Safety Science 92 (2017) 34–43

Contents lists available at ScienceDirect

Safety Science

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

An integrated risk assessment based on uncertainty analysis for cargo vessel safety

Hakan Akyildiz *, Ayhan Mentes

Faculty of Naval Architecture and Ocean Engineering, Department of Ship Building and Ocean Engineering, Istanbul Technical University, Istanbul 34469, Turkey

ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form 14 August 2016
Accepted 20 September 2016

Keywords:
Cargo ship safety
Uncertainty analysis for risk management
Fuzzy Based Risk Assessment

ABSTRACT

The use of risk analysis methods as decision support tools is getting more and more acceptance to analyze, recover or mitigate potential risks in engineering applications. Integrated risk analysis techniques lead to obtain more reliable and realistic solutions. In this paper, 'Fuzzy Based Risk Assessment' has been used and systematically incorporated in terms of a set of plausible model scenarios leading to cargo vessel accidents at the coasts and open seas of Turkey.

Through the analysis, four main aspects of uncertainty proposed by authors, i.e. level of understanding, quality of knowledge, uncertainty level of cargo ship accidents and sensitivity levels of model parameters, are integrated to model parameters to analyze cargo ship accidents. In order to investigate the effects of uncertainty parameters to model parameters, the paper incorporates 'Fuzzy Set Theory', 'fuzzy analytic hierarchy process, AHP' and 'fuzzy technique for order preference by similarity to an ideal solution, TOPSIS' methods due to the nature of subjectivity and ambiguity of the parameters in uncertain marine environment. 'fuzzy analytic hierarchy process' is used to analyze and determine the weights of the aspects of uncertainty while 'fuzzy technique for order preference by similarity to an ideal solution' is employed for ranking the model parameters. The case study demonstrates the effectiveness and feasibility of the proposed methodology. As a result, a risk perspective for the integrated risk management and decision making process is presented.

1. Introduction

More than 80% of the global shipping of goods is done by ships and the total amount of goods transported is continuously increasing as the world trade between various continents. As the world trade expands, systems that offer convenience, speed, safety and low cost evolve increasingly. Following the increasing demand for tonnage, the maritime industry moved to the development of bigger ships and the need for the creation of "economies of scale" resulted in the largest cargo ship sizes. Although there were not many major casualties in terms of loss of lives, cargo ships have more of its fair share of loses involving cargo damage, personnel injury, collision and grounding, ship structural failure and pollution. Collision and grounding may be the biggest dangers to a cargo ship but fire may also have serious consequences (Henley and Kumamoto; 1992). As far as the types of damages are concerned, the result is an equally high percentage of cargo damage for the majority of cargo ships in various aspects. The statistics show that a high percentage of all incidents caused by human errors. Other operational characteristics of cargo ships, as the fact that they rarely travel in ballast condition and the few opportunities for overnight stay at ports, contribute to the overall performance of these vessels and their operators.

In the about last twenty years, more attention has been focused on marine safety on board cargo vessels. This is due to the serious cargo ship accidents taking place during the period. In the maritime industry, International Maritime Organization (IMO) implements the principles of risk management to assess risks and evaluate costs and benefits, support to decision making process. The use of risk analysis methods as decision support tools aims at enhancing maritime safety including protection of life, health, the marine environment and property. They also achieve a balance between the various technical and operational issues, including the human element, maritime safety, protection of the marine environment and costs.

Mentes et al. (2015) carried out an intensive review of the literature about applications of tools in shipping industry. The decision support tools can be used as a proactive methodology, enabling potential hazards to be considered before a serious accident occurs. On the other hand, the word "risk" does not fully reflect the way of the risk description. It is highly technical and complex, yielding

* Corresponding author.
E-mail address: akyildiz@itu.edu.tr (H. Akyildiz).

http://dx.doi.org/10.1016/j.ssci.2016.09.009
0925-7535/

results which may not fully reflect the relevant features of the analyzed system (Devanney, 2013). To facilitate a more flexible and more representation of the real world decision making problems, it may be beneficial to adopt a more systematic risk perspective. To improve safety at sea, risk factors need to be modeled and safety based decisions require to be made in a consistent and efficient way. Additionally, risk modeling and decision-making tools need to be developed and applied in a practical environment. As a result, integration of the techniques leads to acquire more reliable and realistic solutions in maritime domain.

The aim of the study is to present an alternative framework for uncertainty assessment of cargo ship accidents and facilitate a risk modeling for cleaner and safer maritime transport. We elaborate on a risk perspective in terms of aspects of uncertainty for an integrated FBRA. The paper intends to investigate how the uncertainty parameters can be used for cargo ship accidents to learn the effects on model parameters. In order to investigate the effects of the uncertainty parameters to the model parameters, the paper incorporates FST, FAHP and FTOPSIS methods due to the nature of subjectivity and ambiguity of the parameters in uncertain marine environment.

2. Knowledge and understanding

The paper focuses on to create and stimulate main aspects of uncertainty in maritime safety. For this purpose, level of understanding, quality of knowledge, uncertainty level of cargo ship accidents and sensitivity levels of model parameters are used as uncertainty parameters the current study. Some related information is given the following sections.

2.1. Knowledge

Knowledge and understanding are fundamentally different. Knowledge is widely identified with propositional knowledge and is objective, so that the more you work in a field the more you know in it. To acquire knowledge about events, first the events need to exist in favor of expert knowledge (Baumberger, 2014). Therefore, the growth of knowledge is a cognitive advancement that satisfies the additional condition. On the other hand, the main goal of a cognitive process is not to acquire knowledge but to advance understanding (Montewka et al., 2014). "Real" understanding is dynamic and has nothing to do with knowledge.

Identification of risk factors is highly significant, together with the evaluation of their impact on cognitive process for the quantifying of risk and allows corrections and comparison of the results. There can be several relations between the risk assessment and the knowledge. One is how to improve the risk management process by using the knowledge. The other is how to identify and manage risks in the growth of knowledge, in order to obtain the best results in terms of the risk reduction. The growth of knowledge is the collection of people interactions, modern technology with a suitable sharing platform and structure of the risk management. It is also related to the class of information systems as creation new knowledge, storage and retrieval, distribution and application. Therefore, it is of great importance for managing knowledge risks in terms of establishing a learning climate, mitigating knowledge loss, creating channels for knowledge flow and monitoring knowledge risks.

Risk factors may differ depending on many external and internal circumstances and specific characteristics. The selection of these factors should be made by monitoring the process and drawing on other experiences. The assessment of risk factors for achieving the growth of knowledge is crucial for making a good choice. The importance of knowledge could be aimed at analyzing various types of knowledge in order to check and correct the validation of the achieved results.

2.2. Understanding

The main goal of the growth of knowledge is to advance understanding. Besides knowing the important and relevant truths that belong to the comprehensive, "real" understanding is dynamic and has nothing to do with knowledge. It can be indicated that understanding is more ambitious. Therefore, argument and new questions should be carried out within the framework of the account that does not yet provide conclusive answers (see, Baumberger, 2011, 2014; Elgin, 2006).

Knowledge and understanding are fundamentally different with different specific difficulties. Since understanding can be more or less accurate, it must answer to the facts by accommodating the evidence on the entire system. In complex systems, there are numerous causes which interact in complicated manners. Therefore, it is difficult to address all of the causes. Additionally, understanding admits degrees, meaning that with each step in the sequence we understand an analyzed phenomenon better than we did before. As a result, it can be concluded that understanding is not to be factive. As the risk is about future events and we do not possess facts about the future, thus our knowledge implies assumptions, which come from our understanding. This means that risk perspective inherently contains understanding in larger proportion than knowledge.

2.3. Scoring system

A scoring system is presented for the qualitative uncertainty assessment. The system consists of the level of knowledge, the quality of understanding and the joint effect on the uncertainty of a risk model. The main idea of the scoring system is to assign a qualitative description for the quality of knowledge and the level of understanding to each and every element of the model. Each element of the model and relations between the elements are evaluated with respect to the evidence, which is used to describe the element as follows:

- Considering the knowledge; data, models and theories are the factual elements that allow a decision-maker to formulate statements about the risk model.
- Considering the understanding; assumptions, judgments and the ability to assess the level of knowledge about the element are not necessarily the factual elements.

The presented classifiers are crude and can be case-specific and subject to judgments by the analyst. The expert judgments were gathered during several workshops and interviews from the Turkish under secretariat of Maritime Affairs and Directorate General of Coastal Safety respectively. The experts are made judgments by expressing their opinions based on their experience, knowledge and expertise. The following category classification is applied for the qualitative uncertainty scoring system as follows (Table 1):

Table 1
Degree of uncertainty.

	Quality of knowledge		
	High	Medium	Low
Level of understanding			
High	L	L	M
Medium	L	M	M
Low	H	H	H