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Impacts of electric rubber-tired gantries on green port performance

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ABSTRACT

Motivated by the need to reduce operating costs and alleviate noise and exhaust pollution generated by cargo handling equipment in container terminals and container yards, this study compares the performance of rubber tired gantries (RTGs) and electric rubber tired gantries (E-RTGs) from the perspective of energy savings and CO_2 reduction, and analyzes the impact of E-RTG use on the green port policies of international hub ports. This study discovered that (1) E-RTG cranes offer a significant performance improvement compared with RTGs, and can achieve 86.60% energy savings and a 67.79% reduction in CO_2 emissions. (2) ERTG cranes are expected to have an individual payback period of 2.2 years, and are not only friendly to the environment, but also ease the impact of diesel oil price hikes. (3) Government may formulate appropriate regulations or provide incentive measures to encourage terminal operators to upgrade their handling equipment or implement E-RTG conversion projects.

1. Introduction

A container terminal is a distinctive and complex operating area, which is composed of a gate, container yard, and shipside areas, and where several types of equipment (such as tractors, RTGs, RMGs, straddle carriers, and gantry cranes) bear responsibility for handling containers in the three areas. Gantry cranes used in container yards and terminals include rubber tired gantries (RTGs) and rail mounted gantries (RMGs). The former are powered by diesel fuel, and the latter employ electric power. While there are no significant differences between the two in terms of handling efficiency, there are clear differences in energy savings and CO_2 reduction.

The majority of container handling equipment in existing container terminals and container yards at the port of Kaohsiung are RTGs. More than 61 RTGs are used by container terminals and container yards in the port of Kaohsiung, and this equipment consumes vast amounts of fuel oil and produces tremendous exhaust emissions, leading to high operating costs and environmental pollution. Nevertheless, in spite of their drawbacks of high energy consumption, high pollution, and high noise, the majority of shipping companies and container yards still employ diesel RTGs for container handling.

In the wake of severe energy shortages and higher energy costs around the world, some diesel equipment (such as RTGs and straddle carriers) with high operating costs is being gradually replaced with electric handling equipment offering energy savings and environmental friendliness (Yang & Sam, 2009). Energy efficiency has also been improved by applying hybrid technology to cargo-handling equipment, such as through the conversion of diesel RTGs to electric power (APEC, 2009).

In order to lessen operating costs, strengthen business competitiveness, and alleviate environmental pollution, container terminal operators should formulate appropriate strategies for conversion from diesel to electric RTGs in order to achieve the goals of energy conservation and reduced carbon emissions.

Another benefit of electric rubber tired gantry (E-RTG) cranes consists of maintenance and repair costs that are 30% lower than for standard diesel RTGs. Apart from offering fuel cost savings of as much as 70%, the use of E-RTGs can reduce CO_2 emissions by 60–80% compared with conventional diesel-powered RTGs, which can result in the reduction of overall terminal CO_2 emissions by 20% per TEU handled. It is estimated that retrofitting the majority of the existing 400-unit APM terminal RTG fleet with electrical systems will reduce CO_2 emissions by 70,000 t annually (APM, 2011).

Geerlings and Duin (2010) claimed that the replacement of diesel cargo stevedoring equipment with electric equipment can reduce CO_2 emissions by 20% and increase working efficiency by 20%. Wang (2010) noted that E-RTGs reduced CO_2 emissions by more than 40% compared with conventional diesel models, which reduced carbon dioxide emissions per TEU from 19.8 kg to 19 kg.

The Integrated Planning and Development Project for International Commercial Ports in Taiwan (2012–2016) states current development directions for international commercial ports in Taiwan with regard to green port policy. In line with these guidelines, the port of Kaohsiung has implemented a series of energy conservation and CO_2 reduction measures in order to attain the goals of the green port concept. One of these green port measures is to encourage the adoption of electric cargo handling equipment, such as RMGs and

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E-RTGs (Taiwan International commercial ports corporation, 2012). However, this project lacks a detailed account of the main reasons for adopting E-RTGs in compliance with green port policy, and one of the research motivations of this paper is therefore to fill this gap.

Owing to the effect of the global financial crisis and high oil prices, every shipping company is endeavoring to minimize operating costs, while also improving port pollution. This paper therefore focuses on the conversion of RTGs from diesel power to electric power, and compares RTG performance before and after conversion. It then analyzes the advantages and disadvantages, operational limitations, energy savings, and CO_2 reduction benefits of the two types of RTGs. This paper consequently seeks to determine the changes in physical performance occurring as a result of converting RTGs to E-RTGs, compares energy savings and CO_2 reduction performance based on a green port perspective, reviews three different conversion systems (cable reel, bus bar, and touch wire systems) at the case study company, and finally present conclusions and recommendations.

Although there is significant linkage among handling efficiency, operational performance, and cost, in order to achieve better focus and research effectiveness, this paper primarily compares RTGs and E-RTGs, and neglects the other types of cargo handling equipment in container yards.

The goals of this paper can be summarized as follows: (1) to review the literature associated with container terminals and green container terminals; (2) to examine the conversion process and E-RTG usage at the case study company; (3) to compare energy saving and CO_2 reduction performance of RTGs and E-RTGs; (4) to analyze the impact of E-RTGs on the green port policies of the main hub ports in the Far East; (5) and to provide suggestions for terminal operators concerning the assessment of conversion projects and for government authority concerning the formulation of green port policies.

This paper consists of five sections: The first section is an introduction stating the motivations, goals, and framework of the study. The second section contains a review of the literature concerning container terminals and green container port, and the third section examines the E-RTG conversion project at the case study company, including the RTG to E-RTG conversion process. The fourth section contains a performance analysis of the E-RTG conversion project at the case study company focusing on energy savings and CO_2 emission reduction, and examines the impact of E-RTGs on the green port policy of six hub ports in Far East. The final section presents managerial implications for port managers and government concerned, and suggests possible directions for future research.

2. Literature review

2.1. Container terminals

Different terminals, with their unique combinations of liner services, yard layouts, and equipment configurations, may find that different yard planning strategies work better for their circumstances (Ku, Lee, Chew, & Tan, 2010). As human operators drive equipment at traditional terminals, there is no need for computer control of the movement of equipment. When automated equipment is used, however, every movement must be directed, the flow of vehicles must be controlled, and the movement of equipment must be synchronized (Kim, Won, Lim, & Takahshi, 2004).

Container terminal (CT) systems consist of three subsystems: the gate, container yard, and berths. Container handling equipment in these systems includes transfer cranes, gantry cranes, yard tractors, and trailers (Yun & Choi, 1999). The four main subsystems/operations in a container terminal system are ship to shore, transfer, storage, and delivery/receiving. Container terminal operations involve very complicated operating systems, which must be evaluated from the perspective of CT operating performance to assess a CT's competitiveness.

Container handling equipment in a container yard performs the functions of moving and lifting containers, and stevedoring trailers. The choice of a terminal operating system can influence the performance of a container terminal. A container terminal can improve its productivity by increasing the efficiency and effectiveness of cargo handling and storage equipment. The most common types of yard crane comprise rail mounted gantry cranes, rubber tired gantry crane, straddle carriers, reach stackers, and chassis-based transporters. However, only RMG cranes are suited for fully automated container handling (Gunther & Kim, 2006; Lin & Chang, 2006).

A container yard serves as a buffer area for the loading, unloading, and transshipping of containers, and is typically divided into blocks: Each container block is served by one or more yard cranes, which may consist of RTG or RMG cranes, and straddle carriers (SCs). Straddle carriers, automatic guided vehicles, and trucks are commonly used to transport containers between quayside and yard, and between yard and gate, and to relocate containers within the yard (Hsu, 2007; Vacca, Bierlaire, & Salani, 2007). Storage yards at container terminals serve as temporary buffers for inbound and outbound containers, and RTGs are the yards' most frequently-used container handling equipment (Zhang, Wang, Liu, & Linn, 2002).

An E-RTG conversion project is one way for port operators to reduce fuel consumption and CO_2 emissions. Diesel RTGs often account for half of CO_2 emissions generated by terminal operations, and the economic and environmental effects of conversion are correspondingly large(Conductix, 2011). The advantages of E-RTG use include (1) reduced CO_2 and NOx emissions, reduced noise pollution, reduced maintenance costs and downtime, and reduced fuel costs (CAVOTEC, 2011).

The chief advantages of RTGs are as follows: (1) Owing to their high efficiency, RTGs can handle successive lifting, lowering, and stacking operations for a larger number of containers. (2) There is a high container space utilization ratio in cross-block operations. (3) Thanks to the good mobility of RTGs, storage blocks can be used in a complementary fashion to promote operating efficiency.

However, RTGs also have some shortcomings, which include (1) diesel generator operation can lead to a high mechanical breakdown rate and high maintenance costs; (2) heavy fuel consumption can increase operating costs, and (3) exhaust emissions and noise can cause environmental pollution.

There are a total of 26 container terminals at the port of Kaohsiung, and these terminals are managed by ten container terminal operators (Evergreen, Yang Ming, Wan Hai, OOCL, APL, NYK, Han Jin, Hyundai, Kao Ming, and Lien Hai). The container terminals have four types of cargo handling equipment, namely straddle carriers (Han Jin), RTGs (APL, NYK, Evergreen, HyunDai), RMGCs (OOCL, Wan Hai, Yang Ming, Lien Hai), and Automatic rail mounted gantries (A-RMGs) (Evergreen and Kao Ming) (see Table 1).

2.2. Green container port

The control of logistics operations at container terminals is an extremely complex task (Grunow, Günther, & Lehmann, 2006). Effective deployment of material handling equipment at container terminals is crucial to enhancing overall container handling efficiency and performance during the import, export, and transshipment of containers (Lau & Zhao, 2008). In designing a container terminal, one must weigh the value of certain types of storage and retrieval equipment by performing feasibility and economic analysis (Vis, 2006).

Sisson (2006) suggested that the features of a state-of-the-art green terminal comprise cold ironing of vessels with rapid automated berthing, automated transport vehicles with low emission technology, electric end-loaded yard cranes, and electric cranes serving the on-terminal rail yard. Clarke (2006) suggested that automated container terminal equipment meets the chief requirements of green container terminals, which comprise lower greenhouse emissions,