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Ship safety index

Kevin X. Li [a], Jingbo Yin [b,*], Lixian Fan [c]

[a] Dept. of International Logistics, Chung-Ang University, South Korea
[b] Dept. of International Shipping, Shanghai Jiao Tong University, China
[c] School of Management, Shanghai University, China

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A B S T R A C T

This paper develops a new quantitative safety index for each worldwide sea-going vessel based on their condition information and safety records. The safety index can generate a relative risk score using binary logistic regression method and a dataset with both static and dynamic information covering over 90% of the world sea-going merchant fleet. It has a widely potential usage for both industry and academic research, e.g., for port authorities to determine whether an on board inspection is needed; for insurers to determine premium rate; and for shipowners to identify functional areas for repair and maintenance.

1. Introduction

There are a total of around 120,000 sea-going commercial vessels of over 100 dead weight tonnage (dwt) sailing around the world. With an increasing awareness of environmental protection and safety issues, maritime authorities around the world have been making more rigorous efforts than ever before to promote safety and security at sea (Li and Zheng, 2008; Li et al., 2014; Yin et al., 2014). Since 1993, the International Maritime Organization (IMO) has adopted the International Safety Management Code (ISM) as a minimum statutory requirement for vessel operators to establish, implement and maintain their safety management systems. Although this program is implemented as a regulatory to oversee the safety activities of the vessels at the operational level, it cannot be used to measure and predict the safety level of each vessel.

To examine comparative safety levels for safety management and improvement purposes, an evaluation mechanism for measuring the overall safety level of the vessels is needed. In this paper, we establish a new quantitative safety index to serve as a proactive evaluation mechanism to measure the safety level of a vessel, which provides useful information for decision making on safety management and improvements. The safety index, using both static and dynamic data that have been collected from various sources, forms the most comprehensive data set to date on vessel information (for details see Section 2). We investigate the effects of various risk factors using multivariate logistic regression modeling, and assess how the various factors simultaneously affect a vessel's safety level.

The new safety index can be used as a safety benchmark for both industry and academic research. For example, it can be used by port authorities to determine whether the right of access to territorial waters or ports should be granted, or whether on board inspections are required for vessels calling at their ports, in order to prevent oil pollution and accidents within their territorial waters (Yap and Lam, 2013). It can be used by insurers to determine the premium rate prior to an insurance

* Corresponding author. Tel.: +86 021-66137696.
E-mail address: Jingboyin@sjtu.edu.cn (J. Yin).

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contract being concluded, or by any party who is interested in the safety and quality of the vessel and who needs to check the safety index before engaging in any business with the vessel. The safety index can provide useful information for operators to understand the relative safety strengths and weaknesses in terms of manageable safety characteristics, and to identify functional areas for safety improvement and maintenance.

2. Data description

For this study, a total dataset with three sub-datasets has been built. The total dataset is a combination of accounting for about 130,000 vessels, including information about 10,000 lost vessels and 120,000 existing vessels, counting more than 90% of the worldwide commercial fleet.

The first sub-dataset containing the basic information (static data) of a vessel has been compiled from various sources including the World Shipping Encyclopedia (Lloyd's Fairplay, 2008) and Lloyd's Register of Ships. The static data describes each vessel with over 200 variables such as identity number, nationality, date of building, tonnage.

The second is a casualty dataset that comprises 8023 records covering the time period from 1993 to 2008, which is a compilation of data from World Casualty Statistics by Lloyd's Register of Shipping (Lloyd's Fairplay, 1993–2008) and the IMO. The World Casualty Statistics consists of 2552 casualty records and the IMO website provides 6876 casualty records from 1993 to 2008. By eliminating the duplicated observations, there are 8023 records in the final casualty dataset, which includes various descriptive variables, such as, accident records of collisions, contacts, fires and explosions, foundering, hull/machinery damage, and miscellaneous wrecks/stranding/groundings.

The third is an inspection dataset comprising 370,000 inspection cases in 59 countries for the time period from January 1999 to December 2008. These countries are member States of three main Memoranda of Understanding (MoU) on Port State Control (PSC) under the coordination of the IMO, including the member states of China, Japan, India, France, the UK and Canada etc.

3. Methodology – a binary regression approach

Maritime safety is a complex domain, which involves technological, human and organizational factors (Kristiansen, 2005). The consequence of maritime risk ranges from severe environmental damage to large scale loss of life. Numerous studies use safety records or the statistic methods to analyze incidents (Gaarder et al., 1997; Li and Cullinane, 2003; Soares and Teixeira, 2001; Kristiansen, 2005; Li and Zheng, 2008). However, statistic information describes only the past condition of the vessels. Based on the safety records of global vessels, this study develops a maritime safety index to describe the comparative safety level of any particular vessel.

We cannot observe safety directly, but safety outputs such as accidents and incidents can provide information on the underlying distributions of probability of accidents. Then, we can analyze the probability of accidents as a measure of safety performance. Traditionally, the most common way to estimate the probability of accidents is accident frequency, which is regarded as the first type of method that addresses safety levels (Soares and Teixeira, 2001). The statistics concerning the frequency of accidents provide a crucial view of safety performance as in Romer et al. (1995). Most of these studies used accident frequency as a safety measure for examining the relationship between safety performance and a particular indicator, such as the age of vessels (Faragher et al., 1979; Cashman, 1977) and the flag of vessels (Li and Wonham, 1999; Pronce, 1990). There are also some studies using frequency of accidents, which are related to a particular type of vessels (Grabowski et al., 2007; Talley, 2001; Wang et al., 2005; Forsyth, 1991; Roberts and Marlow, 2002) or a particular business section (Mostafa, 2004). All previous studies provide useful insights into the characteristics of maritime accident.

However, there are limitations to all those studies. First, statistics describing the relationship between indicators and characteristics of the accidents do not reveal the degree of the influence of the determining factors. Second, there are some specific criteria and assumptions in some studies, which cannot be easily verified by other sources (Romer et al., 1995). Last, safety records reveal only the past conditions of relevant vessels but cannot predict the occurrence of a future accident directly (Gaarder et al., 1997) especially when maritime accidents are typically very rare events (Chang and Yeh, 2004; Hockaday and Chatziioanou, 1986).

Logistic regression has been proved to be a powerful modeling tool to predict the probability of occurrence of an accident, by fitting data to a logit function. In recent years, it has been suggested as an appropriate analytical technique to use for the multivariate modeling of categorical dependent variables (Uncles, 1987). There are several studies in the maritime domain using logistic regression model (Bergantina and Marlow, 1998; Jin et al., 2002; Jin and Thunberg, 2005).

Given this background, the main aim of this paper is to investigate which factors and to what extent these factors in affecting a vessel's risk level by using logistic regression method. Then, the predicted probability of risk can be transformed to maritime safety index using Eq. (1). Therefore, the maritime safety index can be regarded as a combination of risk indicators.

$$R = 1 - P \tag{1}$$

The probability (P) of an accident to a vessel is parameterized as an exponential function of the vessel's operating characteristics.