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A novel model for the quantitative evaluation of green port development – A case study of major ports in China

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ABSTRACT

Environmental problems that seriously affect both natural systems and social development of human beings have drawn extensive attention from governing authorities all around the world, and become an urgent issue to be addressed. Ports play a significant role in the international shipping which inevitably influence the global environment. Thus, the concept of green port is developed to mitigate the negative impacts of inappropriate port operations on environment. This paper analyzes the current status of green port development worldwide. An evaluation model for quantitative measurement of green port development is established based on the Drivers, Pressures, States, Impacts and Responses (DPSIR) framework. The weight of each index composing the evaluation model is calculated through an analytical hierarchy process method, and the evaluation results of the investigated ports with respect to each index are aggregated using an evidential reasoning approach. The evaluation model is further demonstrated through a comparative analysis of five major ports in China. The novel model developed along with the methods applied in this paper can provide significant insights for the comparative evaluation on the development of green ports in other countries and/or regions, as well as a powerful tool to conduct self-assessment of green port development.

1. Introduction

As crucial nodes in international transport networks, ports play a significant role in promoting regional and global trade and economic development. For example, the cargo throughput of Ningbo-Zhoushan Port reached at 0.87 billion tons in 2014, ranking the first in the world (Wei, 2015). Meanwhile, a large amount of capital was invested in port infrastructure construction, reconstruction and maintenance due to the rapid development of ports. Due to such facts, more attention needs to be paid on the environmental protection urgently to ensure ports' sustainability while facilitating the development of port logistics in the coming decades. In spite of the fact that ports are not the direct places for production processing, nor it has a large amount of material consumption, it, however, is an important distribution center for various goods allowing a large number of vehicles and ships to be engaged in transport operations, which can be a source of contamination (discharge of waste gas and rubbish) (Chen, 2009; Chang and Wang, 2012). Apart from these traffic conveyances, there is certain pollution from goods themselves like coal dust, dangerous materials and chemicals, etc. A recent accident caused by chemical

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goods explosions in Tianjin Port (China) provides supporting evidence. A study (Ma et al., 2014) showed that in 2011, emissions of carbon dioxide (CO_2), nitrogen dioxide (NO_2) and dust from harbor districts in China reached about 127 thousand tons, 146 thousand tons and 1.2 million tons, respectively. They significantly contribute to the environmental deterioration in the country. Pollution from port operations will not only damage the ecological balance of nature and urban environment, but also cause adverse effect on global climate change, which further increases the risk associated with port operations. Development of low-carbon economy is considered to be a fundamental way to solve environmental problems. Nevertheless, port and shipping are still in absence of effective control measures for emissions of greenhouse gas, and the importance of sustainable development is still being ignored by many port authorities (T.S. Wang, 2014). In view of this ignorance, the concept of green port (or low-carbon port) was officially proposed in the United Nations Climate Change conference in 2009 (Wu and Ji, 2013). On the basis of organic combination of port development, utilization of resources and environmental protection, green port refers to the one characterized by healthy ecological environment, reasonable utilization of resources, low energy consumption and low pollution (Chen, 2009).

Started early in United States, Japan and other developed countries, prominent achievements have been obtained through active exploration and implementation of the planning and construction of green port (Gupta et al., 2005; Cai, 2010). As one of the advocates of green port, the Port of Long Beach has made remarkable achievements. The "green port" policy was launched in Port of Long Beach in January 2005 for the first time with a series of environmental protection plans developed from seven aspects, namely water quality protection, improvement of air quality, soil conservation, wildlife and habitat protection, alleviating traffic pressure, sustainable development and community participation. Since the implementation of the above environmental protection plans, the water quality of Long Beach has been much improved. Sydney Harbor carried out the Green Port Guidelines from other aspects, focusing on the importance of quality of the water and air, biological diversity, noise control, rubbish and dangerous cargo management, and environmental education and training, etc. (Lu and Hu, 2009). Strengthening legislation and enforcement was one of their main measures. In Italy, a shore power supply system was equipped in both Venetian Harbor and Port of La Spezia in 2010, leading to about 30% reduction of the CO_2 emissions, 95% reduction of the nitric oxide (NO) emissions, as well as significant noise reduction (Cai, 2010). In Tokyo Harbor, when planning the layout of the port, its influence on the environment is considered in terms of both ecological and living environment. It is also required that the port construction project and the environmental protection planning should be implemented simultaneously (Liu, 2004). The aforementioned countries apply "green" to their port operations and the future design of the port construction to strengthen the port infrastructure and its capability in dealing with emergency response.

In China, research on green port started relatively late, compared to those developed countries. Shanghai Port actively explored the environmental protection measures for the port administration and listed the construction of ecological port as an important research subject. Based on the research of ecological development and countermeasures in Shanghai Port, an evaluation index system of green port development was proposed (Lin, 2010). Tianjin Port officially launched the research project related to green port development in October 2007, elaborating the concrete measures of development of green port from aspects of environmental protection, infrastructure, environmental pollution control, environmental risk prevention and management, development of environmental management system as well as the construction of green logistics networks. Lianyungang Port took the advantages of shore power technology in the control of pollutant emissions, energy saving and noise reduction, which brought considerable economic and social benefits. Qingdao Port introduced new equipment and new technologies to improve the working efficiency and to reduce the energy consumption.

Due to the great environmental impact from port operations and development, an increasing attention has been drawn from both industry and academia. Taking the situation of Kaohsiung Port as an example, Berechman and Tseng (2012) study the environmental costs of port related emissions with emphases on particular matter and volatile organic compounds. The results show that the combined environmental costs of ships and trucks are estimated to be more than 100 million USD per year. Lam and Notteboom (2014) investigate the role of port management tools in the development of green port from the perspective of policy and management. The situation from four leading ports in both developing and developed countries are also studied and compared. Song (2011) reveals that the problems associated with green port development, particularly in the developing countries are as follows.

(a) There are a lot of old ports that came into service a few decades ago. Generally speaking, theses ports are lack of financial support and under the management with outdated techniques.
(b) Weak consciousness of environmental protection and energy saving, which results in the limited resources allocated to conduct systematic and comprehensive analysis when conducting planning and design of a green port.
(c) The incompleteness of important evaluation criteria for development of green port which causes certain blindness in the green port development and seriously affects the sustainable development of port resources, environment and economy.

As a result, it leads to a significant research gap to be fulfilled, wanting an appropriate green port evaluation model developed. This paper aims to establish a novel model for the comprehensive evaluation of green port development and propose supporting methods for realizing the quantitative measurement. To achieve the aim, the rest of the paper is organized as follows. The evaluation model is developed on the basis of the Drivers, Pressures, States, Impacts and Responses (DPSIR) framework in the following section. In the Section 3, background information on the methods used in this paper is introduced. The Analytic Hierarchy Process (AHP) method is applied to determine the weight of individual criterion at each level

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