A Review of Human Error in Marine Engine Maintenance

R. Islam & M. Anantharaman
Australian Maritime College, University of Tasmania, Launceston, Australia

F. Khan
Memorial University of Newfoundland, St. John's, NL, Canada

V. Garaniya
Australian Maritime College, University of Tasmania, Launceston, Australia

ABSTRACT: Maritime safety involves minimizing error in all aspects of the marine system. Human error has received much importance, being responsible for about 80% of the maritime accident worldwide. Currently, more attention has been focused to reduce human error in marine engine maintenance. On-board marine engine maintenance activities are often complex, where seafarers conduct maintenance activities in various marine environmental (i.e. extreme weather, ship motions, noise, and vibration) and operational (i.e. work overload and stress) conditions. These environmental and operational conditions, in combination with generic human error tendencies, results in innumerable forms of error. There are numerous accidents that happened due to the human error during the maintenance activities of a marine engine. The most severe human error results in accidents due to is a loss of life. Moreover, there are other consequences too such as delaying the productivity of marine operations which results in the financial loss. This study reviews methods that are currently available for identifying, reporting and managing human error in marine engine maintenance. As a basis for this discussion, authors provide an overview of approaches for investigating human error, and a description of marine engine maintenance activities and environmental and operational characteristics.

1 INTRODUCTION

Over the years, technological improvement prompted an abatement of mishaps due to technical failures through the use of redundancy and assurance. However, it is difficult to discuss the reliability of a system without considering the failure rate of every one of its parts. One of these parts is "man", whose rate of failure goes to change the rate of breakdowns of segments with which it can collaborate (Armstrong, 2001). This has featured that "human factor" contributes significantly to the progression of accidents, both measurably and as far as the seriousness of the outcomes. As a result, human error is liable for marine accidents. Over the years, many accidents happen in marine operations due to the human error (Islam et al., 2017a, Islam et al., 2016,

Islam et al., 2018a, Islam and Yu, 2018, Islam et al., 2017b). In 2006, a passenger ferry Al-Salam claimed more than 1000 lives due to human error (El-Ladan and Turan, 2012). Moreover, in 2010 explosion of BP Offshore oil rig in the Gulf of Mexico characterized by fatalities and massive oil spillages. Studies of marine accidents confirm that human failure is responsible for about 75-96% of marine causalities globally (Wang and Trbojevic, 2007, Williams, 1996, Youngberg and Hatlie, 2004, Gatfield and IEng, 2006, Islam et al., 2018a). According to the UK P&I, human failure related accident cost maritime industry around $541m per year (Ung et al., 2006, Islam et al., 2017a). Since the accidents of Piper Alpha, there have been increasing promises within the maritime community to clearly classify and address the impact of human failure upon maritime safety. Assessments of the role

of Human and Organization Errors (HOEs) is an example of these commitments (Moore and Bea, 1995). Application of the knowledge addressing HOE in marine and offshore operations are the collection of human error probability data and human error assessment and decision making (Bea, 1998, Basra and Kirwan, 1998, Wang, 2003). Since the human factor is one of the essential causal factors of marine mishaps, human error probability (HEP) is a basic issue to monitor and analyze human reliability. The aim of Human Reliability Assessment (HRA) is to identify the likelihood of human error for a task.

There are several methods available for HRA. Qualitative and quantitative are two types of methods used for the HRA to identify the human contribution to risk. None of the available methods can be considered better; each has strengths and weakness and may be suitable relying upon context to be examined, resources and accessible aptitude. Therefore, this study focused on up to date HRA techniques to have knowledge of the ability of the available methods and an understanding of their strength and weakness. Prepare a summary of the methods. To analyze the strength and weakness the comparison study conducted within the available techniques. A comparison study is performed based on the evaluation of the model, taxonomy, data, and method that characterize each technique. Moreover, there is potential that methods could be used out of perspective or inappropriately, and hence it is considered that human reliability researcher should form a view on the 'acceptability' of such methods for use in HRA and risk assessments.

2 LITERATURE SEARCH

A literature review has been conducted to ascertain published wellsprings of information with respect to qualitative and quantitative HRA methods, including simulation studies and review articles. HRA studies provided various important articles and other data assets thorough internet search by the authors. Moreover, a search has been conducted by the authors for proper articles from a scope of databases, using search terms specified by the authors. The search was intended to collect source articles that complete HRA techniques and ensuring validation and analysis of journal articles. The purpose of the literature review was to draw upon information from existing published articles and evaluate the methodology from source references.

2.1 *Search results*

The data used in this review are collected searching through the Web of science core collection on October 9, 2017, and data-based was update in January 2019. Data collected from the 1900-present in the field of HRA in marine operations. There are several keywords like "Human error", "Human error probability" "Human reliability assessment" "Human Error" and search topics and "marine operations are used. A total of 12 records were found in the database excluding book chapters. The search results categorized based on the temporal trend of

publications and geographical distribution. The available methodologies for marine operations presented in the Table 1.

Table 1. Available Methodologies for marine operations

Serial	Methods
1	Cognitive Reliability and Error Analysis Method
2	Fuzzy set theory and Analytical hierarchy process
3	Human Error Assessment and Reduction Technique by incorporating interval type-2 fuzzy sets
4	Human Error Assessment and Reduction Technique (HEART), Human Factors Analysis and Classification System, Analytical hierarchy process (AHP)
5	Hybrid approach integrating HEART with AHP
6	Cognitive Reliability and Error Analysis Method
7	Success Likelihood Index Method (SLIM)
8	Bayesian Network (BN) integrates elements from the Technique for Retrospective and Predictive Analysis of Cognitive Errors (TRACEr)
9	Fuzzy based Success Likelihood Index Method
10	Integration of Absolute Probability Judgment for End points- Success Likelihood Index Method
11	Cognitive Reliability and Error Analysis Method
12	Bayesian Network (BN)

3 COMPARATIVE EVALUATION OF THE MOST USES METHODOLOGIES

SLIM is an expert judgment method in probabilistic reliability analysis. SLIM is a method for quantifying the preference in a set of options. Applicability of SLIM in assessing human reliability derives from the consideration that human performance is affected by different factors to assess a human response. SLIM is a simple and flexible method based on an expert judgment approach. The basic principle of this method is that the likelihood of an error occurring in a specific situation is associated with the combined effect of PSFs (Islam et al., 2016). The SLIM procedure is demonstrated in Figure 1.
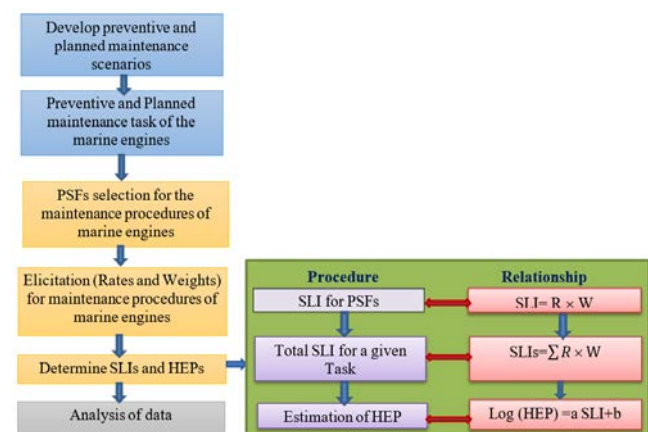

Figure 1. Application of SLIM to estimate HEPs in maintenance procedures of marine engine (Islam et al., 2016)

HEART is a technique for comparing HEP and its approach is based on the degree of error recovery. Its fundamental basis is that in reliability and risk equations, one is interested only in those ergonomics factors which have a large effect on performance. The

factors which have a significant effect are considered in the HEART (Islam et al., 2017a). This method is easy to understand, fast and reliable. However, its approach is quite subjective and heavily reliant on the experience of the analyst (Casamirra et al., 2009). The HEART procedure can be seen in Figure 2.

THERP is the most commonly used method in probabilistic safety assessments (Jae et al, 1995). This methodology includes task analyses and error identification and representation, as well as HEPs quantification. Probably, because of its relatively large human error database, and its resemblance with engineering approaches, it is used extensively in industrial applications in comparison to other techniques (Kirwan, 1994). THERP uses performance-shaping factors to make judgments about specific situations. In some cases, however, it may be difficult to accommodate all the factors that are considered significant. While THERP has the advantage of simplicity, it does not account for a dependency on human performance reliability with respect to time. This method includes a set of tables for evaluating HEPs that provides the basic HEP and the range of effect factors related to the activities (Xiaoming et al., 2005). The procedure of THERP methodology is demonstrated in Figure 3.
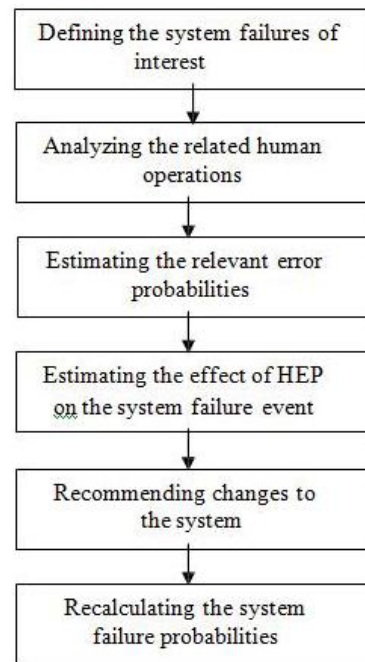

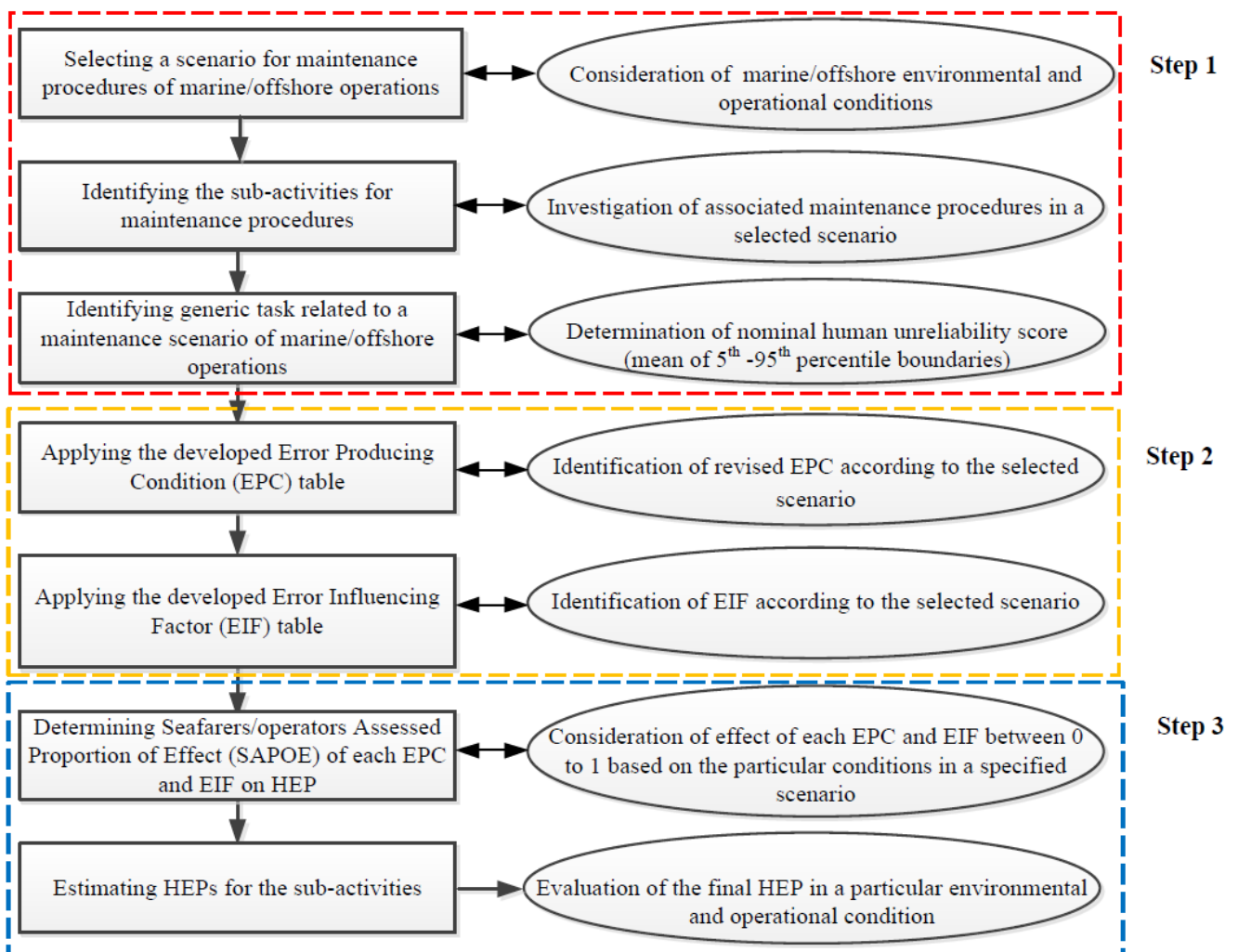Figure 3. The THERP procedure to obtain HEP (Kirwan, 1996)

Figure 2. Developed methodology for estimating the HEP for maintenance procedures of marine operations (Islam et al., 2016)

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Table 2. CPT for environmental factors (Islam et al., 2018)

| Weather conditions | Normal | | Moderate | | Extreme | |
Workplace temperature	Normal	Extreme	Normal	Extreme	Normal	Extreme
Environmental factor (poor)	0.00	0.80	0.80	0.80	0.60	1.00
Environmental factor (good)	1.00	0.20	0.20	0.20	0.40	0.00

BN is a probabilistic model which represents the interaction of variables through the direct acyclic graph and Conditional Probability Tables (CPTs). The networks consist of nodes and edges. Each node represents a probability of distribution either discrete or continuous. The nodes represent a set of random variables and edges joining the nodes represent direct dependencies between the variables. The relationship between the nodes is described using CPTs. All the variables of the network are presented in a CPT. The CPT provides a broad description of probabilistic interaction. If there are "n" variables $X_1, X_2, \ldots, X_n$, in the network and $Pa(X_i)$ represents the set of parents of each X_i, then joint probability distribution for the network is estimated as:

$$P\left(X_1, X_2, ..., X_n = \prod_{i=1}^{n} P\left(X_i | PaX_i \right) \right) \qquad (1)$$

where, $P(X_i | Pa(X_i))$ is the discrete conditional probability distributions of X_1 given its parents. Thus, the following information is required to develop a BN model.

- $X_1, X_2, ..., X_n$, set of variables (nodes)
- The interaction (edges) among the variables
- $P(X_i | Pa(X_i))$ conditional probability distribution for each variable X_1.

Table 2, represents a CPT for environmental factors to give better understanding of a variable in equation 1.

Bayesian Network (BN) is a mathematical graphic based model represented by each variable as a node with the directed links forming arcs between them. BN provides a natural way to handle missing data, allows a combination of data with domain knowledge, and assists in learning about causal relationships among variables. Moreover, BN can provide fast responses to queries. BN has been applied in various industries for assessing the HEP. The procedure of BN methodology is demonstrated in Figure 4.

In step 1, scenario selection, identification of the maintenance activity and category of the seafarers for the maintenance procedures of marine operations are required.
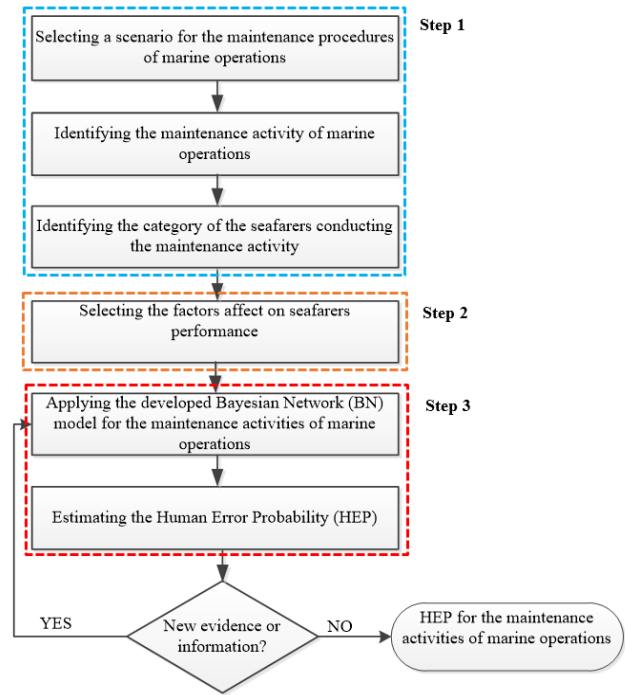

Figure 4. Methodology developed for estimating the HEP during the maintenance activities of marine operations (Islam et al., 2018b, Islam and Yu, 2018)

In step 2, it is necessary to select the factors that affect the seafarers' error making during on-board maintenance activities.

The final step (step 3) is to apply the developed BN model and estimate the HEP. If there is no new Information available regarding seafarers' performance-affecting factor, then it will be the HEP for that maintenance activity of marine operations. However, if new information is available, then it is essential to go back to the start of step 3 to add new evidence to update the estimated HEP.

4 CONCLUSIONS

Based on the comparative analysis of the previous section, none of the techniques have the capability of updating probability when new information is available except BN. Updating probability is important to instantly reanalyze posterior HEP based on newly available information. BN will also help represent the relationships between human factors and seafarers' actions in a hierarchical structure. Therefore, the authors suggest using BN as a powerful technique for more accurate HEP assessment in the maintenance activities of the marine engine.

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