ATLANTIS PRESS
Advances in Economics, Business and Management Research, volume 87
5th Annual International Conference on Management, Economics and Social Development (ICMESD 2019)

A Comprehensive Model for Human Factor Risk Assessment: HFACS-FFT-ANN

Yu Liu[1,a], Yang Liu[1,b] , Xiao-Xue Ma[1,c*] and Wei-Liang Qiao[2,d]

[1] Public Administration and Humanities College, Dalian Maritime University, Dalian, China

[2]Marine Engineering College, Dalian Maritime University, Dalian, China

[a]2281384834@qq.com, [b]yolanda125dmu@163.com, [c]yolanda125dmu@163.com, [d]xiaoqiao_fang@dlmu.edu.cn

Keywords: HFACS, Fuzzy fault tree, Artificial neural network, Fuzzy AHP.

Abstract. With the development of technology and reliability, the human factors are becoming the most contributing casual for the occurrence of accident. In the present study, a comprehensive human factor analysis model, including Human Factors Analysis and Classification System (HFACS), Fuzzy Fault Tree Analysis (F-FTA) and Artificial Neural Network (ANN), is proposed to assess human facors involved in accident or risk event. Under the framework of proposed model, the FFT stemmed from HFACS is mapped into ANN based on fuzzy theory, which may be beneficial for the prediction and assessent of human factors.

1. Introduction

Over decades, every efforts have been making to hence safety navigation of ship at sea at national and international level. However, a large number of marine accidents still take place worldwide, resulting in immense loss of lives and properties, also, the ocean environment is facing oil pollution risk. The causal system leading to marine accident is characterized by high level of complexity and uncertainty, however, it is critical to implement the causal investigation for improving the safety level of marine shipping. According to the statistics and marine accident causal research, an overwhelming part of marine accidents, about 75~96%, are attributable to human factors[1,2], especially with the application of advanced technology in marine shipping, this percentage may increase further.

The objective of the present study is to develop a comprehensive model integrated by HFACS, Fault Tree Analysis (FTA), Fuzzy AHP, as well as Artificial Neural Network (ANN), which is capable of resolving the uncertainty of human factors involved in the collisions at sea. The collisions at sea accident data in Chinese waters is collected in this study to verify the proposed methodology. In particular, the present study is characterized by mapping the FT into ANN under the framework of HFACS, in which the process digitalization and data mining are applied to establish causal relationship by both machine learning and pattern recognition. The proposed methodology in this study provides a complete process (with steps and rules), from the development of FT stemming from HFACS analysis, to the mapping of FT into ANN, which may benefit the investigation of human factors involved in collision accidents at sea.

2. Framework of the Proposed Model

The overview of the methodology proposed in this study is illustrated in figure a, in which the integration of HFACS, FTA, H-AHP and ANN leads to the formation of the comprehensive model to analysis human factors involved in the collisions at sea. As shown in figure a, there are totally 4 step in this study:

Step 1-Hierarchical Structure of the human factors is obtained based on the HFACS framework.

Step 2-modeling the Fault Tree according to the hierarchical structure developed in step1.

Step 3-huzzy APH is employed to calculate the failure probability of Basic Events and Top Events in the FT.

Step 4-map the FT into ANN.

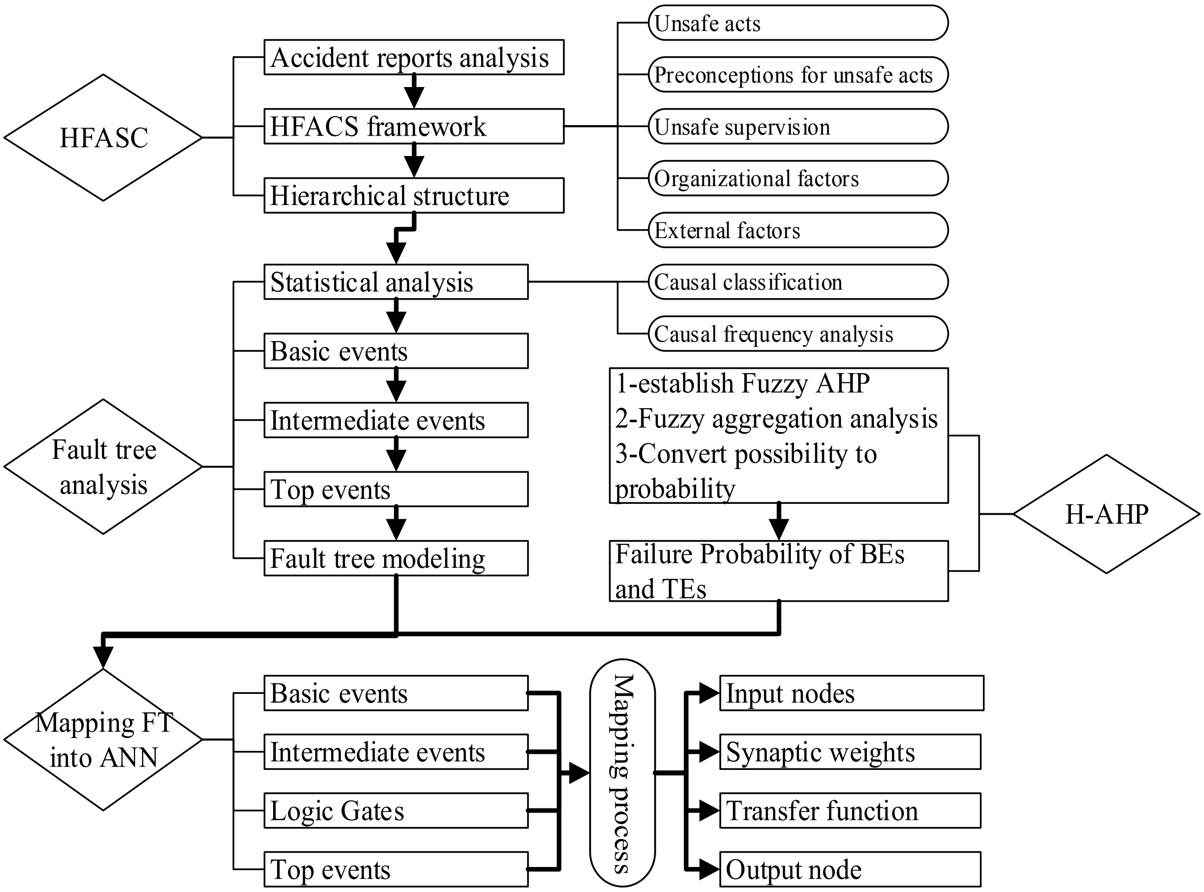

Figure 1. Overview of the proposed comprehensive model in the present study

3. Application of the Proposed Model

3.1. Establishment of HFACS Framework

In the present study, HFACS-based risk analysis model is developed to identify and classify the human factors involved in the collisions. The proposed model consists of five layers and 22 categories, which is illustrated in fig.2. Obviously, this model is established as a five levels framework, being similar to the HFACS-Coll[3], HFACS-Grounding[4] and HFACS-MAM[5]. However, it should be pointed out that the proposed HFACS model includes a special layer, named as Hazard situation, which is regarded as a supplement to the standard HFACS framework. Actually, the introduction of "Hazard situation" is aimed at facilitating the modelling process of Fault Tree, which will be discussed further in the following section 3.2.

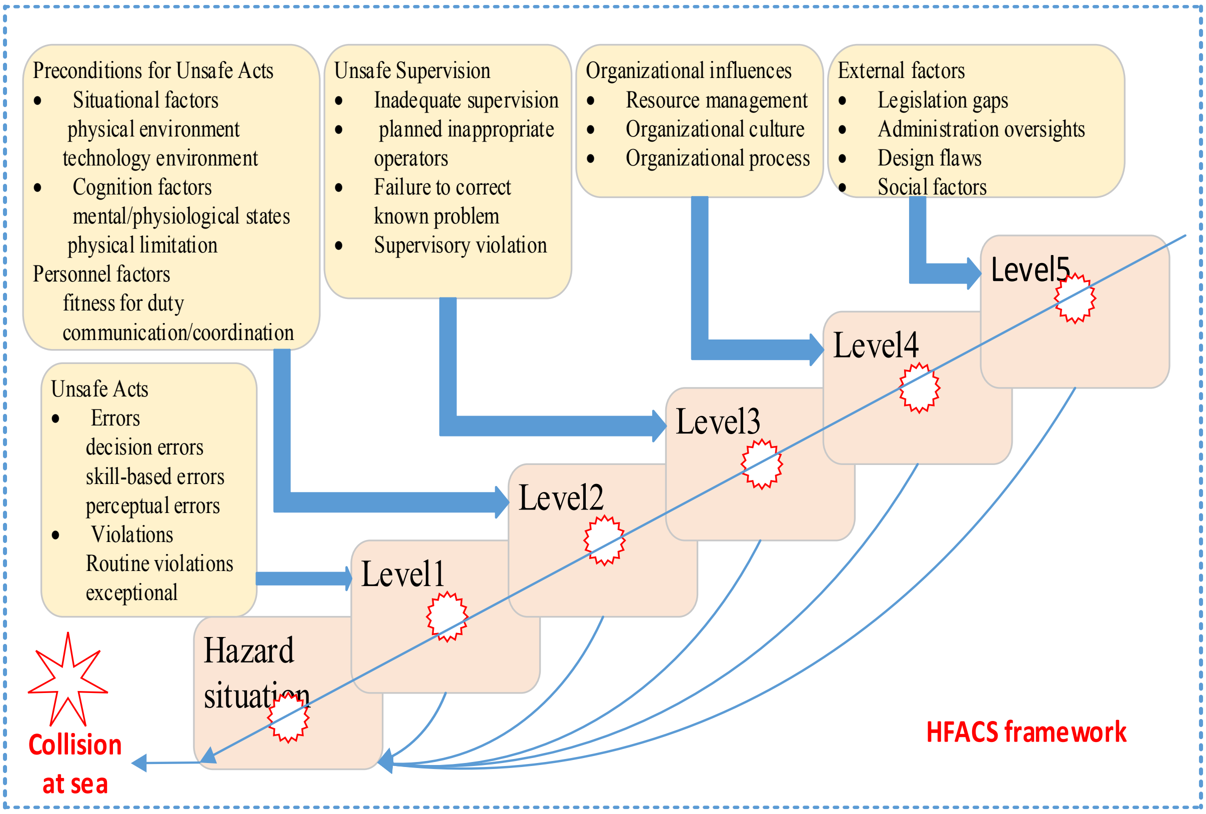

Figure 2. The HFACS framework used in this study

3.2. Fault Tree Analysis

Within the framework of FTA, the failure probability of the system can be decomposed into different kinds of failures and further into failures causes, until into the elementary failure causes, which cannot be decomposed any more. The typical FT is usually presented as a directed acyclic graph, which consists of Top Event (TE), Basic Events (BEs), Intermediate Events (IE) and gates.

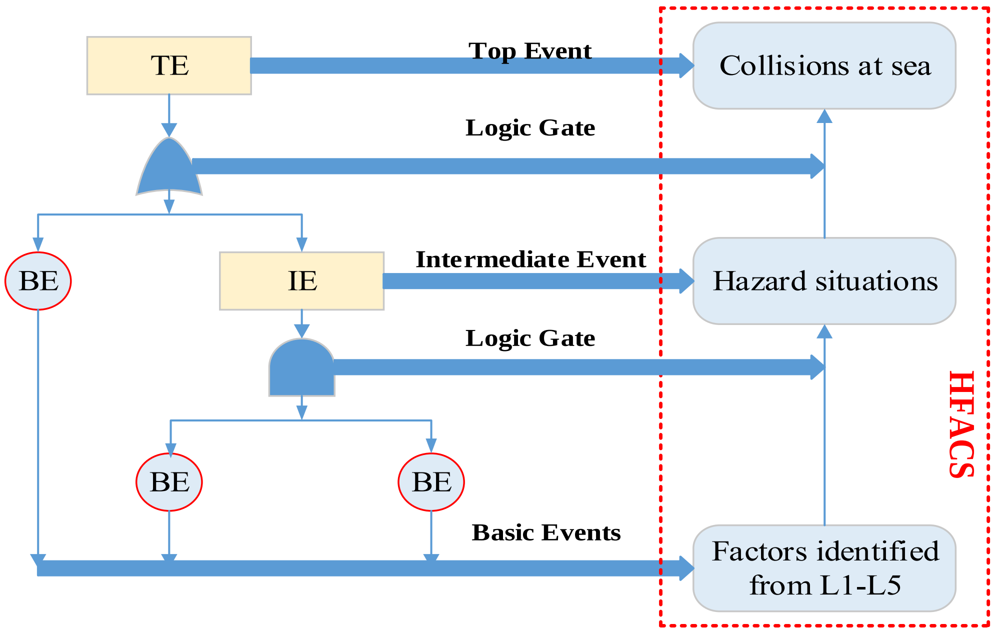

Figure 3. Logic relationship between FT and HFACS

In the present study, the elements, including TE, IEs and BEs, involved in the FT can be transformed from the aforementioned HFACS framework, and the transforming process is illustrated in fig.3. The human factors causing to the occurrence of collisions at sea identified from Level 1 to Level 5 under the framework of HFACS are mapped into the structure of FT as the Basic Events. Meanwhile, the "collisions at sea" in the HFACS framework corresponds to the Top Events in the FT model. The hazard situations identified would be transferred into Intermediate Events in FT, which is the reason why the layer of hazard situation is introduced into the proposed HFACS framework in this study.

3.3. Failure Probability Distribution of BEs and TE in FT Using Fuzzy Theory

Generally, there are three main approaches to addressing the failure probability, statistical methods, extrapolation, and expert judgment, respectively. In this study, the expert judgment approach is chosen as a scientific consensus technique to weight the identified human factors involved in the collisions at sea and to rank expert capability. However, since experts tend to express their opinions on each event based on their individual knowledge, purpose and intellectual characteristics[6], different analysis models have been established, such as fuzzy priority relations, game theory, the max-min Delphi method and the similarity aggregation method (SAM). It is hard to identify a technique that is superior to the others for aggregating expert opinions; however, it is widely accepted that ambiguous expression from experts is extremely common. Thus, the integration of fuzzy set theory and the Analytic Hierarchy Process (AHP) is frequently utilized to aggregate experts' ambiguity.

3.4. Mapping FT into ANN

With the development of computational tools, artificial neural networks (ANN) are created gradually, and have been widely applied as computational techniques for modeling and forecasting in various fields[7]. As is shown in fig.4, the training and testing of network are two main steps based on the establishment of ANN architecture. For the training of the network, the back-propagation algorithm is widely applied for tuning suitable weights of each neuron. The two-step iterations involved in the back-propagation algorithm: the first forward step calculates the results; the second backward step is aimed at error computations and weights updating. The iterations would continuously run until the calculated error satisfies the pre-defined goal tolerance requirement[8]. Among the lists of methods utilized to minimizing the overall error, the Mean Squared Error (MSE) is preferred, and widely used.

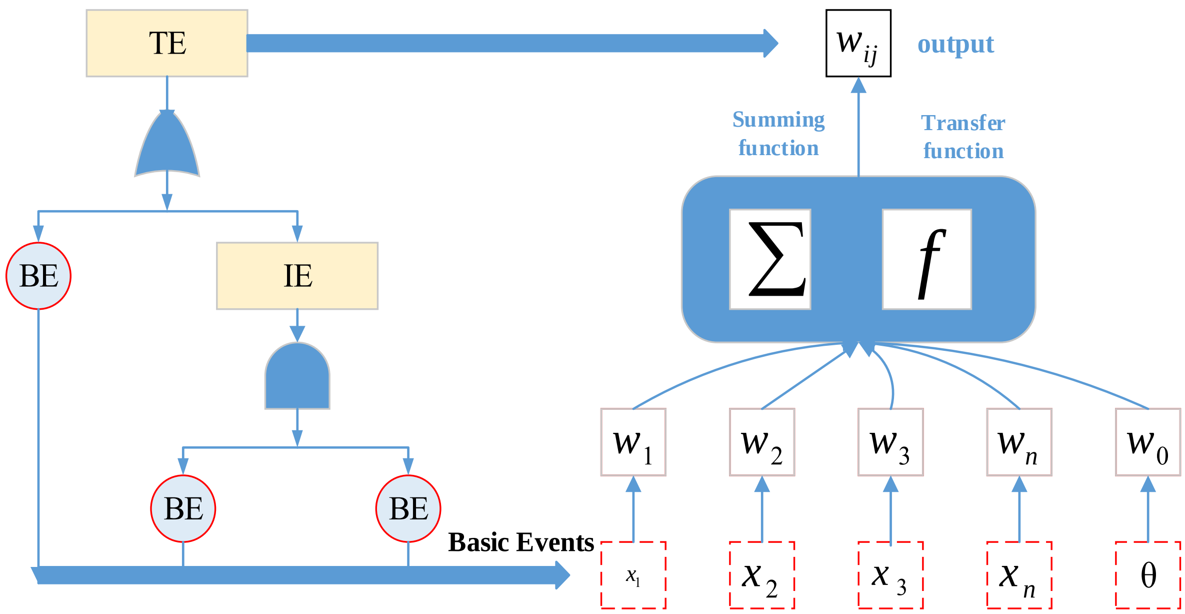

Figure 4. Mapping FT into ANN

4. Summary

In the present study, a comprehensive model is proposed combining fuzzy set theory, HFACS, FTA, AHP, and ANN. Focusing on human factors, the model aims to identify, characterize and rank the human factors involved in accidents or risk events from a causation perspective. The proposed model can effectively handle the uncertainty and intuitive opinions of experts regarding sand carrier accident analysis.

5. Acknowledgement

The authors gratefully acknowledge the financial support provided by the Fundamental Research Funds for the Central Universities (grand No. 3132019190).

6. References

[1] Ugurlu, Application of fuzzy extended AHP methodology for selection of ideal ship for oceangoing watchkeeping officers, Int. J. Ind. Ergonom, 2015, 47(5)132-140.

[2] D. Pennie, N. Brook-Carter, W. Gibson, Human factors guidance for maintenance. In: Human factors in ship design, safety and operation conference. The Royal Institution of Naval Architects, March, London, UK, 2007.

[3] C. Chauvin, S. Lardjane, et al., Human and organisational factors in maritime accidents-Analysis of collisions at sea using the HFACS. Accid. Anal. Prev. 2013, 59, 26–37.

[4] S.T. Chen, A. Wall, et al., A human and organisational factors (hofs) analysis method for marine casualties using hfacs-maritime accidents (hfacs-ma). Saf. Sci. 2013, 60 (12), 105–114.

[5] Mazaheri, J. Montewka, et al., Usability of accident and incident reports for evidence-based risk modeling – a case study on ship grounding reports. Saf. Sci. 2015, 76, 202–214.

[6] D.N. Ford, J. Sterman, Dynamic modeling of product development processes. Syst. Dyn. Rev. 1998, 14 (1), 31–68.

[7] N. Chitsazan, A. Nadiri, et al., Prediction and structural uncertainty analyses of artificial neural networks using hierarchical Bayesian model averaging. J. Hydrol. 2015, 528, 52–62.

[8] I.A. Basheer, M. Hajmeer, Artificial neural networks: fundamentals, computing, design, and application. J. Microbiol. Methods 2000, 43 (1), 3–31.