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A marine accident analysing model to evaluate potential operational causes in cargo ships

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ABSTRACT

This paper introduces a novel hybrid approach to assess potential operational contingencies in a real shipboard accident since safety at sea is of paramount significance in maritime transportation industry. The hybrid accident analysis model integrates an Analytical Network Process (ANP) method with Human Factors Analysis and Classification System (HFACS). To achieve this purpose, the HFACS model provides a schematic conceptual framework to investigate and analyse role of human error in marine accident and the ANP method provides correlation among the factors for assessment. Thus, the most important factors that contribute to the accident are revealed respectively. The novelty of this paper is to present a different perspective during marine accident analysis in which priority weights of accident causes related to the human error are calculated by ANP model. The hybrid accident analysis model is established to enhance safety and prevent loss of life or injury in maritime transportation industry. The proposed hybrid approach is illustrated with a real-ship incident case: a serious liquefied petroleum gas leak from the gas carrier ship. In conclusion, the research is expected to encourage safety researchers and ship-management companies to prevent similar accident occurrence.

1. Introduction

One of the most substantial concerns in the maritime industry is safety at sea. It involves prevention of human life, injuries, environmental pollution. In order to improve safety level at sea, maritime authorities have adopted a set of rules and regulations since marine incidents can cause fatal damages to the human life and environment (E. Akyuz and E. Celik, 2015; Hetherington et al., 2006). Nevertheless, the marine incidents are not reduced desired level as the findings show that a large numbers of marine accidents at ships are due to human error (E. Akyuz and M. Celik, in press; E. Akyuz and E. Celik, 2016; Fotland, 2004; Kirwan, 1987). Recently, investigation of the human contribution to the marine accident has become one of the important topics in the maritime industry. Therefore, safety practitioners have been attempting to offer alternative solution in light of the international marine organisations such as IMO (International Maritime Organization), ILO (International Labour Organisation), IACS (International Association of Classification Societies), ICS (International Chamber of Shipping), etc.

Marine accident investigation is considerably cited topic in maritime literature. Therefore, there are numerous theoretical and practical studies undertaken in recent years. For instance, Wang et al. (2013) discussed a ship collision case in order to prevent similar marine accident. In the paper, the authors develop an accident analysing model on the basis of HFACS and Bayesian network (BN) methods. The hybrid approach is supported by Evidential Reasoning (ER) method to rank preventive measures in accordance with cost-effectiveness manner. Likewise, another accident analysing model was proposed to design a conceptual model for investigation accident causes (Mullai and Paulsson, 2011). In the paper, the authors adopt the structural equation modelling (SEM). Chauvina et al. (2013) introduced a research paper which is analysing collision case. In the paper, the authors modified the HFACS method. Another research paper, which adopts the extended HFACS method, was introduced as a new marine accident analysing tool (Chen et al., 2013). Furthermore, a hybrid marine accident analysing approach was presented by Akyuz and Celik (2014) to analyse role of human error in marine accident. The paper is illustrated with a real-shipboard case and a marine accident prevention plan is recommended. Furthermore, Akyuz (2015a) presented a research paper which is evaluating potential navigational contingencies. In the paper, the author combines the

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AcciMap technique with ANP in order to analyse root causes in ship grounding case.

Since transportation of commodity has increased worldwide gradually, safety researchers and ship managers are trying to enhance marine accident mitigation measures by presenting proactive approaches. Specially, collision (Karahalios, 2014; Chauvina et al., 2013; Tabri et al., 2009), grounding (Akyuz, 2015a; Mazaheri et al., 2015; Nguyen et al., 2011) and fire/explosion (Guo et al., 2013; Reitsma, 2001) accidents can pose potential harm to human life, marine environment and commodity. Most of ships were involved in collision, grounding, stranding, flooding or fire/explosion accident at sea. However, statistics show that liquefied gas carrier ships are rarely involved in marine accidents (EMSA, 2015). In accordance with annual report of EMSA (European Maritime Safety Agency), less than 1% of gas carrier ships were involved in marine accident at sea in 2015. The gas carrier are special type of ships which is capable of carrying gas or chemical gas cargoes in liquefied form (IGC, 1993).

There are limited studies undertaken in the literature with respect to the gas carrier ships in particular marine accident investigation since these types of ships have the best safety record due to strict safety regulations. In the literature, there have been a couple of researches associated with gas carrier ships. For instance, Pitblado (2007) extended boiling liquid expanding vapour explosions (BLEVE) events for marine transportation. The author demonstrated the model in LNG ship fires. Another research paper was introduced to reveal accidental limit state of gas carrier ship during collision (Paik et al., 2001). Likewise, Fay (2003) proposed a model-based approach to estimate oil spill amount from the gas carrier ship. Furthermore, a human reliability analysis on-board LPG ship has recently been performed to assess crew performance during critical LPG shipboard operation (E. Akyuz and M. Celik, 2015). In light of the above, there is a lack of study in the literature to cope with analysing of human factor in evaluating the relative importance of multiple criteria. Therefore, this paper prompts a novel hybrid approach to provide interrelationship among the all causal factors in the same level and adjacent level, adopts supermatrix to extensively analyse the causal factors affecting each other.

In this context, the aim of this paper is to present a hybrid marine accident analysing tool to evaluate potential operational causes. To demonstrate the model, a real shipboard case study, which addresses a gas leakage from the gas carrier ship, is selected. As the aforementioned aspects are very relevant in the maritime transportation industry, the proposed approach and derivable contributes to superintendents and responsible managers in safety department. Therefore, the paper is expected to have a substantial impact on the maritime transportation industry in particular gas carrier shipping companies. Since there is a lack of research in the maritime literature to deal with the analysing role of human error in marine accident systematically, this paper prompts a novel hybrid approach in maritime industry. Within this scope, the paper consists of four main sections. The introduction section presents motivation of the paper and brief literature review about marine accident investigation. The method proposal is introduced in Section 2. A real case study application is demonstrated in Section 3. Conclusion and potential contribution of the study is discussed in Section 4.

2. Method proposal

The purpose of this study is to establish a hybrid accident analysing method to investigate accident causal factor. To achieve this purpose, the ANP technique is integrated into the HFACS. Since the HFACS presents a powerful tool for investigating human contributions to marine accidents under a wide evaluation scheme, the ANP model's judgment matrix is not only from the pair-wise comparison method, but from a combination of accident cases analysis results of factor frequency, the correlation coefficient between the factors, and the way coefficient of structural equation modelling. The next part expresses both methodologies accordingly.

2.1. HFACS

The HFACS is schematic smart tool to analyse role of human factors in accident. It was introduced by Wiegmann and Shappell (2003) to investigate and analyse accident causes in aviation industry. Indeed, it should be noted that the fundamental framework of the HFACS method was tailored from the Swiss cheese model which was initially introduced by Reason (1990). But, the HFACS model was successfully extended by introducing a comprehensive schematic framework to analyse role of the human error in accidents (Akyuz et al., 2016). The main purpose of the method is to provide a schematic framework to assist users for investigating and analysing of human error in accidents. A large numbers of causal classifications are defined within four levels of human failures.

The HFACS consists of four schematic level; organisational influences, unsafe supervision, preconditions for unsafe acts, unsafe acts in order to design a classification system for investigation human error in accident (Wiegmann and Shappell, 2003). In this context, the HFACS framework is provided in Fig. 1. The following identifications are made with respect to the level.

(i) *Organisational influences:* This level of human failures includes the organisational errors which may impact performance at all level. In the level; resource management, organisation climate and operational process are included to address latent failure.
(ii) *Unsafe supervision:* This level consists of the inadequate supervision, planned inappropriate operation, failed to correct problem and supervisory violations which can induce potential human errors due to unsafe supervision.
(iii) *Pre-conditions for unsafe acts:* This level covers crew resource management, personal readiness, physical/mental limitation, adverse physiological states and adverse mental states. The substandard conditions and practice of operators such as fatigue, poor communication, and poor environment condition are tackled by the preconditions for unsafe acts.
(iv) *Unsafe acts:* This layer theoretically has two major key factors; errors and violations since it is the last layer of human failure.

In the figure, each HFACS level defines the active and latent failures in the system (Reason, 1990). Thus, the safety practitioners can utilise the method by defining active or latent failures and can prevent further accident causes.

2.2. ANP technique

The Analytic Network Process (ANP) is an useful multicriteria decision-making (MCDM) method to solve complex problem by taking into account the interdependency between the criteria (Saaty, 1996). The technique basically provides a smart tool to deal with decision-making problem. Moreover, the ANP conceptualises the problem modelling by utilising a network of alternative and criteria. Indeed, all criterias (factors) in the system can be correlated in any potential way either within or among the cluster. Thus, an accurate modelling tool of comprehensive setting and interdependency among the criteria is provided.