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Segmented pinch analysis for environmental risk management

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ABSTRACT

Implementing environmental risk mitigation countermeasures in the context of a business environment requires balancing costs and benefits of projects to be implemented. Systematic environmental risk analysis methods are thus needed to aid decision-making. This paper proposes a segmented pinch analysis methodology that considers the relationship between environmental risk prevention and control countermeasure costs, while also considering the criticality of environmental risk prevention. In this methodology, the countermeasure costs are divided into low-, medium-, and high-cost intervals. This methodology is illustrated using a chemical industry case study to demonstrate how risk countermeasures can be identified under different levels of a firm's "willingness to pay." The final optimal mix of countermeasures can then be determined from candidate solutions. And it makes a firm to best allocate resources to the enterprises' risk points to ensure the normal operation of a chemical enterprise.

1. Introduction

Safety and environmental risk issues are important considerations in the chemical industries. There are many notable historical or recent examples of industrial accidents in chemical plants. For example, the Tianjin Explosion in 2015 killed over 170 people and injured hundreds of people neighboring the accident site in the Port of Tianjin (Berr, 2016). There has been rapid growth of the economy of China in general, and of its chemical industry in particular. China has the largest output among all countries of chemical products in terms of economic value, and the contribution of this sector to GDP increased from 2.2% in 1981 to 4.1% in 2011 (Lin and Long, 2016). Problems associated with enterprise environmental risk of chemical industries cannot be ignored. Furthermore, in China many chemical plants are medium- and small-scale enterprises that do not have mature safety and environmental risk management systems. Once an accident happens, it becomes a catastrophic issue for these enterprises and their neighboring communities. Hence, environmental risk management is critical for the normal production of chemicals, and the rational allocation of environmental risk prevention and control costs is also an important management consideration.

Environmental risk management, as an important aspect of risk preventions in chemical plants has been widely applied in practice for decades. In 1980, the US Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which has been mainly employed to regulate the environmental risks of contaminated sites. US legislation has also been revised via the Resource Conservation and Recycling Law to control the risk of new hazardous waste (Phifer, 2010). In 1990, the UK adopted the Environmental Protection Law, which requires enterprises to carry out genetic variation before environmental risk assessments are conducted. As explained above, many countries have developed legislation to promote environmental risk management. From the aspect of industry, inadequate measure to reduce the risks could result in severe consequences for companies. Environmental risk assessment could achieve a balance between economic investment and risk reduction. It plays a fundamental role in providing decision support for managers on how to choose an optimal risk management plan. Many studies have been reported the application of environmental risk management techniques to industrial plants. For example, Laffont (1995) investigated the tradeoff between cost minimization and safety by considering moral hazard in regulation of a natural monopoly, taking into account aspects such as adverse selection, limited liability, risk aversion and multiple principals. Kamrin (1997) addressed the contrast between risk management and risk assessment. In their work, some recommendations were made to improve the situation of the plants from various perspectives, and a case study was used to show how to harmonize risk assessment and management.

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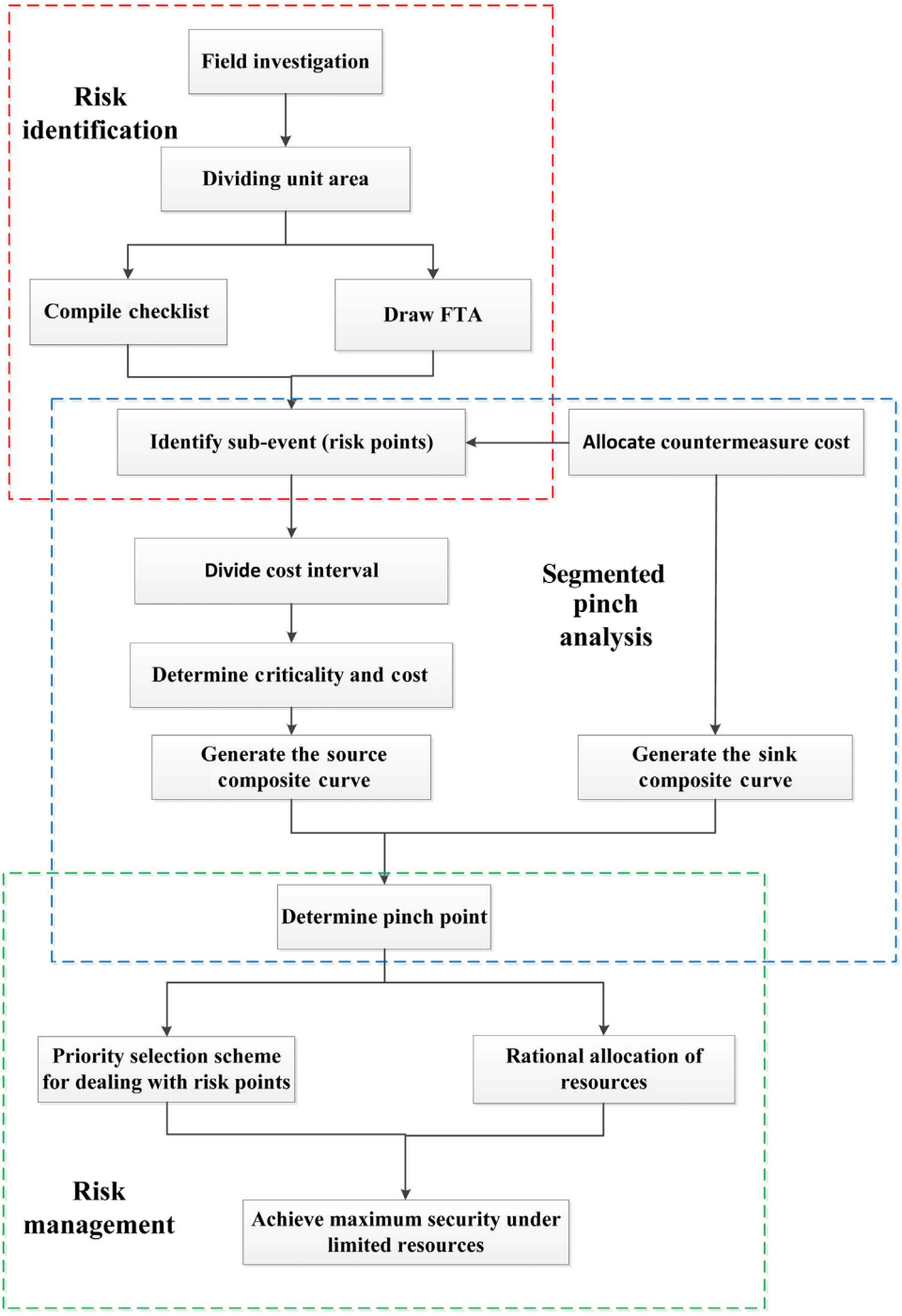

Fig. 1. Integrated framework for environmental risk management.

Environmental risk management is important for the planning of chemical plants. The detailed process of environmental risk management is complex, because it is a holistic process of identifying, analyzing, and accepting or mitigating uncertainty. When environmental risk management is employed for the plants, enterprise managers first attempt to analyze and quantify potential losses. Next, managers should make a comparison between different alternatives to select an optimal plan to achieve investment objective and risk tolerance. Finally, environmental risk management could aid managers to discuss with engineers on how to take the appropriate actions to implement the selected plan. In general, the process of environmental risk management consists of three parts, i.e., risk identification, risk assessment, and management.

Risk identification plays a vital role in environmental risk management. If some risks are ignored at this stage, these risks as hidden dangers can have a significant impact on environmental risk management. In extreme cases, such risks may result in catastrophic events that can lead to the failure of a firm. Numerous methods are proposed to identify risks, such as expert investigation, safety checklist, fault tree analysis (Choi and Chang, 2016; Hyun et al., 2015), event tree analysis (Ramzali et al., 2015), and hazard and operability analysis (Ahn and Chang, 2016). Environmental risk assessment has become an indispensable tool for the design of new processes, as well as for the operation and retrofit of existing processes (Villa et al., 2016). For the latter case, systematic risk assessment and risk management activities are essential to aid managers in industry to identify potential risks,