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Developing a conceptual framework to evaluate effectiveness of emergency response system for oil spill

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Abstract: The increase of oil spill accidents has made significant impacts on life, property and the environment. Facing ever-increasing risk of disaster losses, how to cope with and response to large scale oil spill disaster effectively is becoming more and more important. And it is extremely onerous and arduous to develop a highly capable assessment technique to evaluate the effectiveness of emergency response system (ERS) for oil spill. An ERS for oil spill is a complex and dynamic system comprising a number of elements, one of which fails to accomplish its function would result in potential adverse impacts on the whole system. Evaluating the effectiveness of the system requires the consideration of all failures identified in the system simultaneously. Aims to propose a decision-making framework, this paper uses failure mode effect and criticality analysis (FMECA) to evaluate the effectiveness of ERS to make improvements in oil spill emergency management. It is achieved by analysing the components and bounds of the system, identification of generic failure modes which are considered as key factors of ERS for oil spill. And lastly a case study is demonstrated to validate the methodology framework.

Key words: emergency response system (ERS); oil spill; effectiveness; FMECA

1 Introduction

According to the statistics of Clarkson Research Services Limited, the total oil tanker fleet is up to 493 million tons by the end of 2012. The development of vessel traffic increases the occurrence probability of oil spill, and the significant impacts on local economies and environment. In April 2010, the British Petroleam licensed transocean drilling rig deepwater horizon sank in the Gulf of Mexico took away eleven lives and sent over 200 million gallons of oil into the water (Alijani et al. 2012). An oil spill disaster of a pipeline explosion at port of Dalian, north-east of China, happened in 2010. 1500 tons of oil spilled from the pipes created 180 km^2 slick in the Yellow Sea, which grew to 430 km^2 later (The Huffington Post 2010). The container ship "Cosco Busan" slammed into a bridge tower in 2007, which was not

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handled effectively because the officials misjudged the severity of the oil spill, and more than 50000 gallons of oil spilled in the bay (Fimrite 2007).

Facing ever-increasing risk of disaster losses, how to cope and deal with large scale oil spill disaster effectively is becoming more and more important. It is a system engineering involved in many subsystems which act as prevention, mitigation, preparation, response and recovery. An emergency response system (ERS) for oil spill is designed to assess, react, and recover an emergency as quickly and effectively as possible. It comprises a series of interrelated and interdependent subsystems and activities to complete the tasks in the ERS for oil spill.

The effectiveness evaluation of ERS for oil spill can measure the expected objectives achievement, and detect the failures in response. A recent reviews demonstrate that there are many literatures and research highlights of the importance of ERS. However, relative scarcity of the literature on the effectiveness evaluation of ERS is emphasized, and the area of ERS for oil spill is particularly underdeveloped.

Some literatures only focus on the part of the ERS, which includes coordination between the military and civilian organizations during emergency (Salmon et al. 2011), the importance of updating information during the emergence response (Vivacqua and Borges 2012), the improvement of the response time to increase the effectiveness of ERS (Mustaffa and Kazunori 2012), effectiveness of response team features (Leach and Mayo 2013), the effectiveness of training in organizations(Winfred et al. 2003), the stakeholders' perspective of prioritizing oil spill objectives (Tuler and Webler 2009), and post-incident assessment of environmental contamination and damage (Kirby and Law 2010). However, the emergency response comprises a series of interrelated and interdependent components and activities. The increased performance of single component can't represent for the increase of the whole system. It is necessary to break the system into "pieces" to find its failure and potential causes, but most important is from the system perspective to analyze how these "pieces" fit together to reach the goal of the system.

Other literatures highlight the effectiveness of ERS from the view of system engineering. Abrahamsson et al. (2010) built a framework to evaluate the effectiveness of ERS and exemplified by a power supply system; Smith and Clark (2006) used the combination of Value Focused Thinking (VFT) and BN influence diagram to model the effectiveness between the system components, which needed large amount of precise information to define the prior probability. Jackson et al. (2010) used FMECA to evaluate the reliability of ERS and took chlorine release as an example based on historic data. It is relative easy to evaluate the effectiveness of ERS based on the historic data. However, the data are usually insufficient for oil spill, which usually appears randomness and vagueness with high uncertainty, and some data are confidential.

Oil spill disaster is considered to be unpredictable because of number of people involved, short decision in limited time, unavailability of resources, uncertainty about the situation, pressure and stress involved, and damage to the sea environment (Vivacqua and Borges 2012). Consequently, effectiveness evaluation of ERS detected from past accidents provides an insight of problems might happen in future (Jackson et al. 2011), no matter the corporation mechanism running smoothly or not, or how the performance of emergency manager is (Hockings et al. 2006). Uhr et al. (2005) develops a metric to evaluate the effectiveness of ERS, which includes saving of lives and property, the efforts of responders to aid casualties, the response time period, and the safety of the response with respect to responders. However, this metrics is too rough to reflect the ERS operation. The emergency response process is dynamic and full of uncertainties. It is, therefore, necessary to analyze the functions of each component or element, and trace back their direct and indirect impacts on the final outcome.

This paper aims to propose a decision-making framework to evaluate the effectiveness of ERS for oil spill. Identification failure modes will be done to influence the effectiveness of ERS. The failure means activities involved in response process do not complete their functions at a given time of contingency plan. Based on this, an analytical framework of ef-