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An assessment model of safety factors for product tankers in coastal shipping

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ABSTRACT

The purpose of this paper is to assess the safety factors (SFs) of product tankers in coastal shipping. Based on the operational features and relevant literature, the safety factors of product tankers in coastal shipping were examined. A Safety Management Index (SMI) based on fuzzy AHP model was then proposed to assess those SFs, by which tanker carriers may make policies to improve the safety performance of product tankers. Finally, to validate the proposed model, the fleet of product tankers of Chinese Petroleum Corporation (CPC) in Taiwan was empirically investigated. The results proposed 16 SFs for product tankers in coastal shipping, in which, the SFs in need of improvement for CPC's fleet are: *safety climate onboard the ship*, *crew self-regulation*, *crew safety knowledge*, *safety drill onboard the ship* and *the condition of ship's machinery*. Based on the results, the theoretical and managerial implications for tanker carriers in improving ship safety are discussed.

1. Introduction

Petroleum oil is consumed in large amounts all over the world and the large bulk ships that transport this valuable resource are called oil tankers. Since they carry huge amounts of oil, oil tankers are vulnerable to oil spills and the resulting environmental and humanitarian consequences. Thus, the safety issue of oil tankers has been paid much attention. To prevent oil tanker accidents, the IMO (International Maritime Organization) involved the ISM Code (International Safety Management Code) in the SOLAS (Safety of Life at Sea) in 1994 to strictly regulate ship carriers to make safety management policies and safety management systems for oil tankers.

Different oil tankers types are used based on clients' needs. When crude oil is taken from an oil outlet, it must be relocated to an oil refinery so that it can be prepared for public use as petroleum product. In practice, there are two basic types of oil tankers: crude tankers and product tankers. Crude tankers are designed to carry a large quantities of unrefined crude oil. Their size are among the largest, ranging from 55,000 DWT (Panamax-sized vessel) to ultra-large crude carriers (ULCCs) of over 440,000 DWT. Product tankers fall under the smaller size tankers, ranging from under 10,000 DWT to the Panamax-sized vessels (60,000–80,000 DWT), generally carry refined petroleum products and work near coast (or inland waterway) (Hayler et al., 2003). In practice, the mission of a product tanker is to move refined oil to places where it is used, such as gas companies. Thus, product tankers generally work for domestic shipping. For example, Fig. 1 is the shipping routes of CPC's fleet of product tankers. Currently, CPC (Chinese Petroleum Corporation) is the biggest refinery and the main supplier of petroleum products in Taiwan. CPC imports crude oil to refine at Kaohsiung, and then transport product oil to gas companies around Taiwanese islands. For the gas companies located in southern Taiwan, the product oil is transported from Kaohsiung to those gas companies by tanker trucks directly. While, for the gas stations in northern Taiwan, the product oil is first transported by a product tanker to the seashore ports of northern Taiwan, and then transferred to gas stations by tanker trucks. Currently, CPC's costal product tanker fleet has 7 vessels for six shipping routes shown in Fig. 1. The longest route, Kaohsiung to Suo bay, is only 248 kn, whose sailing time is about one day for a ship. Since a product tanker generally works for coastal shipping, its operational feature contain working near coast, berthing at dock frequently, unloading cargos more often, etc.

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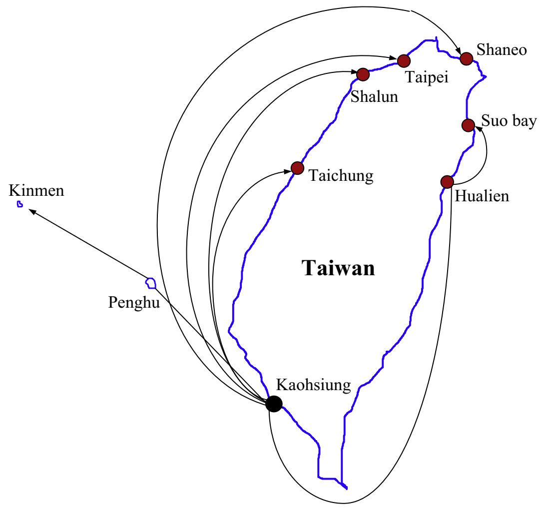

Fig. 1. The shipping routes of CPC′ fleet of product tankers in coastal shipping.

Generally, marine casualties most frequently occur near coastal waters. Common accidents include collisions, running on a reef, and grounding (Liu et al., 2006; Hsu, 2012). Further, for oil tankers, an oil spill most frequently occurs during the cargo loading/unloading operations (Hayler and Keever, 2003). Thus, the safety issues of product tankers should be of concern. Unfortunately, there is a lack of previous studies on such topics. Most of the relevant research focused on crude oil tankers (e.g. Havold, 2010; Ismail and Karim, 2013) and container ships (e.g. Lu and Tsai, 2008).

The purpose of this paper is to assess the safety factors (SFs) of product tankers in coastal shipping. In practice, the SFs' assessment is a MCDM (multi-criteria decisions making) problem, for which AHP is one of the most popular approaches. Further, the relevant studies indicated AHP is adequate for MSDM on industrial safety problems (e.g. Gnoni et al., 2012; Hassan and Khan, 2012; González et al., 2013; Salzano et al., 2013; Hsu, 2015). Thus, this paper adopts AHP to assess the SFs in coastal shipping. Based on the operational features and relevant literature, a two-layer hierarchical structure of SFs for product tankers is first identified. According to those SFs, a Safety Management Index (SMI) based on fuzzy AHP mode is then proposed to assess the SFs, The SMI consists of two sub-indexes, the SFs' importance weights and performance weights. In practice, the former depends on the SF's effects on safety, and the latter depends on the safety management performance of product tankers. In the relevant literature, such an assessment index was discussed less. Finally, to validate the proposed SMI model, the fleet of product tankers of CPC (Chinese Petroleum Corporation) in Taiwan was empirically investigated.

The rest of this paper is organized as follows. Section 2 describes the literature reviews. Section 3 explains the research method in this paper. The results are then examined in Section 4. Finally, some general conclusions and limitations for further research are given.

2. Literature reviews

Most relevant studies about ship safety focus on human factors such as fatigue, carelessness, and mistakes (Lu and Tsai, 2008; Hsu, 2012, 2015). However, in addition to the human factors, the ship's machinery and the external environment of a ship voyage may also affect ship navigation safety (Hsu, 2012; Ugurlu et al., 2015). Based on the relevant studies, this paper reviews the determinants of ship safety from five constructs: Liveware, Hardware, Software, Environment and Organization (Chang and Wang, 2010).

2.1. Liveware

Liveware is used in computer industry to refer to users, often in humorous contexts, by analogy with Hardware and Software. Most relevant studies indicated the human factor is the most significant determinant of ship safety. For example, Hetherington et al. (2006) indicated the concept of work safety originated from workers' safety knowledge, and the determinants of work safety contain fatigue, stress and the work environment. Henning et al. (2009) indicated workers' individual differences would affect their performance of safety behaviors, including safety attitudes and personal self-regulation of work. Havold (2010) examined the effect of the safety culture on safety management. The study verified 22 safety attributes, by which, four factor constructs were extracted, including the management style of the shipping company, crew work stress, crew safety, knowledge and crew perceived fatalism. Further, previous research also indicated crew physical and mental health may affect their work concentration, affecting ship navigation safety (Hsu, 2012). Potentially disastrous outcomes from fatigue in terms of poor health diminished the safety performance of shipping (Hetherington et al., 2006). Human capital, including safety skill and personal skill, is one of the determinants of safety capability in off-shore oil and gas industry (Griffin et al., 2014).

2.2. Hardware

Hardware is defined as the condition of the ship's facilities and equipment for work safety. The relevant studies indicate the maintenance of personal safety equipment may significantly reduce the threats to worker's safety (Gordor et al.,2005). Crew improper operations, machinery failure (Hsu, 2015), and vessel performance (Liu et al., 2006) may lead to marine disasters. The type, size, age and condition of the vessel at the time of the accident are significant determinants of ship loss (Kokotos and Smirlis, 2005). The condition of the communications equipment and personal safety equipment, and maintenance operations significantly affect aviation safety (Chang and Wang, 2010). The performance of the ship's machinery, including the main engine, steering gear and deck's winches, is one of the determinants of ship navigation in port (Hsu, 2012). Further, according to the SOLAS Convention, a ship must set up rescue equipment for emergencies, such as fire pumps, generators, air compressor and lifeboats etc., and these devices must be available at any time.

2.3. Software

Software is defined as the implementation of the safety system and crew perceived safety climate onboard the ship. Lu and Tsai (2008) empirically evaluated the influence of the safety climate on vessel accidents in the container shipping context, in which the safety climate is defined as six safety climate dimensions: management safety practices, supervisor safety practices, safety attitude, safety training, job safety, and co-workers' safety practices. The result indicates job safety has the most significant effect on vessel accidents, followed by management safety practices and safety training. Fabiano et al. (2010) suggested the operational procedure, regulations and performance assessment of trainings are the important determinants of occupational accidents. Further, the results of Hetherington et al. (2006) indicate educational training has the most effect on safety in the shipping industry. Safety culture and team process may affect the safety capability in off-shore oil and gas industry (Griffin et al., 2014).