

THE QUEUING ANALYSIS FOR THE QUAY CONTAINER CRANES OPERATIONS AT THE JAKARTA INTERNATIONAL CONTAINER TERMINAL (JICT)

Hendro Kuntohadi

Trisakti, hkuntohadi2011@gmail.com

Johar Samosir

ITL Trisakti, joharsamosir@yahoo.co.id*

Yusuf Munandar

Badan Kebijakan Fiskal Kemenkeu, yusuf.munandar@kemenkeu.go.id

Magaretha Sri Udari

Budi Luhur, margaretha.sriudari@budiluhur.ac.id

Irwan

PKN STAN, irwan_aribowo@pknstan.ac.id ITL

Abstract

The Jakarta International Container Terminal (JICT) is the Biggest and Busiest Container Terminal in Indonesia. The Throughput (Loading-Unloading) of Container is 1,405,385 boxes per year 2,047,422 TEUS per year. The Performance of Quay Container Crane (QCC) Crane in the JICT can influence the performance of the all services given by the JICT. The JICT operates 16 QCC 2019 and categorized QCC as version of Panamax until Super Post Panamax. In 2019 the throughput of container handled (λ)=1,405,385 boxes/year=3,903.85 boxes/day=162.66 boxes/hour. One of the performance of quay container crane (QCC) in JICT has notation (μ) = B/C/H (Boxes/Crane/Hour) = 27,52 per hour. This research calculated that the utilization (ρ) of the whole QCC = ρ = 36.28%, for the operation of The 16 QCC. ρ = 36.28% is categorized as "Normally Utilized". Length of the container queuing (L_q)= 0 boxes. Waiting time for the container to be served is W_q = 0 seconds. Time spent for the each container to be served by the QCC (W)= 2.17 minutes = 130.81 seconds. The amount of the containers is being served by the QCC (L) = 5.80 boxes.

Keywords: The JICT, 16 QCC, The Utilization (ρ) of QCC

PRELIMINARY

The role of the JICT in Indonesia is very important, because it handles around 60% - 70% of container traffic in Indonesia. The JICT is a container terminal that uses a lot of

container terminal equipment, including: QCC (Quay Container Crane), RTGS (Rubber Tire Gantry Crane), Tractor Head, Reach Stacker, etc.

QCC service performance is influenced by 4 (four) variables, namely: traffic, GCR (Gross Crane Rate), number of QCCs, and time. After measuring the utilization (level of activity) of the QCC, we will know how many QCCs must be operated. It is expected that the research output will be in the form of:

1) The measurement results of the unloaded container traffic are added with those loaded with the notation

λ , in units of boxes per hour, or boxes per day, or boxes per month.

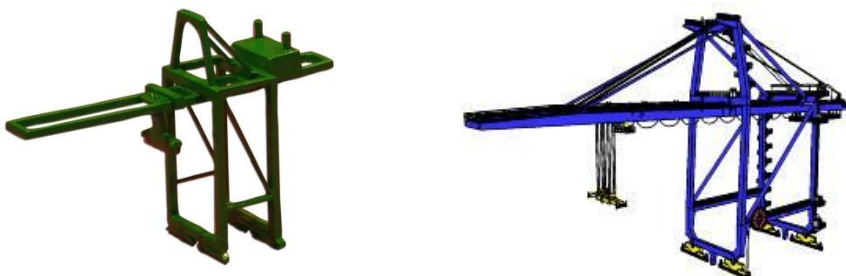
2) The results of the measurement of container loading and unloading performance with the notation μ , in units of B/C/H (Boxes / Crane / Hour), or units with the same meaning, namely GCR (Gross Crane Rate)

3) The measurement results of the utilization or utilization rate of QCC are obtained with the notation ρ , which is the unit in%. Here it can be recommended how many QCCs there should be to guarantee the overall performance of the JICT.

RESEARCH METHOD

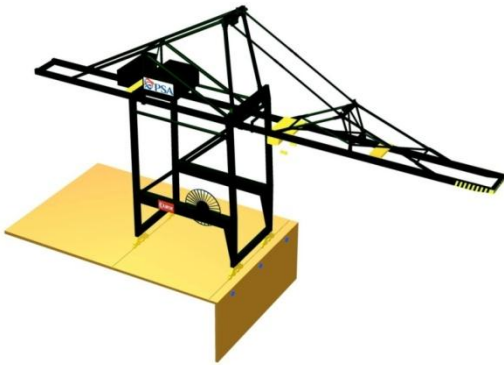
The data collected are primary data and secondary data. Primary data were obtained from JICT in the form of statistical data for 2019 monthly reports. Secondary data were obtained from library reference books and from web sites / portals on the internet network. The theoretical basis used in this research is Queuing Theory. This Queuing Theory formulates mathematically about:

- Traffic becomes λ per unit time, service performance becomes μ per unit time
- Utilization becomes ρ in units of%

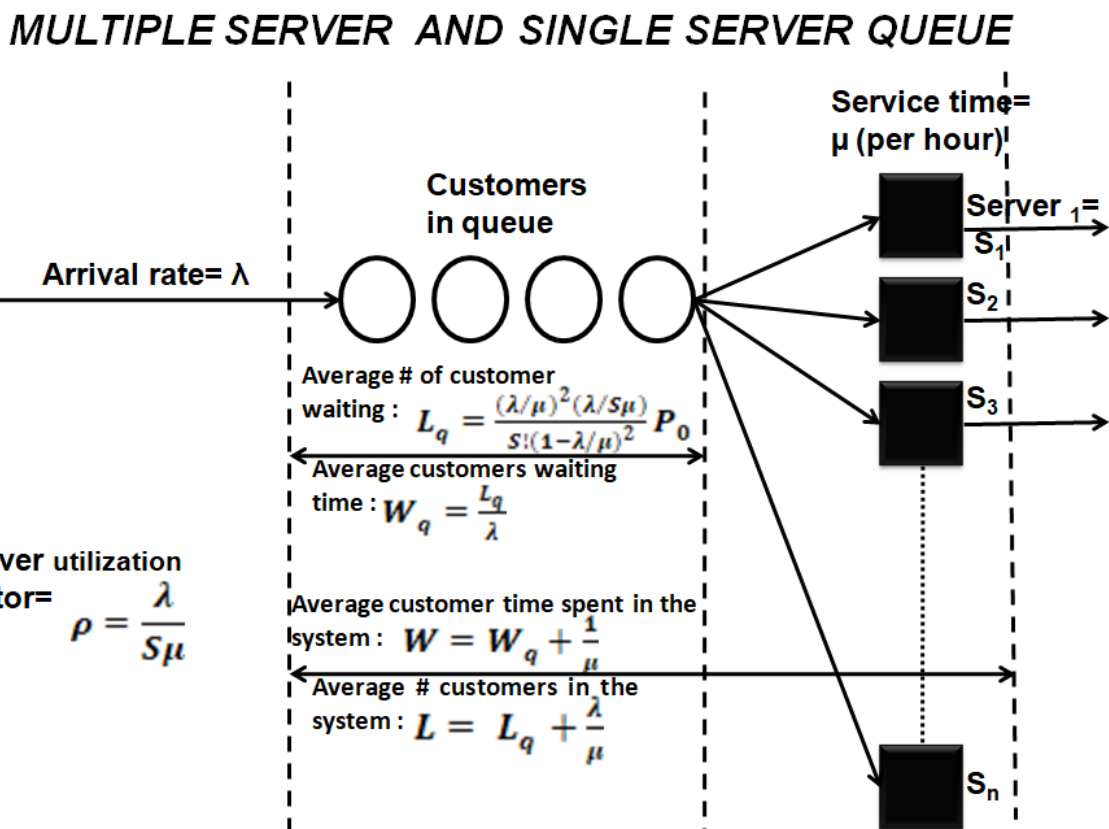


Picture 1. The Panamax Quay Container Crane and The Post Panamax Quay Container Crane

Sources: Google, Picture, 15 December 2012



Picture 2. The Super Post Panamax Quay Container Crane
 Source: Google, Picturer, 15 Desember 2012



Picture. Multiple Server and Single Server Queue
 Source: Authors

FORMULATION OF QUEUING THEORY

(Multiple Servers)

λ = arrival rate; μ = customer # per unit of time; S = # of servers

Average # of customer waiting : $L_q = \frac{(\lambda/\mu)^2(\lambda/S\mu)}{S!(1-\lambda/\mu)^2} P_0$

Average customers waiting time : $W_q = \frac{L_q}{\lambda}$

Average customer time spent in the system : $W = W_q + \frac{1}{\mu}$

Average # customers in the system : $L = L_q + \frac{\lambda}{\mu}$

Server utilization factor : $\rho = \frac{\lambda}{S\mu}$

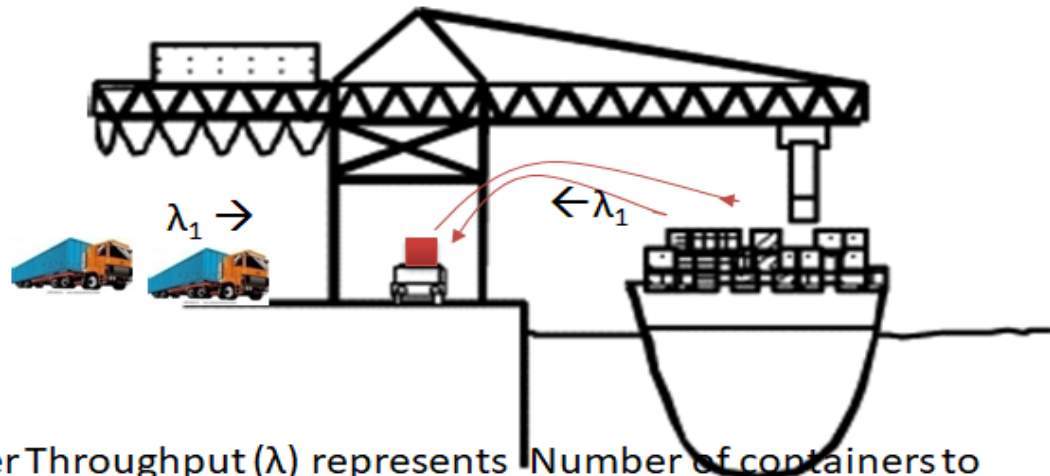
RESULTS AND DISCUSSION

Calculating container throughput (container traffic) (λ)

In calculating container traffic (container throughput) ($= \lambda$) at JICT (Jakarta International Container Terminal) we look at secondary data collected by JICT in 2019, from January to December. This container throughput includes import-export activities, as well as inter-island loading and unloading, as well as regular and tramper shipping. The throughput data taken is in the units of its boxes, because it is usually used to calculate QCC performance.

The throughput container data consists of:

- Containers to be loaded either for export or for inter-island trade
- Unloaded containers, whether imported or unloaded, for inter-island trade



Container Throughput (λ) represents Number of containers to be unloaded and loaded: who came to the QCC and loaded onto the ship (λ_1) Unloaded from the ship by QCC (λ_2) $\lambda = \lambda_1 + \lambda_2$

Picture 4. Loading-Unloading Container to-from ships

Sources: Google, Drawing, 15 Desember 2012

Table 1. Throughput of Containers TERMINAL 1& 2 in JICT 2020

Table Container Throughput at the JICT

No	Year	Boxes	TEUS
1	2016	1,469,518	2,144,278
2	2017	1,132,482	1,607,159
3	2018	1,393,328	2,047,461
4	2019	1,405,385	2,047,422
5	2020	1,211,860	1,792,122
6	2021 until May	501,258	751,267

Source: JICT 2021

So from the table above we get the λ (container traffic) data, the biggest throughput for 2019 is taken in boxes.

$\lambda = 1,405,385$ boxes / year

$\lambda = 3,850.4$ boxes / day = 160.4 boxes / hour = 2.67 boxes / minute

Mean (average) Time Between Customer Arrivals (minutes) = 2.6700000000

Standard Deviation of the Time Between Customer Arrivals = 0.0000000000

Mean (average) Service Time (minutes)= 0.46

Standard Deviation of the Service Time = 0.0000000000

Number of Servers = 16.0000000000

Customer Arrival Rate (customers per minute) $\lambda = 2.67$

Service Rate (customers per minute) $\mu = 0.46$

Expected Server Utilization	$\rho =$	0.3627717391
Coefficient of Variation of Customer Arrival Time	$C_a =$	0.0000000000
Coefficient of Variation of Service Time	$C_s =$	0.0000000000
Expected Number of Customers Waiting in Line	$L_q =$	0.0000000000
Expected Number of Customers in the System	$L_s =$	5.8043478261
Expected Time Waiting to be Served	$W_q =$	0.0000000000
Expected Time Waiting to be Served	$W_s =$	2.1739130435

Source: compile by Authors

Calculating the QCC service performance (μ)

QCC service performance can also be referred to as QCC service speed in unloading from the ship or loading containers onto the ship. The data regarding QCC performance is listed in the secondary data released by JICT, which is listed in table 2. QCC performance is expressed in Gross Crane Rate (BCR), or Moves / hour, or Boxes / Crane / Hour (B / C / H). This performance can be in the form of: speed of loading containers onto ship or unloading containers from ship to dock.

Table 2. Average Gross Crane Rate (GCR, Moves / hour)

<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>May</i>	<i>Jun</i>	<i>Jul</i>	<i>Aug</i>	<i>Sep</i>	<i>Oct</i>	<i>Nov</i>	<i>Dec</i>
28.87	28.12	26.92	26.78	27.57	27.78	27.11	29.09	26.27			

Source: JICT

Table 3 Gross Crane Rate (GCR)

1-Sep	Target 2012	Average GCR
26.27	29.00	27.52

Source: JICT 2019

So, from the secondary data issued by JICT, the average result is $\mu = \text{GCR} = 27.52$ boxes / hour = 0.46 boxes / minute, this is the performance of QCC services in JICT.

Calculate the overall QCC utilization (ρ)

In calculating the overall utilization (level of use, level of activity) the author uses the queue theory formula as follows:

$$\rho = \frac{\lambda}{S\mu}$$

ρ is the utilization that in other words is the the average level of usage of QCC.

Meanwhile, the container traffic is $\lambda = 160.4$ boxes / hour = 2.67 boxes / minute. The number of servers (S) is 16 units = the number of QCC in JICT.

Service performance QCC = $\mu = 27.52$ boxes / hour = 0.46 boxes / minute

Table. Calculation of QCC Utilization

ρ=	36.27%	For S=	16
	38.70%		15
	41.46%		14
	44.65%		13
	48,37%		12

Source: Authors

ρ is the utilization of the QCC.

S is the number of QCC being operated

Table 3. Description of Utilization

Description	Remarks
0 – <30%	Under Utilized
30% - <50%	Normally Utilized
50% - <60%	Fully Utilized
60% - 100%	Over Utilized

Sources: Training UNCTAD and implementation JICT

The average queue length waiting for QCC service is mathematically = L_q

$$L_q = \frac{(\lambda/\mu)^2 (\lambda/S\mu)}{S! (1 - \lambda/\mu)^2} P_0$$

P₀ = Probability of zero customer in the system

$$L_q = (162.66 / 27.52)^2 \times (162.66 / (16 \times 27.52)) / 16! \times (1 - 176.49 / (16 \times 27.52)) \times 0.001640246$$

$$L_q = 0.0000000000156 \text{ boxes} = 0$$

Average service waiting time by QCC = W_q

$$W_q = \frac{L_q}{\lambda}$$

$$W_q = 0.0000000000000000360007/27.52$$

$$W_q = 0.000000000000006 \text{ hour} = 0.000000000034 \text{ minutes} = 0$$

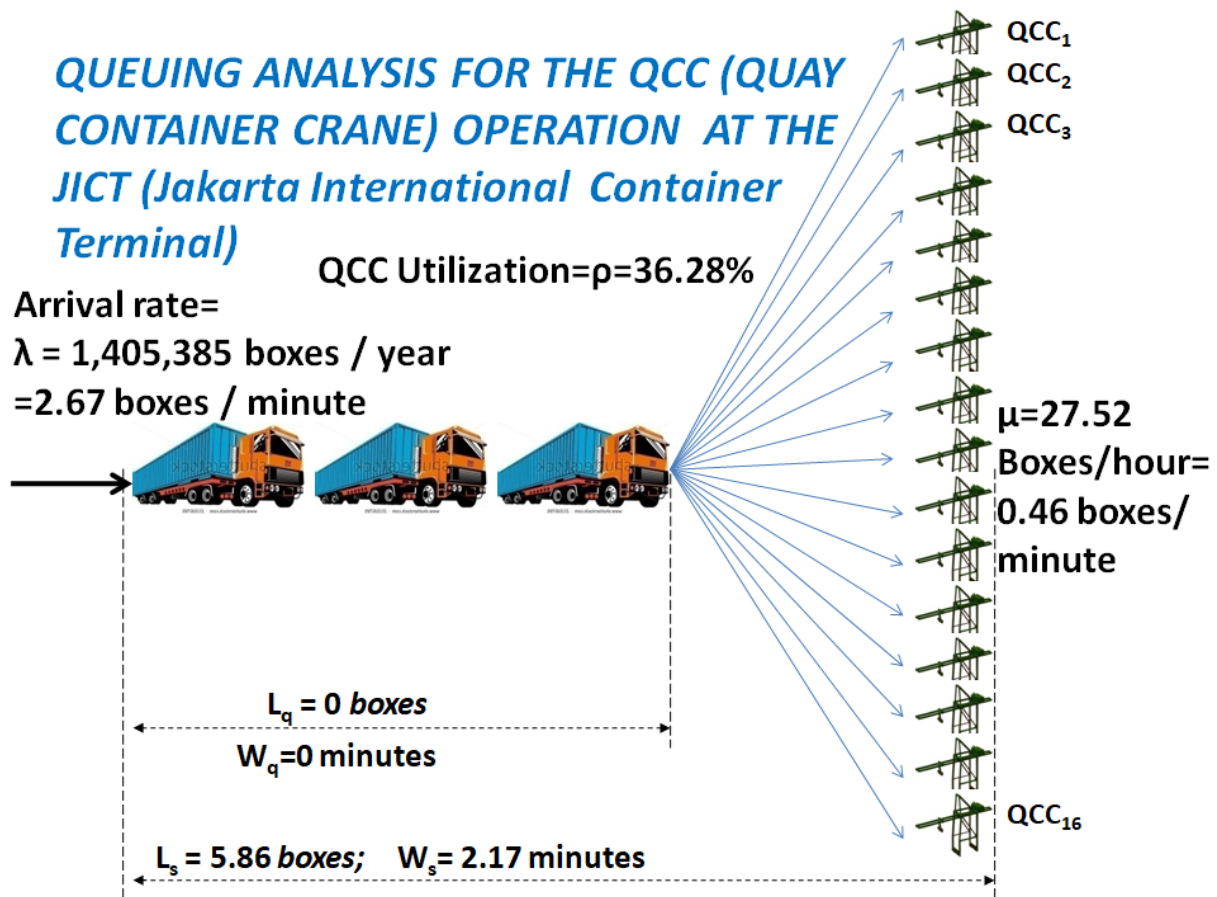
Average waiting time in the system (W), which means starting from queuing for QCC services until being served by the QCC. $W = W_q + \frac{1}{\mu}$

$$W = 2.17 \text{ minutes}$$

The average number of containers in the system (L), which are waiting for services plus those being served

$$L = L_q + \frac{\lambda}{\mu}$$

$$L = 5.86 \text{ boxes}$$



Picture. Conclusion of Queuing Analysis for the Quay Container Crane (QCC by the) Operation. Source: Authors

Conclusion

1) From this research it was found that the container traffic (λ) that is unloaded and loaded per unit time:

$$\lambda = 1,405,385 \text{ boxes / year} = 4.235.84 \text{ boxes per day} = 162.66 \text{ boxes per hour} \\ = 2.67 \text{ boxes/ minute}$$

2) From this research, the loading and unloading performance carried out by QCC is:

$$\mu = 27.52 \text{ boxes / hour} = 0.46 \text{ boxes/minute}$$

3) From this research, it was found that the utilization (level of activity) of 16 QCC units was 36.28%, and this means that it is still normally utilized. That the number of 16 QCC units is still sufficient in 2020

Suggestion

- 1) With a total of 16 QCC units, it is concluded that the number is still sufficient in 2020, no need to be added.
- 2) The maximum number of QCC that can be treated / repaired at any one time is 4 units.

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Agner Kraup, a Danish engineer who worked for the Copenhagen Telephone Exchange, published the first paper on queuing theory in 1909.

David G. Kendall introduced an A/B/C queuing notation in 1953.