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Prioritizing safety critical human and organizational factors of EER systems of offshore installations in a harsh environment

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ABSTRACT

This paper introduces a methodology for identifying critical human and organizational factors in the escape, evacuation and rescue (EER) systems of offshore installations in a harsh environment. To elucidate the complex dependence of human and organizational factors on risky incidents, this methodology uses a Bayesian network (BN) and a sensitivity analysis to assess the criticality of these factors. As a case study, the methodology is applied to the activation of an emergency alarm and considers the consequences introduced because of a harsh environment. The results of the case study show that the probability of success for personnel to become aware of an emergency alarm is most likely affected by noise due to strong wind. Using the proposed methodology, the probability calculations include the human and organizational factors that stem from the organizational level and extend to the evacuation procedures, emergency equipment, and personnel to provide a more practical result than the probabilities estimated by expert judgements.

1. Introduction

Human and organizational factors can be defined as environmental, individual, organizational, cultural, and equipment, affecting human physical perception, behaviour and performance. Both human and organizational factors are primarily concerned with optimizing human performance in all tasks with the aim of achieving a safe operation (CCPS, 2007; UK Energy Institute, 2011). Human and organizational factors in the escape, evacuation and rescue (EER) system of offshore installations operating in a harsh environment must be well understood to avoid harm to personnel and damage to structure. Examples of human and organizational failures as described in the Piper Alpha platform disaster are inadequate training, lack of communication between personnel and management, and insufficient procedures and arrangement for safe EER operations (Mearns et al., 2001).

An initiating event, such as a well blowout, loss of containment, fire and explosion, and collision, require personnel to leave their work area, move to a safe place, and abandon the installation (OGP, 2010). Previous studies investigated and discussed qualitative methods for identifying hazards in the EER operation (Kennedy, 1993; Gould and Au, 1995; Boyle and Smith, 2000; Woodcock and Au, 2013). Fire and toxic or flammable gas releases are better known as chemical hazards (AIChE, 1999; Assael and Kakosimos, 2010). Heat radiation from a fire or explosion and subsequent structural damage of emergency equipment are other potential hazards (USCG, 2011). Congestion in escape routes, unavailable alternative escape routes, inaudible alarms, and environmental conditions such as darkness, fog, cold temperature, and storms, jeopardise the safety outcomes of EER operations (Timco and Dickins, 2005; Matskevitch, 2007).

Performing EER activities in the presence of harsh environmental conditions is challenging to personnel and management on offshore installations (Bercha et al., 2004). There is a need to study human and organizational factors in EER systems associated with harsh environmental conditions and hazards to improve safety of personnel. This paper presents a methodology for prioritizing human and organizational factors and discusses the relationships of harsh environmental conditions to these factors in the EER system. The methodology is a probabilistic analysis of EER systems considering human and organizational factors for offshore installations in a harsh environment. The safety of the EER system is assessed in terms of (a) the probability of human responses influenced by human and organizational factors and environment conditions, and (b) the contributions of critical human and

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organizational factors to safe operations. To reflect the complex dependence of the human and organizational factors and harsh environmental conditions on the risks, the methodology uses a Bayesian network (BN) and a sensitivity analysis.

2. Development of a methodology for prioritizing human and organizational factors

Fig. 1 shows the methodology for identifying and assessing critical human and organizational factors in the EER system of offshore installations.

2.1. Identify input and output parameters

EER systems consist of safety planning and management, evacuation procedures, emergency equipment, and human actions (HSE, 1997, 2002; CAPP, 2010). From the EER system, two types of parameters, input and output, can be assigned to begin the study. Input parameters are safety planning and management, evacuation procedures, emergency equipment, and personnel physical abilities. Harsh environments and weather conditions, such as cold temperature, poor visibility, sea ice and wind, can also be added as input parameters. An output parameter is a human response that depends on input parameters. The output parameter can also be called a basic event.

2.2. Assign probabilities for input parameter

Data on the failure probability for evacuation operations have been reported in the literature (DiMattia et al., 2005; Khan et al., 2006; Deacon et al., 2010, 2013; Musharraf et al., 2013). Oil and gas regulatory and industry guidelines on emergency response and evacuation operations, specifically the prevention of fire and explosion, and emergency response (PFEER) (HSE, 1997) and EER (CAPP, 2010), medical assessment (CAPP, 2013a), and standard practice for training (CAPP, 2013b), can be useful references for estimating probabilities involving human and organizational factors for offshore installations in a harsh environment. Provisions in the guidelines can be considered as factors affecting human responses, as well as the performance of EER systems. The guidelines incorporate useful guidewords that can be translated to numerical values for provisions applied to input parameters using a scale of probability (Norrington et al., 2008). For the purpose of illustrating the methodology presented in this paper, we have posited probabilities corresponding to the guidewords in the PFEER and CAPP guidelines, as shown in Table 1.

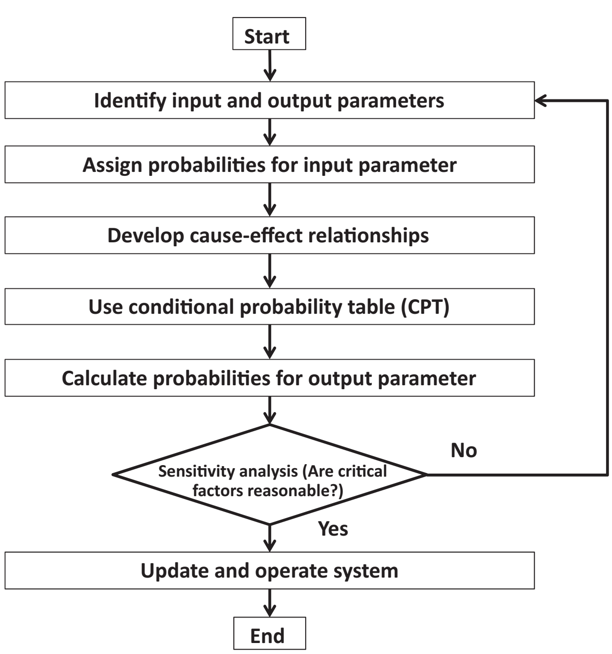

Fig. 1. Procedures for analysing critical human and organizational factors in the EER system.

2.3. Develop cause-effect relationships

A Bayesian network (BN) can provide an assessment of uncertainties in the context of the assumed relationships of human and organizational factors (Ren et al., 2008; Trucco et al., 2008; Wang et al., 2011a, 2011b). The relationship can be based on three types of structural properties of the BN, which are serial, common cause, and common effect connections (Celeux et al., 2006; Langseth and Portinale, 2007; Fenton and Neil, 2013). The development of the relationship is known as a directed acyclic graph (DAG), which also refers to a qualitative element. For this study, the relationship may consist of safety planning and management, emergency equipment, evacuation procedures, and human responses. Figs. 2 and 3 show examples of common cause and effect relationships used for analysing evacuation operations considering human and organizational factors, and harsh environmental conditions.

2.4. Provide conditional probability table

The output parameter depends on its relationships to input parameters and their probabilities. Both the probability and cause-effect relationship can be placed in a conditional probability table (CPT). The CPT can show the interaction between input and output parameters in terms of a quantitative measure. In this paper, each parameter is discrete and has binary states, such as 'yes' or 'no' and 'good' or 'poor'. Table 2 lists an example of a CPT for an alarm system and an audible alarm used in EER operations (Chen, 2011). When the alarm system is available and reliable, the audible alarm may either work properly or ineffectively. The audible alarm can be activated manually by personnel. The availability of the alarm system refers to data obtained from probability of failure on demand (PFD).

The CPT involving the alarm system can be extended with the inclusion of environment conditions and human response. Table 3 shows an example of a CPT for personnel to be aware of an alarm. The CPT consists of an alarm system, a visual alarm, darkness, and human response (Chen, 2011; Yun and Marsden, 2010). These parameters in the CPT show an interaction based on noisy-OR gates. In a Bayesian network, the noisy-OR gate can describe the interaction between causes and their common effects (Oniśko et al., 2001). This is illustrated by parameters in Table 3. As the alarm system is available, the visual alarm can be visible in darkness. Human response, such as *personnel aware of or detect alarm*, may depend on effectiveness of the visual alarm in darkness.

Table 1
Numerical conversion of guidewords.

Guideword	Probability
Shall	0.80–1.00
Should	0.65–0.79
Can or May	0.50–0.64