A HYBRID FUZZY APPROACH OF RISK ANALYSIS, WITH APPLICATION TO OIL TANKERS

PHD Thesis

By

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ABSTRACT

Recently, the growth in the oil tanker industry has significantly increased; the quantity of crude oil transported by tankers reached 55.3 million barrels per day (bpd) in 2012. On the other hand, the number of oil spill accidents related to oil tanker reached 10000 in the period from 1967 to 2013 and led to 5.74 million tons of oil spilled to the sea. These accidents occurred because of many reasons such as fire/explosion, hull failure, equipment failure, collision and grounding and the consequences of these accidents in human, environmental and economic aspects are in some cases disastrous, which reflects the urgent need for more effective risk management system within a framework of total quality. For a complex system such as oil tanker industry, this is challenging because knowledge of the different hazards in such a system is inadequate, which, in turn, leads to problems of high level of uncertainty in risk analysis results.

This research effort was undertaken to (a) review Multi-Criteria Decision Making (MCDM) and risk analysis approaches showing their salient features, potential capabilities and fields of application, (b) choose a number of these approaches to apply in the oil tanker industry as a case study, (c) compare the results of these approaches and investigate their individual strengths and shortcomings, and (d) possibly propose a hybrid approach to overcome the individual shortcomings of these approaches. Two sources of data were recoursed to: (i) Safedor project (2007) to select the scenarios considered and (ii) a group of nine specialists from the oil tanker industry, with appropriate skills and experience, to evaluate these scenarios.

Three MCDM approaches were selected, namely: qualitative, FTOPSIS and FAHP, for ranking 21 hazard scenarios, which are likely to take place on PANAMAX oil tanker, based on 8 criteria. The results obtained show that each approach has its own advantages and shortcomings; the qualitative approach, for instance, depends essentially on human evaluation and any change in the nature of the experts team carrying out the process of evaluation will cause variations in results, which, in turn, causes uncertainty in these results. FTOPSIS has the advantage of dealing with the uncertainties, but it does not take into account the effect of the weight of the individual criteria on the evaluation of risk values,

which is another source of uncertainty. Moreover, in FTOPSIS there is no unique process to transfer the qualitative variables to fuzzy numbers. The main shortcoming of the FAHP approach is the burden put on the experts in performing the pair-wise comparisons, with increasing the number of scenarios, which may result in inconsistency of the data they provide.

Conclusions

Based on the results obtained from applying the different approaches, i.e. qualitative, FTOSIS, FAHP and Hybrid approaches, to the oil tanker considered, the following conclusions can be drawn.

- There are a huge number of qualitative, quantitative and fuzzy MCDM methods each of which can be used in risk analysis applications.
- One can hardly decide which of the MCDM methods is the most effective and suitable method, as each one has its own advantages and limitations, and the selection of the proper approach depends mainly on the problem to be investigated.
- Risk analysis of MCDM problems can be a vital tool for decision makers in the oil tanker industry.

Comparisons among the qualitative, FTOPSIS, FAHP and Hybrid approaches have revealed the following:

- The qualitative approach is mainly based on experts' judgments which vary from one to anther depending on many factors such as education, experience, age, mode and work environment. These judgments are posed using linguistic variables, which are a source of uncertainties in risk analysis results. These uncertainties can lead to ineffective safety management and affect project objectives diversely.
- The FTOPSIS approach solves the problem of uncertainties, but it still has its shortcomings: (i) Linguistic variables should be transferred to fuzzy numbers and (ii) It does not assign weights to the individual criteria when evaluating the hazard scenarios, thus contributing to uncertainties in results.
- Although the FAHP solves the problems of uncertainties associated with the qualitative and FTOPSIS approaches, it still has its own shortcomings: (i) Increased number of mathematical operations, which is directly proportional to the number of scenarios, and (ii) Increased number of pair-wise comparisons, which could lead to inconsistency in results.
- Two new criteria, detectability and reduction measures, are used as negative criteria in this study, probably for the first time.

- The hybrid approach which is the main contribution of this endeavour, solves the uncertainty problems associated with the approaches used herein.

Recommendations

Based on the current work and its findings, the following topics are recommended, first for the industry and second for future research in the same field.

First: for the industry:

As it has been concluded, the risk analysis is a vital tool for decision makers to use to achieve the strategic goals of their organizations such as payback period and project safety. As such:

- The risk analysis team should be selected from qualified risk analysts and field experts.
- Robust approaches should be tested in the same field and environment before being used.

Second: for future research:

- To try other types of fuzzy numbers and to compare the results with those obtained when using the TFNs and to possibly propose a procedure for selecting the most appropriate FN for a specific application.
- To broaden the scope of the current study by considering other MCDM approaches.
- To investigate the possibility of finding a methodology of selecting an optimum approach or a combination of approaches to solve MCDM problems.
- To apply the procedures followed in the current study on other types of vessels, such as LPG and LNG carriers.