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Ship Safety Policy Recommendations for Korea: Application of System Dynamics

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ABSTRACT

This study aimed to demonstrate and quantify the factors that influence ship safety and ship accidents and suggest policy recommendations for both government and the marine industry in Korea based on the application of system dynamics (SD). Korea was selected as the target country because a number of recent ship accidents have focused attention on ship safety in the region. Three factors that can influence ship safety were considered: economic factors, ship-handling and management factors, and government budget allocation of ship industry. SD was then applied to model the factors involved in ship accidents. Data on ship accidents in Korea from 2009–2014 were included in the model simulation. To measure the simulation accuracy, mean absolute percentage error (MAPE) analysis was employed. Following the simulation, a sensitivity analysis was conducted to determine the relationships among the factors involved in ship accidents. Finally, a simulation incorporating ship accident data and government budget allocated to the ship industry was performed. The results of this study can be used in government policy recommendations on ship safety to prevent and reduce ship accidents.

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1. Introduction

Ship accidents generally result in serious damage, death, loss, injury, or pollution and have major political, economic, and environmental consequences. They also affect several entities in the marine industry: the ship's company and owners, flag states, freight carriers, other sailing ships, coastal states, the shipbuilding industry, and the ship insurer (Poyraz, 1998). Improvements in marine technology and the implementation of safety-related regulations in the International Maritime Organization (IMO) and shipping nations have succeeded in reducing the number of ship accidents (Celik, et al., 2010). However, as ship accidents can cause significant damage to the environment and result in substantial human losses, they remain a major concern for global maritime interests (Celik and Cebi, 2009). Today, almost all vessels are equipped with modern

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navigation devices in accordance with regulation requirements. However, it is difficult to eliminate ship accidents because of the complex and high-risk environment at sea, where various dynamic agents, including geography, water, environment, and human-related factors, play a role in collisions. These collisions can result in fires, grounding, hull damage, or sinking. As the causative factors also change over time, preventing accidents can be difficult (Shu, 2014).

Most previous studies of ship accidents have focused on the role of human error (Hetherington et al., 2006; Celik and Cebi, 2009; Mullai and Paulsson, 2011; Ventikos and Giannopoulos, 2013; Akyuz and Celik; 2014) or the economic environment (Toffoli et al., 2005; Uğurlu et al., 2015a; Lu and Tsai, 2008; Knudsen and Hassler, 2011) and utilized simple data analysis or expert advisors. Although the investigation of a marine ship accident is complex and requires a professional and fair judgment, at the same time, it depends on accurate and comprehensive statistical data to detect the role of dynamic changes in ship accident causes.

In the present paper, system dynamics (SD) was employed to represent the complex causal relationships of ship accidents, with an SD model used to simulate the factors that influence ship accidents and maritime safety.

The contribution of this research is twofold. First, this research establishes a ship accident causation model to analyze the various factors responsible for ship accidents and to determine whether government budget allocated to maritime safety are sufficient. Second, the results of this research can be utilized by policy makers when allocating resources to ship safety and proposing strategies to reduce ship accidents.

In Section II, the factors influencing ship accidents are introduced. The SD model for ship accidents is established and validated in Section III. A sensitivity analysis based on various scenarios is described in Section IV to determine whether current budget allocated by the Korean government to ship safety are effectively used. Finally, the conclusions are presented in Section V.

2. Factors Influencing Ship Accidents

Ship accidents continue to occur, despite ongoing prevention efforts. The main purpose of most ship accident studies is to identify causative factors and provide valid and reliable information for decision makers (Psarros, et al., 2010; Nikolaos, et al. 2013). They then utilize this information to make informed decisions, which are aimed at avoiding injuries to seafarers and damage to property and the environment. According to ship accident analysis reports, the most common causes of ship accidents are human errors, technical and mechanical failures, legislative shortcomings, and environmental factors (Hassel, 2011; Weng and Yang, 2015; Sahin and Senol, 2015). Toffoli et al. (2005) proposed that there were two main sources of ship accidents, operational and maintenance, with about 60% due to operational causes (e.g., fire, collision, machinery damage) and 40% due to design and maintenance issues (e.g., water ingress, hull breaking in two, and capsizing). A grounded theory model based on a large amount of empirical data was previously used to analyze marine accidents caused by macroscopic and microscopic factors (Mullai and Paulsson, 2011). The macroscopic factors included the number of people on board, type of cargo, and environmental conditions. The microscopic factors consisted of (a) the construction of the ship; (b) equipment-related technical faults; (c) the operation, management, and design of the equipment; (d) communication, organization, and procedures; (e) human factors; and (f) noncompliance with regulations. Fuzzy theory has also been utilized as a tool in an effort to prevent ship collisions (Shu et al., 2014). A review of ships involved in collisions and grounding based on historical data and expert opinion concluded that structural crashworthiness, oil outflow, and the residual strength of the damaged ship were the main factors governing ship accident causing (Wang et al., 2002). A framework for marine risk assessments of ship accidents was developed that considered the two main consequences of ship accidents: human losses and pollution of the environment (oil leakage from cargo or fuel) (Ventikos and Giannopoulos, 2013). Ugurlu et al. (2015a) proposed that human factors, heavy weather conditions, equipment failure, and unknown factors were critical causes of ship accidents. Blanc and Rucks (1996) analyzed data on 936 ship accidents that occurred from 1979–1987 for various reasons, including sea traffic levels, system utilization, accident type, weather, location, and other variables. They reported that a lack of knowledge about the position of other vessels and inadequate ship-to-ship communication played a pivotal role in ship accidents. Ugurlu et al. (2015b) found that human error, technical and mechanical failures, lack of communication, regulation violations, and environmental factors (bad weather or voyage conditions) were common factors underling ship accidents.

Human error, which includes technical and management failures, as well as operational errors, is the primary factor that contributes to marine accidents. Celik and Cebi (2009) identified the role of human error in ship accidents by the Fuzzy-AHP method and quantified the human contributions to ship accidents. Their results showed that skill-based errors were the primary cause of ship accidents, followed by lack of coordination, communication, and operation planning. Akyuz and Celik (2014) proposed a ship accident analysis and prevention model basing on human error factors. They found that unsafe preconditions played a major role in ship accidents, and proposed preventative steps to reduce human errors leading to ship accidents. Hetherington et al. (2006) reported that various human factors, including poor communication, decision making, situational awareness, and teamwork, in addition to fatigue, stress, health, automation, and lack of a safety culture, were involved in ship accidents.

Maritime regulations have evolved over time in response to historical experience, mainly because of serious ship accidents. Knudsen and Hassler (2011) investigated the failure of the IMO to implement appropriate ship safety legislation and regulations to reduce the ship accident rate. They concluded that the core problem was the absence of a strong link between the IMO and national maritime administrations, with new rules sometimes negatively affecting the functioning of existing regulations or language difficulties impeding their implementation. As a result, some ship accidents occurred due to violations of regulations caused by faulty implementation or nonimplementation of the complex marine regulations and policies of each nation.

Economic growth stimulates increases in international business, including international marine transportation, leading to greater maritime traffic. Due to advantages of scale, large-sized ships are preferred. Increases in maritime traffic, cargo, and passenger numbers augment the risk of ship accidents.

Lu and Tsai (2008) evaluated the influence of climate on ship accidents in the container shipping industry. They assessed six dimensions of climate-related effects: safety attitudes, safety training, management safety practices, supervisor safety practices, job safety, and coworkers' safety practices.

According to the aforementioned literature and statistical data from the Ministry of Oceans and Fisheries in Korea (2014), the factors responsible for ship accidents can be divided into three areas: economic factors, ship-handling and management factors, and government budget allocation

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