Estimation of Users' Waiting Cost at Container Terminals in Northern Vietnam

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Abstract: Container terminals in Northern Vietnam have recorded an impressive development in recent years. This development, however, also raises a fierce competition among local container terminals to attract customers. Aside from the handling charges, the vessels' waiting cost is also an important factor that drives the opinion of users in choosing appropriate terminals. This research plans to estimate the waiting cost in different container terminals in Northern Vietnam by building regression equations that describe the relationship between the rate of throughput/capacity and waiting cost/TEU. Queuing theory with the application of Poisson distribution is used to estimate the waiting time of arrival vessels, and uncertainty theory is applied to estimate the vessel's daily expenses. Previous studies suggested two different formations of the equation, and according to the research results, cubic equation is more suitable in the given case. The research results are also useful for further research which require calculation of waiting cost per TEU in each container terminal in Northern Vietnam.

Keywords: Container Terminals, Northern Vietnam, Waiting Cost, Queuing Theory, Uncertainty Theory

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Introduction
- There are 14 container terminals in Northern Vietnam, 12 in Haiphong city and 2 others in Quang Ninh province;
- Considerable development has been recorded in the port industry in the area. However, it also accompanies with fierce competition among container terminals to attract customers;
- Aside from the handling charges, the vessels' waiting cost is also an important factor that drives the opinion of users in choosing appropriate terminals;
- This research plans to estimate the waiting cost in different container terminals in Northern Vietnam. The results can be used for number of further research

Literature review
- Related previous research present the waiting cost of vessels in port/terminal by the equation \( f(X/CAP) \), where \( X \) is the volume of containers handled, \( CAP \) is port/terminal's capacity.
- It is commonly accepted that it is non-linear and the waiting cost will increase rapidly when the throughput increase.
- Seoed and Larsen (2010) and Munim et al (2017) estimate the equation by:
  \[
  f(X/CAP) = 0.5(X/0.8*CAP)^d
  \]
- Park and Suh (2015) present cubic equations. For example, for the KBCT terminal in Busan:
  \[
  f(X/CAP) = 0.6352(X/CAP)^3 - 7.2568(X/CAP)^2 + 25.051(X/CAP) - 17.269
  \]

Estimation of vessel's waiting time

Application of queuing theory
Queuing theory is the study of waiting lines. There are three parts of a queuing system, including: arrivals to the system, queue line itself and service facilities.

Arrival of calling vessels to container terminals follows Poisson distribution:

\[
POX = \frac{e^{-X}}{X}
\]

Where:
- \( POX \) is the probability of \( X \) arrivals
- \( X \) is number of arrivals per unit of time
- \( \lambda \) is the average of arrival rate
- \( \lambda = 2.7133 \)

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Estimation of vessel’s waiting time

According to Radmilovic (1994), by mathematical derivations, the average waiting time/average service time ratio can be defined as:

\[ \frac{W}{T} = \left( \frac{1}{\lambda} + \frac{1}{\mu} \right) \frac{1}{\lambda} \frac{1}{\mu} \left( 1 + \frac{1}{\lambda} + \frac{1}{2 \mu} \right) \]

Where:
- \( W \) is average number of containers
- \( \lambda \) is steady-state probability that n containers are in port at time
- In this case, \( \lambda \) is berth occupancy and it is estimated as follow:
  \[ \lambda = \frac{n}{T} \]

Where: \( n \) is average of arrival rate, \( n \) is average of service time

Estimation of vessel’s daily costs

Application of Uncertainty theory

Uncertainty statistics is based on experts' experimental data rather than historical data. Liu (2015) proposed a questionnaire survey for collecting experts' experimental data. The starting point is to make domain experts to complete a questionnaire about the meaning of an uncertain variable \( \Lambda \). How much do you think of the daily operating cost of container vessels which is \( \Lambda \) in capitol \( M \)? The size of concerned vessels are the average size of vessels which call container terminals in Northern Vietnam. We first ask all the domain experts to choose a possible value \( \Lambda \) that the uncertain variable \( \Lambda \) may take, and then plot these "What do you think of the daily operating cost of container vessels which is \( \Lambda \) in capitol \( M \)?" values in a curve. Then, ask the experts to choose the belief degree \( \alpha_i \) and a curve is obtained. The curve is called an experts' experimental data. After the questionnaire, the following experts' experimental data are obtained by the questionnaire: [25, 42, 54, 65, ...]. And based on these experts' experimental data, Liu (2015) suggests an empirical uncertainty distribution:

\[ \alpha_i = \frac{2 x_i - \frac{1}{2} + \sqrt{\frac{3}{2} - \frac{1}{2} x_i}}{x_i - \frac{1}{2}} \]

The empirical uncertainty distribution has an expected value:

\[ E[\Lambda] = \frac{1}{2} \frac{\alpha_i}{x_i} - \frac{1}{2} \frac{1}{x_i} \]

Estimation of vessel’s waiting time

Input for the queuing theory model to estimate the waiting time of arriving vessels, therefore include:
- Arrival rate of vessel: steady rate - number of container handled in each vessel: number of berth - capacity of the terminal.

Among these inputs, arrival rate of vessels and number of containers handled in each vessel will be randomized.

Other input is shown in Table 1. By repeating the calculation with series of randomized data, we will have delays of waiting time for different cases.

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
<th>Capacity</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival rate</td>
<td>100</td>
<td>1000</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Handling rate</td>
<td>200</td>
<td>200</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Berth</td>
<td>5</td>
<td>50</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Cap</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 1. Input data
Estimation of vessel’s daily costs

Survey's results

The survey is performed for vessels with a capacity of 400 TEUs, 600 TEUs, 1,000 TEUs, 1,200 TEUs, 1,600 TEUs and 2,000 TEUs.

<table>
<thead>
<tr>
<th>Vessel size (TEUs)</th>
<th>Number of feedback</th>
<th>Vessel daily expenses (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>6</td>
<td>2,043</td>
</tr>
<tr>
<td>600</td>
<td>14</td>
<td>3,128</td>
</tr>
<tr>
<td>1,000</td>
<td>22</td>
<td>6,529</td>
</tr>
<tr>
<td>1,200</td>
<td>28</td>
<td>7,732</td>
</tr>
<tr>
<td>1,600</td>
<td>8</td>
<td>6,719</td>
</tr>
<tr>
<td>2,000</td>
<td>5</td>
<td>6,275</td>
</tr>
</tbody>
</table>

Non-Linear regression

Based on the vessel’s daily cost, the waiting cost/TEU can be calculated and we have series of rate of X/CAP and waiting cost/TEU. The non-linear regression is performed for both the formation of Saeed and Larsen (2010) and Park and Suh (2015).

For example, we have for the case of Chuse V terminal:

\[ f(X/CAP) = 1.697(X/CAP)^4 \quad (R^2 = 0.901) \]

\[ f(X/CAP) = 19.644(X/CAP)^3 - 59.457(X/CAP)^2 + 50.878(X/CAP) - 5.85 \quad (R^2 = 0.945) \]

For all the other cases of container terminals, the cubic equation returns better results of R squared. Therefore, in this research, the formation of cubic equation is chosen.

Conclusion

The research performs a simulation based on queuing theory and Poisson distribution to estimate the relationship between rate of terminals throughput/capacity and waiting cost/TEU. Uncertainty theory is used to examine the vessel’s daily expenses. Survey is sent to experts who work in the fields of container ship management or ship brokerage.

The results imply that the formation of cubic equation is more suitable to present the targeted relationship.

Reference


