Safety Science 87 (2016) 63–75

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

A phase of comprehensive research to determine marine-specific EPC values in human error assessment and reduction technique

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ARTICLE INFO

Article history:
Received 28 November 2015
Received in revised form 17 February 2016
Accepted 12 March 2016
Available online 24 March 2016

Keywords:
Human error
Ship safety
Error-producing conditions
Decision-making

ABSTRACT

Human Error Assessment and Reduction Technique (HEART) is a well-known approach for performing critical operations in safety analysis. It has various applications in many different disciplines such as nuclear energy, railway transportation, aviation and healthcare services. In addition to identifying human error categories, determining and weighting of error-producing conditions (EPCs) is the key aspect of human reliability quantification. Although EPC values are defined specifically for some disciplines, for the maritime industry these values have not been derived yet in terms of ship operational management. The aim of this paper is to produce marine specific EPC values (m-EPCs) in accordance with an advanced methodological framework, including accident causation, weighting, decision-making consensus, and statistical validation. For these purposes, a multi-dimensional approach involving Majority Rule, HEART, HFACS, AHP, and validation techniques has been utilised. Finally, a comparison between existing EPC values (i.e. for the nuclear industry) and m-EPCs is also provided to clarify industrial safety perspectives. Furthermore, this research encourages maritime safety professionals and practitioners to perform human error predictions for various critical shipboard operations.

1. Introduction

Human error is one of the most critical contributory factors in marine accidents. More than 80% of marine accidents are due to human error (Kirwan, 1987). Nowadays, in addition to equipment failure research, factors affecting human performance have become one of the main research subjects of the marine industry and academic organisations. There are many studies of human error in various fields, such as nuclear energy, health services, medical, defence, electronic systems and transportation industries. Despite the fact that most marine on-board accidents are due to human factors, insufficient effort has been devoted to enhancing safety and decreasing the number of accidents in the maritime industry. In recent years, it has been observed that maritime regulatory authorities such as the International Maritime Organization (IMO), the International Labour Organization (ILO) and Ship Classification Societies (IACS) have shown greater concern about this issue. However, marine accidents are still common (EMSA, 2013). Thus there is a greater willingness among maritime safety researchers and practitioners to seek alternative, proactive solutions to minimise human error in marine accidents.

In the literature, there is no specific approach to handling human errors in the marine industry despite a few techniques being applied to predicting human error conditions in different domains. To remedy this lack, this paper proposes a methodological approach to establishing marine-specific error-producing conditions (EPCs) which would define the performance shaping factors (PSF) of human beings for specific tasks (Williams, 1988). The EPC is one of the unique parameters of the HEART along with generic task type (GTT). Although there are specific EPC values for aviation (Kirwan and Gibson, 2008), nuclear (Kirwan et al., 2004) and railway (Gibson et al., 2012) industries, there are no specific EPC values for the marine industry. In light of the above, this paper demonstrates how marine-specific EPCs can be generated and validated by using advanced methodological frameworks including accident causation, cause distribution, group consensus, consistent weight distributions, and statistical validation. In this context, the paper is organised as following. This first section provides an introduction as well as setting out the aims of the study. The second part provides a review of the literature dealing with human error assessment in the marine industry. A proposed approach and its components are described in part three. The fourth chapter

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http://dx.doi.org/10.1016/j.ssci.2016.03.013
0925-7535/

provides an application of the methodology. The paper ends with concluding remarks regarding the study.

2. Literature review

Human factor is an essential issue for maritime safety. Since the assessment is subjective and it is hard to obtain human error data in the marine industry, human error assessment has been a critical issue for marine safety experts, risk researchers, and marine engineers. In order to cope with these limitations, safety researchers and practitioners have attempted to introduce a variety of techniques. Most of these are empirical techniques and based mainly on the experts' judgement. For instance, the technique for human error rate prediction (THERP) is considered a first generation method and it aims at assessing human error by dealing with task analysis, failure definition and quantification of HEP values (Swain and Guttmann, 1983). The method assesses human error data by using a large human reliability database which is involving available experimental literature, interviews with and observations of NPP personnel in the countries, plant data and the experience of the authors. Likewise, the success likelihood index methodology (SLIM) was introduced by Embrey et al. (1984) in order to evaluate human failure in task or action sequences. The authors performed a comprehensive expert research to assess human error and structure expert judgments which were converted into probability of success or failure of specific human actions. The feasibility and usefulness of the method was evaluated by an interactive computer program based upon Multi-Attribute Utility Decomposition (MAUD) and validated accordingly. A technique for human error analysis (ATHEANA), developed by the US Nuclear Regulatory Commission, enables users to assess human error probability while performing a specific task. Since the technique is post-incident HRA, it may serve as a diagnostic modelling tool. Therefore, the technique may not produce HEP value but provides various human actions within a system.

Furthermore, the cognitive reliability and error analysis method (CREAM) was developed to predict human error as well as reliability (Hollnagel, 1998) and it provides a predictive estimation of human error as well as a retrospective analysis and calculation of the same. The author did an extensive research involving number of classification schemes to guide empirical investigations of erroneous actions and emphasises the relative abundance of classification schemes in order to assess human error. Williams (1988) introduced a more powerful technique called HEART (human error assessment and reduction technique). This method allows users to estimate human error values empirically. In the paper, the author presented a guideline for identifying potential major sources, types and strengths of human error and utilised a human engineering data-base to quantify the human error. Kirwan et al. (2004) proposed the Nuclear Action Reliability Assessment (NARA) technique which is based on a data mining of UK power plant (NPP) information by using an extension of the HEART technique. This technique presents a smart solution to quantify the human error interactions in the NPP. This method was derived from HEART and EPCs are specified for NPP. In the method, the authors performed a comprehensive data-mining research by using Computerised Operator Reliability and Error Database (CORE-DATA). The database includes almost 400 HEP values from different industries such as nuclear power, chemical industry and offshore platform industry. During the EPC calculation, the authors accumulated core data values and aggregated respectively. Likewise, Kirwan and Gibson (2008) introduced the Controller Action Reliability Assessment (CARA) technique – another method based on HEART. The objective of the method is to analyse human error probability for a relevant task. Unique GTT and EPC parameters are defined in accordance with those of the aviation industry. A similar technique with NARA is followed to quantify EPC values. The authors did an extensive research (including air transportation) to elicit and weight EPC. An extended CORE-DATA base was used. In addition, actual data were collected from simulations and expert judgement was undertaken for quantification process of EPCs. Furthermore, the Railway Action Reliability Assessment (RARA) was proposed as a railway-specific approach to human error quantification (Gibson et al., 2012). The aim of the method is to provide an easy tool for human error quantification in the rail industry. The method utilised modified CORE-DATA base in the event of EPC quantification process. Unlike NARA and CARA, taxonomy was performed before EPC quantification process. Three categories were ascertained to reflect of human performance; Skill, Rule and Knowledge (S–R–K).

Apparently, the HEART method has been extended to different industries with the aim of enhancing compatibility – with the exception of the marine industry where limited studies of human error prediction have been presented. In the literature, a gap still exists with regards to human error prediction. Limited studies of human error prediction have been done in the marine transportation industry. For instance, Amrozowicz et al. (1997) proposed a probabilistic risk analysis method to identify tanker ship accident risks. The paper proposed an integrated method including fault trees and event trees and THERP techniques in order to quantify human errors. Furthermore, Konstandinidoua et al. (2006) presented a different approach combining the CREAM with a fuzzy set theory to determine the probability of human error actions. Another method for estimating human error probability (HEP), called cognitive reliability theory, was discussed in order to establish a systematised technique for risk assessment (Yoshimura et al., 2010). In this paper, more than six thousand marine accidents were examined in order to develop a systematic approach to human error. Another approach based on a formal safety assessment theory was introduced by Martins and Matuna (2010) and applied to performing a quantitative analysis of human failure contribution in the collision and grounding of oil tankers. Xi and Guo (2011) introduced a hybrid technique combining APJE and SLIM methodologies in order to predictively generate HEP values. The paper focuses on researching human errors in the marine industry and presents how the context affects human behaviour. Another study was performed by Yang and Wang (2012) in order to develop a generic method by modifying CREAM methodology. In the paper, fuzzy evidential reasoning and Bayesian inference logic are integrated into CREAM methodology to facilitate the quantification of human failure in the marine industry. Later, a new approach called human entropy (HENT) was presented by El-Laden and Turan (2012) to find generic root causes of human errors for marine and offshore applications. Likewise, Musharraf et al. (2013) introduced a quantitative approach to human error probability during offshore emergency conditions. Deacon et al. (2013) utilised the HEART approach to calculate human error values for critical steps of off-shore evacuation processes. A similar study determined human error probabilities in off-shore platform operations (DiMattia et al., 2005; Noroozi et al., 2014). In addition, Akyuz and Celik (2015a) have recently presented a novel approach by integrating the AHP method into the HEART approach to evaluate human error and reliability performance in chemical tanker ships. Recently, an application of the CREAM method into the cargo loading processes of LPG tankers has been implemented (Akyuz and Celik, 2015b). In the paper, the main focus of this research is to predict human error potentials for identified tasks and to determine required safety control levels on-board LPG ships. Accordingly, Akyuz (2015) has recently presented an approach to quantify human error probability in the gas inerting process of crude oil tankers. The paper provides a CREAM quantification approach on the case of a critical shipboard operation.