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Operating strategies of CO_2 reduction for a container terminal based on carbon footprint perspective

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ABSTRACT

This paper investigates CO_2 emissions produced by two different container terminal operating models (tire transtainers and rail transtainers) at the port of Kaohsiung, and seeks to determine energy saving and CO_2 reduction strategies for shipping companies and terminal operators in order to comply with green port requirements.

This paper's research methodology involves carbon footprint analysis and gray relational analysis. Carbon footprint analysis is employed to calculate the CO_2 emissions per container of two different container terminal operating models employing data for various areas (such as the berthing area, container yard, and gate area), where the raw data is collected from shipping companies or terminal operating companies at the port of Kaohsiung. Gray relational analysis is then used to determine the ranking order of different container terminal operating models based on the green port assessment criteria of working time efficiency, energy consumption, and CO_2 emissions.

The chief findings of this paper are that the ranking order of container terminal types based on carbon footprint is tire transtainer ahead of rail transtainer; optimal green port assessment criteria constituted working time efficiency, energy cost, and CO_2 emissions; and use of container handling equipment with high operating efficiency can not only accomplish work rapidly, lessening the berthing time of ships in port, but also reduce energy costs and CO_2 emissions.

1. Introduction

According to the International Association of Ports and Harbors (IAPH, 2010), growing emissions of greenhouse gases have been shown to be the cause of global climate change, and these greenhouse gases chiefly constitute carbon dioxide (CO_2), methane (CH_4), and nitrogen dioxide (N_2O) in port operations. International ports serve as supply chain logistics hubs and transshipment centers, and a wide range of industrial and logistics activities occur in the port area. These activities typically result in exhaust emissions, including the discharge of such pollutants as CO_2, nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM2.5). The shipping industry generates approximately 1260 million tons of CO_2 emissions annually, and accounts for 3.9% of global carbon emissions, making it a major source of CO_2 emissions (Jurong port, 2011). Eide et al. (2011) found that cargo handling equipment is the main source of exhaust emissions in a container terminal.

A search of the academic literature associated with green container terminals found that while there are many papers concerning container terminals, there are only a few studies of green container terminals from a carbon footprint perspective. Sisson (2006) and Pedrick (2006) provide a definition of green container terminals stating that green terminals should be designed in harmony with their sites, promote high efficiency, improve economic aspects, enhance the overall infrastructure, and provide links to the community. While Lazic (2006) and Clarke (2006) claim that green container terminals are distinguished by the use of automatic equipment and semi-automatic cargo handling equipment, their papers lack quantitative analysis. Lun (2011) also investigates the elements of green management practices and their association with a company's container terminal operating performance.

With respect to calculation of green container terminals' CO2 emissions, Geerlings and Duin (2010) employed a promising approach to calculate the CO2 emissions of container terminals, and proposed several countermeasures to lessen carbon emissions. Yang and Lin (2013) determined the ranking order of container handling equipment in terms of CO2 mitigation performance, and obtained an order of electric tire transtainer (E-TT) >automated rail transtainer (ART) >rail transtainer (RT) >tire transtainer (TT). Liao

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Table 1
Container terminal operating models at the port of Kaohsiung.

Categories	Company name	Container terminal no.
Straddle Carrier model	Han Jin Shipping	76W/77W/78W
Tire Transtainer Model	American President Line	68W/69W
	Evergreen Marine Corporation	115W/116W/117W
	Hyun Dai	118W/119W
	NYK	121W
Electric Tire Transtainer Model	Evergreen Marine Corporation	115W/116W/117W
Rail Transtainer Model	Lien Hai	41W/42W
	Wan Hai	63W/64W
	OOCL	65W/66W
	Yang Ming	70W
	Evergreen Marine Corporation	79W/80W/81W
Automatic Rail Transtainer Model	Kao Ming	108W/109W
	Evergreen Marine Corporation	79W/80W/81W

et al. (2010), the Herbert Engineering corporation (2011), and Mckinnon (2009) proposed calculation formulas for the CO2 emissions of different types of tractors.

Yang and Shen (2013) suggested that if the overall green port performance of container handling equipment can be evaluated from a carbon footprint perspective, this will not only allow the assessment of the energy savings and CO2 emissions of different types of container handling equipment, but also facilitate the formulation of solutions able to achieve green port targets. Yang and Shen (2013) employed a carbon footprint perspective reflecting energy savings and CO2 emissions to assess the relative green port performance of TT and E-TT use, and determined the impact of E-TT use on the green port performance of an international hub port.

There are a total of 26 container terminals at the Port of Kaohsiung in Taiwan, and these terminals are managed by ten container terminal operators (Evergreen, Yang Ming, Wan Hai, OOCL, APL, NYK, Han Jin, Hyun Dai, Kao Ming, and Lien Hai). As shown in Table 1, these container terminals employ four models of cargo handling equipment, namely straddle carrier model (Han Jin), tire transtainer model (APL, Evergreen, Hyun Dai and NYK), rail transtainer model (Lien Hai, Wan Hai, OOCL, Yang Ming and Evergreen), and automated rail transtainer model (Kao Ming and Evergreen).

The Kao Ming Container Terminal (KMCT) at the port of Kaohsiung belongs to the Yang Ming Group and began operation on January 1, 2011. This BOT project is the first green terminal in Taiwan. KMCT uses state-of-the-art technology to conserve energy, and its eight advanced tandem-lifting quay cranes and 22 ARTs can enhance operating efficiency by 45 more moves/hour per crane. At a time when environmental protection has become a universal concern, the KMCT green terminal is a milestone in the history of container terminals in Taiwan.

As noted by Levelton Consultants (2006), cargo handling equipment is an important source of pollutants, including greenhouse gases. Since the tire transtainer model and rail transtainer model are known to be the two most common container terminal operating models at the port of Kaohsiung, this paper focuses on these two operating models in comparing the green port performance of equipment types from a carbon footprint perspective.

This study applies a carbon footprint perspective in comparing two types of container terminal operating models (rail transtainer operating model and tire transtainer operating model). This comparison is based on the two performance assessment dimensions of energy saving performance and carbon reduction performance.

This paper seeks to determine the ranking order of the two operating models based on gray relational analysis. Gray relational analysis (GRA) was proposed by Julong Deng in 1982 as an offshoot of gray theory, which had already been shown to be a simple and accurate method for handling decision-making problems with multiple attributes (Tsai et al., 2003). Gray system theory offers the advantages of minimal data requirements, simplicity of use, and reasonable expected results (Liu et al., 2008).

Following empirical analysis, this paper proposes several conclusions and suggestions for terminal operators and shipping companies concerning options for reorganizing or upgrading their container terminal operating models in order to meet green port requirements. The goals of this paper are summarized as follows:

(1) To review the concepts of container terminal, green container terminal, and measurement of a container terminal's carbon footprint;
(2) To calculate the CO_2 emissions of various container terminal operating models based on a carbon footprint approach;
(3) To examine the ranking order in terms of CO_2 emissions of different container terminal operating models via gray relational analysis;
(4) To provide suggestions and options for shipping companies and government authorities facilitating formulation of green port strategies.

This paper consists of five sections: The current section is an introduction describing the motivation, goals, and framework of the study. The next sections provide a review of the literature concerning the container terminal, green container terminal, and container terminal carbon footprint measurement concepts, and present the results of carbon footprint measurement and gray relational analysis. Conclusions drawn from analysis, the implications of this paper for shipping companies and container terminal operators, and possible directions for future research are discussed in the final section.

2. Literature review

2.1. Green container terminals

A number of studies have attempted to characterize what constitutes a green terminal, and list the different elements that make up a green terminal. The effective deployment of container terminal material handling equipment is a crucial means of enhancing the overall efficiency and performance of container handling in import, export, and transshipment operations (Lau and Zhao, 2008). Geerlings and Duin (2010) used the case of the port of Rotterdam to illustrate the optimal layout of a container terminal for reducing CO2 emissions, which could be reduced by approximately 70%.

Sisson (2006) suggested that the features of a state-of-the-art green terminal include cold ironing for vessels with rapid automated berthing, automated transport vehicles with low emissions