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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. Beside the handling charges, the vessels waiting cost is also an important factor that drive the opinion of users in choosing appropriate terminal. This research plans to estimate the waiting cost in different container terminals in Northern Vietnam by building regression equation that describe the relationship between the rate of throughput/capacity and waiting cost/TEU. Queuing theory with the application of Poisson distibution 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 formation 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, Unceratinty 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;
- Beside the handling charges, the vessel's waiting cost is also an important factor that drive the opinion of users in choosing appropriate terminal;
- 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 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.
- Saeed and Larsen (2010) and Munim et al (2017) estimate the equation by:

$$f(X/CAP) = 0.5(X/(0.8*CAP))^4$$

- Park and Suh (2015) present cubic equations. For example, for the KBCT terminal in Busan:

$$f(X/CAP) = 0.6192(X/CAP)^3 - 7.2968(X/CAP)^2 + 25.051(X/CAP) - 17.209$$

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.

$$P(X) = \frac{e^{-\lambda}\lambda^X}{X!}$$

Where:

- P(X) is the probability of X arrivals
- X is number of arrivals per unit of time
- λ is the average of arrival rate
- e equals to 2.7183

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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:

$$\gamma = \frac{1+\bar{a}}{2c(1-\rho)} + \frac{\sum_{n=0}^{c-1} n(c-n)P_n}{c^2\rho(1-\rho)}$$

Where:

- $\bar{a}$ is average number of containers
- P_n is steady-state probability that n containers are in port at time
- In this case, ρ is berth occupancy and it is calculated as follow:

$$\rho = \frac{\lambda\bar{a}}{c\mu}$$

Where: λ is average of arrival rate, μ is average of service rate

Estimation of vessel's waiting time

Assumptions required to validate the model:

- Number of arrival vessels in a period of time is random
- All berths of a terminal have the same service rate
- There is no constraint to the length of the queue, all arrival vessels wait until their turn
- Arrival vessels are served under the basis of first come, first served

Estimation of vessel's daily costs

Application of Uncertainty theory

Uncertain statistic is based on expert's experimental data rather than historical data. Liu (2015) proposed a questionnaire survey for collecting expert's experimental data. The starting point is to invite domain experts to complete a questionnaire about the meaning of an uncertain variable ξ *"How much do you think is the daily operating cost of container vessel which is ... TEUs in capacity ?"*. The size of concerned vessels are the average size of vessels which call container terminals in Northern Vietnam. We first ask the domain experts to choose a possible value x that the uncertain variable ξ may take, and then quiz him: *"How likely is ξ less than or equal to x ?"* Denote the expert's belief degree by α. Note that the expert's belief degree of ξ greater than x must be 1 − α due to the self-duality of uncertain measure. An expert's experimental data (x, α) is thus acquired from the domain expert. Repeating the above process, the following expert's experimental data are obtained by the questionnaire : (x1, α1), (x2, α2), ... (xn, αn)

Based on those experts' experimental data, Liu (2015) suggests an empirical uncertainty distribution:

$$\Phi(x) = \begin{cases} 0 & \text{if } x < x1 \\ \alpha_i + \frac{(\alpha_{i+1} - \alpha_i)(x - x_i)}{x_{i+1} - x_i} & \text{if } x_i \le x \le x_{i+1}, 1 \le i \le n \\ 1 & \text{if } x > x_n \end{cases}$$

The empirical uncertainty distribution has an expected value:

$$E[\xi] = \frac{\alpha_1 + \alpha_2}{2}x_1 + \sum_{i=2}^{n-1}\frac{\alpha_{i+1} - \alpha_{i-1}}{2}x_i + \left(1 - \frac{\alpha_{n-1} + \alpha_n}{2}\right)x_n$$

Estimation of vessel's daily costs

In this paper, the term *daily costs* refers to all expenses rising per day during the period that the vessels are served at ports, excluding handling charges and port charges

They may include, but not limited, to: fuel cost, crew cost, depreciation cost, management cost, maintenance cost, insurance cost ...

Previous researches tried to estimate container vessels' operating costs by several quantitative methods.

In this research, a survey is performed by interviewing operation managers from shipping lines for their container vessels' daily expenses at terminals.

The survey method follow the uncertainty theory proposed by Liu (2015)

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, - service rate, - number of containers handled in each vessel , - number of berth, - capacity of the terminal.

Among those input, 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 series of waiting time for difference cases.

Table 1. Input data

Terminals	Number of berth	Handling speed (TEUs/vessel/h)	Capacity (,000 TEUs)
Chua Ve	5	40	550
Tan Vu	5	60	1,000
Dinh Vu	2	60	500
Nam Hai	1	50	150
Nam Hai Dinh Vu	3	60	500
Hai An	1	40	250
PTSC	1	40	250
Doan Xa	1	40	250
Green Port	2	50	350
VIP Green Port	2	60	350
SNP	1	40	250
Transvina	1	40	250
CICT	3	40	520
Quang Ninh	3	40	500

CONTAINER SHIPS' DAILY EXPENSES AT PORT SURVEY

The survey is designed for experts who are working at container ships management in order to examine the most recent ships' daily expenses at port. These expenses include all expenses rising per day, not limited to: *depreciation cost/ crew cost / fuel cost / maintenance cost/ insurance cost / management cost* ... but **NOT** include *port charges and handling charges*. In this survey, the ship size is **600 TEUs**. Please answer the Question 1-5. In Question 4, 6, 8 the expected answer is in percentage. If the answer in Question 5 is NO, please stop the survey. If the answer in Question 5 is YES, please continue until the answer is NO.

Interviewee's information:

- Company:
- Position:
- Time for working at container ships operation/management:

QUESTIONS

Q1: How much do you think is the minimum daily expenses of container ship which is 600 TEUs in capacity during served at port?
Answer:

Q2: How much do you think is the maximum daily expenses?
Answer:

Q3: How much do you think is likely daily expenses?
Answer:

Q4: To what degree do you think the real daily expenses are less than the figure in Q3?
Answer:

Q5: Is there another number those expenses may be? If YES, how much?
Answer:

Q6: To what degree do you think that the daily expenses are less than the figure in Q5?
Answer:

Q7: Is there another number those expenses may be? If YES, how much?
Answer:

Q8: To what degree do you think that the daily expenses are less than the figure in Q7?
Answer:

Estimation of vessel's daily costs

Survey's results

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

Vessel size (TEUs)	Number of feedback	Vessel daily expenses (USD)
400	6	2,983
600	14	3,128
1,000	21	4,326
1,200	18	4,752
1,600	8	5,739
2,000	5	6,275

Non-Linear regression

Base 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 Chua Ve terminal:

f(X/CAP) = 1.697(X/CAP)^4 (R^2 = 0.901)

f(X/CAP) = 19.644(X/CAP)^3 – 59.457(X/CAP)^2 + 50.878(X/CAP) – 5.85 (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 perform a simulation based on queuing theory and poisson distribution to estimate the relationship between rate of terminal's 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.

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