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Estimating the economic losses of port disruption due to extreme wind events

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ABSTRACT

The operation of a seaport is highly dependent on the ocean climate, where a necessary consideration of the later is essential to govern the normal running of the seaborne transportation. To estimate the port risks associated with the climate factors is a challenging task. Not only because of the complexity in the weather, but also the variations in the daily trade volume. This paper develops an approach of estimating the economic losses of port disruptions induced by extreme wind events, and conducts a study for two selected ports, Ningbo and Shanghai. The loss considers both the variation in the daily cargo throughput and the climate. The throughput is analyzed in a regression analysis which accounts for both the long term trend and yearly cyclic components. The likelihood of port disruptions is estimated from a climate analysis based on the historic record at both ports. The calculation of the total economic loss is split into four parts, namely, reputational loss, loss to the shippers, loss to the carriers and loss to the ports. The results are illustrated in a comparison between Shanghai and Ningbo to provide the information of associated risks within different months. The study is also extended to investigate the influence of extreme wind events on the port of Shenzhen which is located in a different geographical region for comparison. The impact of the extreme wind events on the ports and the economy is then discussed.

1. Introduction

The stability in port operations is the key factor in facilitating the international trade market. It is reported that maritime transport contributes 90% of the world trade volume which implies its crucial role in providing various kinds of shipping services and thus has a very close relationship with the related industries (Lam and Yap, 2011). As a result, risks and uncertainties in ports are considered as important issues in port management research (Mokhtari et al., 2012). Factors including climate extremes, security, social stability, and political stability need to be fully analyzed in the risk management for port planning and operations.

Being a platform linking the sea and inland transportation, a port and its stakeholders are much affected by any port disruption. Disruptions, being one of the risks, include a wide coverage of events that lead to a halt in cargo and trade flows (Kleindorfer and Saad, 2005). Basically, port disruption events can be classified into man-made events (e.g. terrorist acts) and natural calamities (Stecke and Kumar, 2009). One should note that there is a difference between delay and disruption. Both delay and disruption will postpone the time of arrival of the products (Omer et al., 2012) but disruption stops the flow entirely while delay refers to a slower flow rate. The consequence of a port disruption could be disastrous. The influence is usually international and the impact may spread to many aspects in the society: political, environmental, economic and so on. Chang (2000) has found that an earthquake-induced port disruption could lead to a loss of share of transshipment traffic. The economic impacts of port disruption resulted from terrorists attacks have been discussed by Park et al. (2008). The propagation of the port disruption risks to the other industrial factors has also been discussed by Peck (2006). Generally, there are two key observations from the literature. Firstly, the consequence of a disruption can sometimes be irreversible for the affected port. Secondly, the port and the port network as a whole can be designed to be more adaptive to adverse situations. It is thus crucial to understand how a port is affected by disruptions, in order to develop strategies and policies to maintain its capacity and resilience.

The operation of a seaport is highly dependent on the ocean climate (Du et al., 2015). Climate extreme is a significant issue that should be taken into consideration when one analyses port disruption (Lam and Su, 2015). In particular, this is critical for ports

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that have seasonal hurricanes. There are a few research papers on the discussion of this issue. Hubbert and McInnes (1999) developed a storm surge inundation model to assess a coastal area's resistance to flooding. Hanson et al. (2011) provided a comprehensive study to compare the performance of large port cities when facing sea level rise risks. The method of calculating the natural accident related cost and damage suffered by ports is investigated in Ronza et al. (2009). The common finding from these studies is that port economy is sensitive to environmental changes. Among climate extremes, wind related risks should be addressed with great attention for the coastal areas. It is reported that hurricane Katrina, which was the deadliest and most destructive Atlantic tropical cyclone, has caused a total loss of about USD 73–90 billion to the east coast of America in 2005 (Hallegatte et al., 2011). It could not be imagined how the consequences of various levels are when this type of rare event happens. Therefore, it is essential to have a scientific approach to quantify the consequences of an extreme wind event leading to a port disruption. The understanding of the economic importance for considering the climate factors will facilitate investment and port planning. However, very little work can be found in the economic estimations specifically focusing on port disruption risks associated with extreme wind events. As such, the significance of our study is justified.

The analysis of cargo flows, especially to know exactly how the daily flow fluctuates, is a challenging problem. One should realize the fluctuation in the shipping market is a fundamental determinant of its financial performance (Doldan-Garcia et al., 2011). The economy experiences business cycles when the growth of production, income and spending fluctuates. In port risk management, changes in the cargo volume could result in various levels of risk exposure. It is directly linked to the amount of economic loss when a port disruption happens. Quite a number of companies have implemented a time dependent dynamic shipping market to allow them to exploit the advantages within the market as well as protect the value of commodities they have. Rand and Tarp (2002) conducted studies to compare the business cyclic behaviors in the developing countries and conclude that the duration of the cycles can be affected by political stability. Mise et al. (2005) have implemented the Hodrick–Prescott filter in the trend analysis for the business market. Scarsi (2007) has provided a detailed discussion about the market cycles in the maritime industry. Yap and Lam (2013) analyzed the long term cyclical cargo throughput of major Asian ports. A good port management decision maker should be able to read the market well and select the right timing for every investment action.

Therefore, this paper aims to develop an approach of estimating the economic losses of port disruptions induced by extreme wind events. The estimation of economic loss of port disruption is going to be performed for two large ports in China: Shanghai and Ningbo (see Fig. 1). Shanghai and Ningbo are both important and busy shipping gateways in East Asia. They are the main channels between the mainland China and the Pacific Ocean, linking China and the major economies in the world. In 2013, the annual container throughput in Shanghai and Ningbo was ranked 1st and 6th among all the ports in the world. The economic importance of these two ports necessitates the study to analyze their potential risks regarding the maritime environment. Particularly, both Shanghai and Ningbo are in the coastal areas that can suffer seasonal typhoons periodically. Extreme wind events are the key issue for risk management in these two major ports. The study is also extended to investigate the influence of extreme wind events on the port of Shenzhen which is located in a different geographical region for comparison.

The rest of the paper is thus organized as follows. Section 2 presents the methodology and data analysis on the time varying properties in the cargo throughput from eight selected seaport terminals from Shanghai and Ningbo. Section 3 provides the results and discussion of the climate analysis and estimation of the economic losses for the ports. Finally, Section 4 provides our concluding remarks and possible areas for future research.

2. Methodology and data analysis

2.1. Cargo throughput analysis

Before the estimation of the economic losses at the ports, an

Fig. 1. Geographical locations of Shanghai and Ningbo.