to assign individuals or groups of individuals specific tasks to complete as part of the scenario (see [7,8] for a review of model types). These models produce a wide variety of simulation outputs, such as time to assemble, levels of congestion experienced, time required to undertake specific tasks, number of operations performed in completing specific tasks, distance travelled by individuals in achieving goals, number of likely fatalities resulting from fire, likely injury levels sustained from fire, etc. As the number of different scenarios investigated increases, so does the volume of output data. It therefore becomes increasingly difficult to consistently assess changes in HF performance associated with changes in vessel configuration across a wide range of scenarios and performance requirements.

The challenge therefore is to develop a procedure that allows accurate and rapid assessment of the large-scale model outputs produced by HF simulation models and to determine if specified modifications to vessel layout or operating procedures generate improvements in human performance across a range of potentially competing requirements.

In this paper we explore a methodology to assess changes in HF performance resulting from changes to vessel configuration and/or crew procedures. Furthermore, the methodology is intended to determine whether or not a net benefit results from imposed changes to the configuration/procedures and identify specific areas where performance may be improved. The approach is therefore intended to be both diagnostic and discriminating. The identified methodology is being developed as part of a collaborative project between the authors and the Design Research Centre (DRC) of University College London, funded by the UK EPSRC with support from MoD [9]. While the proposed methodology is generic in nature, the development focuses on naval vessels to demonstrate proof of concept on a demanding set of ship operations. The methodology is similar in some respects to weighted point schemes used to rank fire safety provision in buildings, where points are awarded for the presence or absences of certain fire safety measures and the relative importance of the particular measure is represented by the assigned weight [10]. These types of schemes are common in quantitative fire risk assessment and are sometimes called "Indexing Schemes" [11]. A key difference between these schemes and the proposed methodology is that the performance measures are determined directly from detailed computer simulation of selected scenarios and not from experience of past performance or from expert judgement.

2. Methodology for assessing human factors performance

In order to gauge the HF performance of the vessel it is essential to define a range of relevant evaluation scenarios (ES) against which the vessel will be tested. These scenarios are intended to define the scope of the