Comparison of container terminal operation models from carbon footprint perspective

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1. Introduction
Introduction

Different types of logistic activities

Transport vehicles

Container Terminal

Various industries

Supply chain activities

“Cargo handling equipment” is the main source of exhaust emissions in the container terminal service supply chain.

Lessen operating cost

Strengthen market competitiveness

The use of handing equipment with high efficiency and effectiveness
Introduction

Green container terminals

Automatic equipment

Semi-automatic cargo handling equipment

CO₂ mitigation performance

the two most common container terminal operating models at the port of Kaohsiung

TT type

RT type
Carbon footprint analysis

TT

Energy saving performance

Comparing

Carbon reduction performance

ART

Gray relational analysis

Introduction

The ranking order of the two operating models
To review the concepts of container terminal, green container terminal, and measurement of a container terminal's carbon footprint

To calculate the CO$_2$ emissions of various container terminal operating models based on a carbon footprint approach
To examine the ranking order in terms of CO2 emissions of different container terminal operating models via gray relational analysis

To provide suggestions and options for shipping companies and government authorities facilitating formulation of green port strategies

goals of paper
2. Literature Review
The requirement of a green container terminal

- Improved environmental quality
- Beneficial site planning
- The features of green terminals
- Lower water usage
- Greater energy efficiency
- Minimum impact on the local environment
- Minimum impact on the macro environment

- Lazic (2006)

**Automatic and semi-automatic equipment should be used in green container terminals**

- Clarke (2006)

**Automatic equipment to green container terminal requirements**

- Lower greenhouse emissions
- Less energy consumption
- Reduction of container damages
- Control of pollutant emissions
- Mitigation of noise pollution
- Improved operating efficiency
- Lower climate impact

**Green container terminals**
The container handling equipment in the systems:

- Yun and Choi (1999)

Subsystems in container terminal systems:
- The gate
- Container yard
- Berths

Transfer cranes
Gantry cranes
Yard tractors
Trailers
Fig. 1. The structure of a CTS.
Container terminal can improve the productivity by **increasing the efficiency and effectiveness of container handling equipment**

Types of the equipment

- RTs
- TTs
- SCs
- RSs
ART vs TT

Automatic Rail Transtainer

Tire Transtianer
<table>
<thead>
<tr>
<th>Item</th>
<th>TT</th>
<th>ART</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>Average</td>
<td>Poor</td>
</tr>
<tr>
<td>Safety</td>
<td>Average</td>
<td>Good</td>
</tr>
<tr>
<td>Operating system integration method</td>
<td>Wireless</td>
<td>Fiber transmission system</td>
</tr>
<tr>
<td>Stability of Signal</td>
<td>Unstable</td>
<td>Stable</td>
</tr>
<tr>
<td>Breakdown rate</td>
<td>Average</td>
<td>Low</td>
</tr>
<tr>
<td>Mechanical method</td>
<td>Hydraulic</td>
<td>Electronic control</td>
</tr>
<tr>
<td>Repair and maintenance time</td>
<td>Average</td>
<td>Short</td>
</tr>
<tr>
<td>Energy source</td>
<td>Diesel</td>
<td>Electric</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Air pollution</td>
<td>Severe</td>
<td>Zero</td>
</tr>
</tbody>
</table>
3. Methodology
Carbon footprint analysis

Compared based on

$\text{TCO} = \text{ET}_\text{CO} + \text{IT}_\text{CO} + \text{YC}_\text{CO} + \text{GC}_\text{CO}$

$\text{ET}_\text{CO} = \text{ET}_\text{AE} \times \text{ET}_\text{CC}$

$\text{IT}_\text{CO} = \text{IT}_\text{AE} \times \text{IT}_\text{CC}$

$\text{YC}_\text{CO} = \text{YC}_\text{AE} \times \text{YC}_\text{CC}$

$\text{GC}_\text{CO} = \text{GC}_\text{AE} \times \text{GC}_\text{CC}$

- **TCO**: Total CO$_2$ emissions from all equipment (kg)
- **ET$_\text{CO}$**: Total CO$_2$ emissions from external tractor (kg)
- **IT$_\text{CO}$**: Total CO$_2$ emissions from internal tractor (kg)
- **YC$_\text{CO}$**: Total CO$_2$ emissions from yard crane (kg)
- **GC$_\text{CO}$**: Total CO$_2$ emissions from gantry crane (kg)
To determine the degree of correlation between influencing factors in a system with uncertain information.

The ranking order of different models:
- Working time efficiency
- Energy consumption
- CO₂ emissions

Gray relational analysis
A company & B company, both operating container terminals in Kaohsiung

**ART Operating model**

<table>
<thead>
<tr>
<th></th>
<th>B company</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number</strong></td>
<td>22</td>
</tr>
<tr>
<td><strong>Terminal quay length</strong></td>
<td>640 meters</td>
</tr>
<tr>
<td><strong>Terminal quay width</strong></td>
<td>520 meters</td>
</tr>
<tr>
<td><strong>Terminal size</strong></td>
<td>33.28 hectares</td>
</tr>
<tr>
<td><strong>per crane’s performance</strong></td>
<td>40-45 moves/hr</td>
</tr>
</tbody>
</table>
1. Container movements are limited to the movements of export containers.

2. Container movement areas are composed of a gate area, container yard, and berth area.

3. The ART has a working efficiency of 29 moves/per hour faster than TT with 21 moves.

4. One export container movement is considered a continuous action.

5. Sailing schedule is not taken into consideration.

Hypothetical conditions
4. Empirical examination
Using the data from CPC & TPC, the study found the result below:

Average CO2 emissions for TTs: **16.68kg** /per container

Average CO2 emissions for ARTs: **12.85kg** /per container
### Carbon footprint perspective

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>Total</th>
<th>ET</th>
<th>YC</th>
<th>IT</th>
<th>GC</th>
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</thead>
<tbody>
<tr>
<td><strong>TT</strong></td>
<td>23.86</td>
<td>13.5</td>
<td>2.86</td>
<td>6</td>
<td>1.5</td>
</tr>
<tr>
<td>Working time efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Consumption cost</td>
<td>129.91</td>
<td>43.05</td>
<td>58.23</td>
<td>14.35</td>
<td>14.28</td>
</tr>
<tr>
<td>Carbon dioxide emission</td>
<td>16.68</td>
<td>4.76</td>
<td>6.51</td>
<td>1.59</td>
<td>3.82</td>
</tr>
<tr>
<td><strong>ART</strong></td>
<td>24.47</td>
<td>13.5</td>
<td>2.07</td>
<td>7.5</td>
<td>1.4</td>
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<tr>
<td>Working time efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Consumption cost</td>
<td>81.68</td>
<td>43.05</td>
<td>7.95</td>
<td>14.35</td>
<td>14.28</td>
</tr>
<tr>
<td>Carbon dioxide emission</td>
<td>12.85</td>
<td>4.76</td>
<td>2.68</td>
<td>1.59</td>
<td>3.82</td>
</tr>
</tbody>
</table>

Unit: Minutes; TWD; KG

- Total working time
- The annual operating output
- Average working efficiency of each type of equipment
- Average energy consumption
- CO2 emission coefficient

- of one piece of equipment
The ART model (24.47mins) took more time than the TT model (23.86mins)
NT$129.91 for the TT model (diesel fuel)
NT$81.68  for the ART model
Working time efficiency

Energy consumption cost

Carbon dioxide emission

Carbon footprint perspective

Working efficiency

TT > ART

Energy consumption cost

TT ≤ ART

Carbon dioxide emission

TT ≤ ART
## Raw data

<table>
<thead>
<tr>
<th>Raw data</th>
<th>WE</th>
<th>EC</th>
<th>CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT model</td>
<td>23.86</td>
<td>129.91</td>
<td>16.68</td>
</tr>
<tr>
<td>ART model</td>
<td>24.47</td>
<td>81.68</td>
<td>12.85</td>
</tr>
<tr>
<td>Reference sequence</td>
<td>23.86</td>
<td>81.68</td>
<td>12.85</td>
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</table>

## Difference between reference sequence and inspected sequence

<table>
<thead>
<tr>
<th></th>
<th>WE</th>
<th>EC</th>
<th>CE</th>
<th>MAX</th>
<th>MIN</th>
<th>ζ</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT model</td>
<td>0.00</td>
<td>48.23</td>
<td>3.83</td>
<td>48.23</td>
<td>0.00</td>
<td>0.5</td>
</tr>
<tr>
<td>ART model</td>
<td>0.61</td>
<td>0.00</td>
<td>0.00</td>
<td>0.61</td>
<td>0.00</td>
<td>0.5</td>
</tr>
</tbody>
</table>

## Gray relational grade values

<table>
<thead>
<tr>
<th></th>
<th>WE</th>
<th>EC</th>
<th>CE</th>
<th>GRD</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT model</td>
<td>1</td>
<td>0.333</td>
<td>0.863</td>
<td>0.732</td>
<td>2</td>
</tr>
<tr>
<td>ART model</td>
<td>0.975</td>
<td>1.000</td>
<td>1.000</td>
<td>0.992</td>
<td>1</td>
</tr>
</tbody>
</table>

Gray relation analysis
5. Conclusions
A green container terminal should be designed to harmonize container terminal operation with the ecological environment.

If diesel TTs can be converted to E-TTs, the advantages can be obtained.

Conclusions

1. No greenhouse gas emissions
2. No diesel engineering noise pollution
3. Improved air quality
4. Reduced equipment idling time
5. Energy savings can be obtained
E-TT

- Bus Bar System for Electric Tire Transtainer in EMC terminal
There are some issues awaiting for further discussion for:

1. Idling vehicle time reduce
2. Revision issue of existing operating system to remote control system
3. Laser remote sensing technology

Further research issues could be extended research scope to other Asia hub ports.

To collect the terminal data is not easy. To deal with the problems, we had adopted personal interview approach to collect data.
Thank you for Listening

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