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Container-handling operation optimization at Koja Container Terminal

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CONTAINER-HANDLING OPERATION OPTIMIZATION AT KOJA CONTAINER TERMINAL

By

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation : **Container-handling Operation Optimization at KOJA Container Terminal**

Degree : **Master of Science in International Transport and Logistics**

This research paper tries to look at the proper container-handling on port operations including quay crane productivity. There are single and double cycling model that can be analyzed. Single cycling model is known as a conventional model which operates all unloading and loading sequence separately. Double cycling model is a complex model by combining unloading operation with loading operation in certain condition. In double cycle model, empty crane or trailer moves are converted into productive ones.

A framework is provided to analyze a proper method by using a simple formula. The formula is developed to find when the time to start a combination method and calculate the impact of the model to port performance and benefit.

As the result, it shows that double cycling can reduce the container-handling sequence. The quay crane operation will take cycle sequence for 15.58% less than single ones. It brings impact on the reducing of ships cost at berth for about 16.67% and improving the quay crane's performance into 18.46% higher.

Consequently, the author suggests the container terminal try to establish a double cycle method to improve its terminal performance.

KEYWORDS: container-handling operation model, queuing theory, port performance.

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LIST OF ABBREVIATIONS

RTG	Rubber Tyred Gantry
QCC	Quay Container Crane
K-S Test	Kolmogorov Smirnov Goodness of Fit Test
TEUs	Twenty Equivalent Units
b/c/h	Boxes per Crane per Hour
GRT	Gross Registered Ton

Chapter 1 INTRODUCTION

1.1. Background

Along with the increasing of global container handling volume (World Cargo News Online, 2011), the need for reliability of container handling especially in a container terminal becomes very important. One factor that became a unit of measurement is the cycle time of loading and unloading activities. Through optimum cycle time, the best port service will be achieved. It will also impact on increasing the productivity of port services in general. Some thought that are always become a concern in the development of port services are the issues related to the current growth forecast of ships and goods that may affect the possibility of congestion as well as consideration of the need for berth capacity or proper yard area. According to that, several techniques or models associated with the anticipated of container growth can be taken into consideration in the development of port services.

KOJA container terminal is a subsidiary of Indonesia Port Corporation II located in Jakarta, Indonesia. From year to year, the volume of container handled increased at KOJA (Tpk KOJA, 2011). Some progress related to the operational activities has been made to anticipate the consequences that will arise associated with the increased of container volume. In 2012, KOJA will expand its container yard, adding more gate lanes, build supporting facilities. KOJA also will add a superstructure facilities, such as, 1 unit of container crane, 3 units of rubber tyre gantry (RTG), 8 Truck Head unit, superstructure and other facilities to support the container growth rate (Tpk KOJA, 2011).

Along with progress in these operations, this research will attempt to provide a method of increasing the speed of loading and unloading through the use of container-handling operational model. During this time, the system is probably not a lot of concern in an effort to increase the productivity of loading and unloading. There are two systems in container-handling operational model, namely single and double container-handling operation. Therefore, this research will attempt to assess where the most appropriate system for use in KOJA to enhance the productivity of loading and unloading operation further.

1.2. Problem Description

The main objective of container-handling operation is to provide the efficient system by minimizing the waiting time of equipments to handle the containers. The efficient system can be determined by the time of container delivered from quay side to yard area and vice versa. Therefore, this system is depend on the availability of handling equipments such as quay container cranes (QCCs), trailer, and rubber tyred gantry (RTG).

Generally, the terminal usually does not provide specific system to handle import containers. Container, which is handled by QCCs, will be transferred to the trailer to be lifted off to the yard area by RTG. Then, the trailer will moves back to the quay side to receive another container. In order word, trailer will moves without any container on it. Some literatures describe this as single container-handling operational model (GoodChild & Daganzo, 2006). For export operation, it happens as the opposite way from import. There is another way to optimize the trailer, namely, using double container-handling operational model that will be explained further.

According to that, the aim of this study is trying to answer the following question, *what is the suitable container-handling operation model to optimize the operation activities?* To answer that question, several issues need to be investigated as follow:

1) The current situation and challenges at KOJA Container Terminal
2) What are the possible alternatives to optimize the operation
3) What are the advantages and disadvantages of each alternative
4) How suitable is the model for certain scenarios

1.3. Restriction

This study does not investigate any project to a new system and the results and analysis provided are valid for KOJA Container Terminal. The observation of this study is restricted to the operational side in quay and yard area. The assumption that this research provided are implementing the system for one berth with number of QCCs for loading or unloading activities, truck system as transport activities and the use of RTG System to operate in Container Yard.

Due to limitation of time, it will be presented by a general mathematical method with a simple simulation model. The uncertainty of container throughput and the capacity existed do not come into account.

1.4. Research Structure

This study will be generated by the following outline:

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1.1. Background
1.2. Problem Description
1.3. Restriction
1.4. Research Structure

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2.1. Container Terminal Operation

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2.2.2. Double Container-handling Operation

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Chapter 2 LITERATURE REVIEW

2.1. Container Terminal Operation

Container Terminal is the facility for transferring containers using different modes of transport. It is also defined as an interface of land and sea transport. Container terminal can also provide the whole services to handle the containers from another mode of transport such as from ship to railway or ship to road, and vice versa. It is a restricted area from containers are derived from ship until began to be delivered out of the port. A container terminal provides a point where containers are moved from one mode of transport to another (Kozan E. , 2000). Other literature described that in the container terminal, different types of container handling equipments are used to transship containers from ships to barges, trucks and train, and vice versa (Vis & Koster, 2003).

In container terminal, generally, to load and unload and even transshipped containers are required a short time activities with minimizing the use of equipments. Through effective terminal management and optimum allocation of terminal resources, the productivity of terminal can be improved. In term of operation system, container terminal can be divided into two areas, quay side and yard area (Steenken, Vob, & Stahlbock, 2004), as further explained in figure 1.

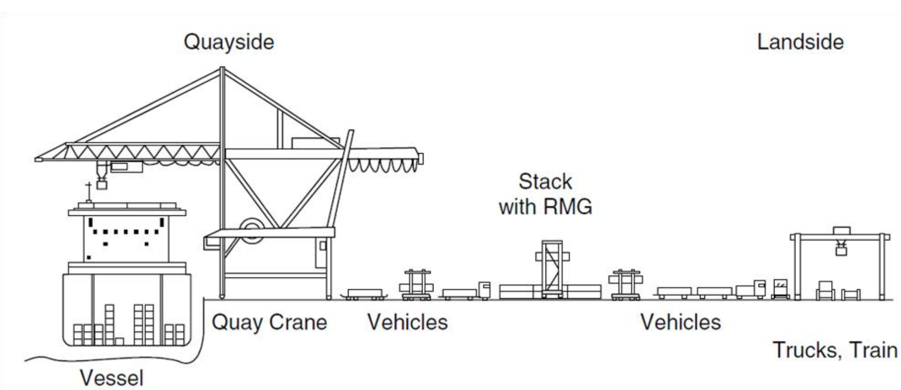


Figure 1: *Container Terminal System*
Source : (Steenken, Vob, & Stahlbock, 2004)

On the quay operation system, it is known also as ship-to-shore operation and described with a process by using QCCs to load or unload containers from a ship to the quay, and vice versa. When ship arrives at the port, it is assigned to a berth which equipped with QCCs. For import containers, it will be transferred to yard area near the location where they will be transshipped later on. Instead of import, it also handles export containers. They come from railway or road system into a port to be stacked near the quay area before transported to a ship.

The operation system of Containers stacked in yard area is generally known as the yard operation system or stacking operation. In yard operation, containers are lifted on or lifted off using specific equipment which is known as RTG system. In yard area, it can be divided into several areas depend on terminal management to allocate the land used. Commonly, yard area is plotted into export area, import area, empty containers, and reefer plug area.

Transfer process is an activity where containers are moved by trailer from quay side to be distributed to the respective stack in the yard and vice versa. The way trailer transferred the containers is nowadays equipped with trailer system or straddle carrier.

Every operation system in the container terminal affects to each other, therefore, many studies had tried to analyze the operation system problems and finally provide an integrated solution. (Bish, LEONG, Li, Jonathan, & David, 2001), (Kozan & Preston, 2006), and (Lee, Cao, Shi, & Chen, 2009) provided a research study to combine yard block allocation and container transfers problems. (GoodChild & Daganzo, 2006) and (GoodChild & Daganzo, 2007) analyzed an integrated research on double cycling quay cranes operations.

According to (HOSHINO, FUJISAWA, MARUYAMA, HINO, & OTA, 2008), the operation area in container terminal can be described as figure 2.

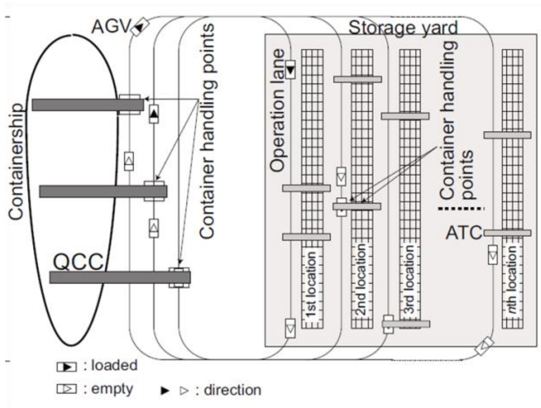


Figure 2: *Transfer Process Layout with QCCs, Trailer, and RTG in Container Terminal*
Source : (HOSHINO, FUJISAWA, MARUYAMA, HINO, & OTA, 2008)

2.2. Container-handling Operation

Regarding this container-handling operation model, many studies deal with automated systems. (Liu, Jula, & Ioannou, 2002) have used multi-load vehicles and addressed the task allocation problem. (Grunow, Gunther, & Lehmann, 2004) have described the usage of such a multi-load vehicle in a seaport container terminal.

Many studies had tried to analyze more specific related to the operation model. (Heijden, Ebben, Gademann, & Harten, 2002), (Gunther & Kim, 2005), and (Vis & Harika, 2004) described an automated transportation system. (Alicke, 2002) and (Ebben, Heijden, Hurink, & Schutten, 2003) explained more detail about modeling of transportation system.

The aim of achieving this operation method is increasing the container throughput in the terminal. The bottleneck of container terminal operation can be located in quay side where containers are loaded and unloaded to and from the containership. By using container-handling operation method, quay crane utilization is expected to increase with eliminating wasted crane moves.

In order to determine which container-handling operation model is suitable for specific container terminal, there are two operation model proposed to be explained as follows:

2.2.1 Single Container-handling Operation Model

Generally, import containers are unloaded from the containership at first before transferred onto a yard area to be stacked. After import containers are all unloaded, then export containers from yard area will be delivered to a quay side to be loaded onto a containership. This activity is known as single container-handling operation model or conventional system as presented in Figure 3.

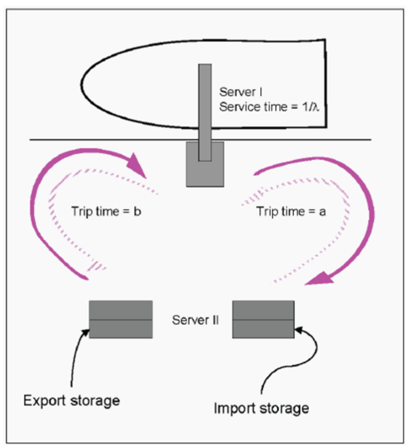


Figure 3: *Single container-handling operation model*
Source : (GoodChild & Daganzo, 2007)

In figure 3, it is shown detail operation procedure as follows:

1. Import containers are unloaded by QCCs from the containership onto trailer and it will be transported to yard area.
2. Import containers transported by trailer are lifted off by RTG to be stacked and trailer will go to quay side in empty to receive other import containers.
3. After import containers are unloaded, QCCs will start to load the export containers.

4. Trailer which finished of unloaded import containers will carry export containers from yard area to be loaded into a containership.
5. Once again, trailer will go back without containers onto yard area to carry other export containers.

2.2.2 Double Container-handling Operation Model

In this operational model, import and export containers are handled at the same time. Import containers are unloaded and transferred onto the yard while export containers will be delivered onto the quay side to be loaded directly after the import already stacked. This operation model can be used to increase the QCCs utilization by keeping empty crane cycle into productive activity. This activity can be presented further in Figure 4.

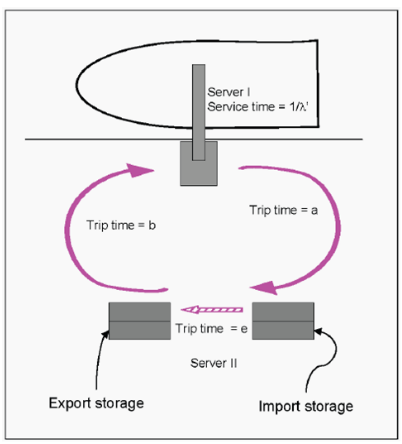


Figure 4: *Double container-handling operation model*
Source : (GoodChild & Daganzo, 2007)

In figure 4, it is shown detail operation procedure as follows:

1. Import containers are unloaded by QCCs from the containership onto trailer and it will be transported to yard area.

2. Import containers transported by trailer are lifted off by RTG to be stacked and trailer afterward will go to export area to delivered export containers onto the quay side.
3. After import containers are unloaded, QCCs continuously will load the export containers which carried by trailer after it transferred import ones simultaneously.

2.3. Trailer System

Generally, the trailer transportation system can be divided into three areas. They are transportation system at the quay side, container yard areas, delivery activity from quay side to yard areas (vice versa). The trailer will simultaneously circulate until they are finish to complete the whole cycle according to these cycles, as follows:

1. The quay cranes are unloading the containers from the container ship and put them on the trailer.
2. Next step, the trailer leaves the quay area to a specific location in the container yard that is assigned as the destination allocated before. It can be import area, empty pool or others.
3. Then, the trailer arrives at that assigned location to be handled by RTG when it is ready.
4. When RTG is ready, then the container will be lifted off from the trailer and lifted on in the assigned location.
5. Finally, empty trailer will go back to the quay area or another specific location to handle other container.

(Back to cycle number 1).

2.4. Arrival and Service Time Pattern

Arrival and Service time pattern of each system will be analyzed by using some statistic method, as follows:

The diagram will provide a histogram layout which determining the frequency of every cycle. In order to analyze the frequency, it must set the following steps (Calyampudi, 2005):

a. Determine the bins (k) using the formula:

$$k = 1 + Log_2 n \quad (1)$$

Where,

n = number of data

b. Next step is determining the bins width (h) using the formula:

$$h = \frac{X_{max} - X_{min}}{k} \quad (2)$$

Where,

X_{max} = maximum data observed

X_{min} = minimum data observed

c. Determine the frequency of each data based on the bins sequence.

2.4.1. **Kolmogorov Smirnov Goodness of Fit Test (K-S test)**

In order to find the proper queue model, arrival and service time patterns have to be determined. Therefore, it will test the frequency distribution of arrival and service time at first.

The test is presented by Kolmogorov Smirnov Goodness of fit test (K-S test) and it is explained as follow (Rajagopalan, 2006):

a. Objective

Verifying the population distribution $F_{(x)} = F_{0(x)}$, by using a random sample.

b. Data

$X_{i(1,2,\ldots n)}$ is considered as a random sample of *n* observations from a population and $F_{0(x)}$ is the cumulative distribution function of a specified population.

c. Hypothesis

H_0 : the population distribution $F_{(x)}$ is equal to $F_{0(x)}$, $F_{(x)} = F_{0(x)}$

H_1 : the population distribution $F_{(x)}$ is not equal to $F_{0(x)}$, $F_{(x)} \neq F_{0(x)}$

d. Level of significance (α) and critical value (D_α)

The critical value (D_α) for the level of significance α with the number of sample size (*n*) for more than 35 is presented, as follows:

Table 1 Critical values of the Kolmogorov-Smirnov Test Statistic

Sample Size (*n*)	1- α		
	0.9	0.95	0.99
> 35	$\frac{1.224}{\sqrt{n}}$	$\frac{1.358}{\sqrt{n}}$	$\frac{1.628}{\sqrt{n}}$

Source: (Sachs, 1997)

e. Method

1) Determining the cumulative distribution $F_{0(x)}$.
2) Obtain the cumulative distribution of the sample and let $F_{n(x)}$Fn(x) be the empirical distribution function while $F_{n(x)}$ is equal to the number of observations ($X_i \leq x$) divided by *n*.
3) Calculate the absolute difference, I$F_{0(x)}$ - $F_{n(x)}$I

f. Test Statistic

D = maximum value of $|F_{0(x)} - F_{n(x)}|$

g. Conclusion

If, value of $D \leq D_\alpha$, accept H_0

If, value of $D > D_\alpha$, reject H_0 or accept H1

2.4.2. **Frequency Distribution**

In order to impose the proper queuing model, frequency distribution is tested based on poisson and exponential distribution. In this research, the arrival of containers is assumed to use an exponential distribution for their time between arrival. The service time is considered to follow an exponential distribution.

Then, probability density function (pdf) of the poisson distribution is described by using the formula, as follows:

$$f_{(x)} = \frac{\lambda^x . e^{-\lambda}}{x!} \tag{3}$$

Where,

$f_{(x)}$: probability density function of containers arrival

x : 0,1,2,3, …

λ : average arrival of containers per unit time ($\lambda>0$)

And the probability density function (pdf) of exponential distribution is described by using the formula, as follows:

$$f_{(t<x\leq T)} = \left| e^{-\frac{t}{m}} - e^{-\frac{T}{m}} \right| \tag{4}$$

Where,

$f_{(t<x\leq T)}$: probability density function for service from t to T.

m : average service time

2.5. Queuing Theory

(Moon, 2011) describe that queuing theory is a branch of applied probability theory which can be used to design a system that enable organizations to perform optimally according to some criteria such as maximum profits and desired service level. The aim of this model is to provide all system that is understandable and analysis the service processes in the system. The possible service process can be measured, as follows:

- Average time a customer spends in the queue
- Average length of the waiting line
- Average time spent in the system
- The mean number of customers in the system
- The probability that an arriving customer must wait for service

Several elements are determined in this theory, namely, input source, arrival pattern, queue discipline, queue length, service pattern, and finally output as the result.

In order to describe the characteristic of queuing system, (Willig, 1996) introduced a notation using the format of A/B/m/N–S. In this format, A is shown as an arrival distribution, B is the service time distribution, then, m is number of servers while N is the maximum size of the waiting line, and finally, S is queue discipline. Several patterns can be used to determine the arrival and service time distribution for instance, with M (Markov), D (Deterministic), G (General), Ek (Erlang–k), or Hk (Hyper-k). M is used for exponential distribution, D is provided when the customers have the same value, G is used for general distribution, Ek is used for erlangian distribution, and Hk is used for hyper-exponential distribution.

(Moon, 2011) also described the general structure of queuing system from input resources into final result as shown in figure 5.

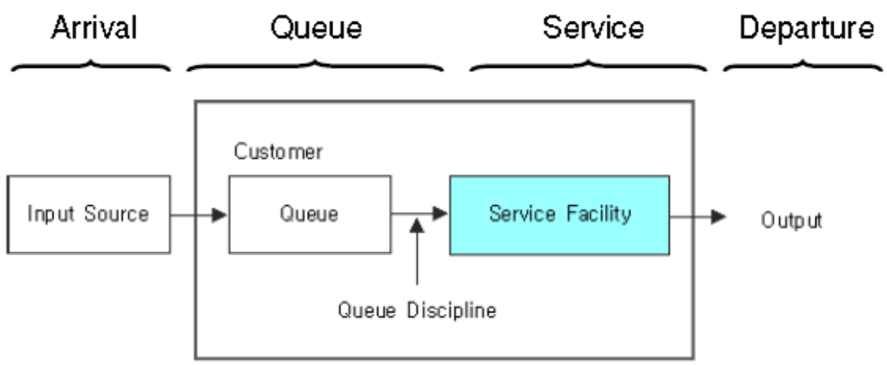


Figure 5: General Structure of Queuing System
Source: (Moon, 2011)

Other characteristic of queuing system is a queuing model of M/M/k. It can be applied to analyze the container-handling operation model. (Moon, 2011) explained the characteristic of M/M/k model, as follows:

- Customers arrive according to a Poisson process at a mean rate l.
- Service times follow an exponential distribution.
- There are k servers, each of who works at a rate of μ customers (with kμ> l).
- Infinite population and possibly infinite line.

According to that, the statistical method of M/M/k can be described further, as follows:

$$P_0 = \frac{1}{\sum_{n=0}^{k-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k \left(\frac{k\mu}{k\mu-\lambda}\right)} \quad (5)$$

$$W_q = \frac{(\frac{\lambda}{\mu})^k \mu}{(k-1)!\,(k\mu - \lambda)^2} P_0 + \frac{1}{\mu} \qquad (6)$$

$$L_q = P_0 \frac{(\frac{\lambda}{\mu})^k \rho}{k!\,(1-\rho)^2} \qquad (7)$$

$$\rho = \frac{\lambda}{k\mu} \qquad (8)$$

$$W = W_q + \frac{1}{\mu} \qquad (9)$$

$$L = \lambda(W_q + \frac{1}{\mu}) = L_q + \frac{\lambda}{\mu} \qquad (10)$$

Where :

λ : Average rate of arrival (number of customers per unit time)
μ : Average rate of service (number of customers per unit time)
s : Number of server
ρ : Utilization rate for each server
ρ_0 : Probability that there are no customers in the system
L : Average number of customers in the system
L_q : Average number of customers in the queue
W : Average time a customer spends in the system
W_q : Average time a customer spends in the queue

When there is infinite queuing length, then M/M/1(∞) can be used to determine the queuing system. It means that there is only operates in one single server system with arrival and service pattern are following poisson distribution. Other assumptions are applicable to this system to run, for instance infinite population and free-in free out queue discipline.

According to that, the statistical method of M/M/1(∞) can be described further, as follows:

$$\rho = \frac{\lambda}{\mu} \tag{11}$$

$$P_0 = 1 - \rho \tag{12}$$

$$L = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu - \lambda} \tag{13}$$

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu - \lambda)} \tag{14}$$

$$W = \frac{1}{\mu - \lambda} \tag{15}$$

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} \tag{16}$$

Where :

λ : Average rate of arrival (number of customers per unit time)
μ : Average rate of service (number of customers per unit time)
ρ : Utilization rate
ρ_0 : Probability that there are no customers in the system
L : Average number of customers in the system
L_q : Average number of customers in the queue
W : Average time a customer spends in the system
W_q : Average time a customer spends in the queue

Chapter 3 CONSTRUCTION OF CONTAINER-HANDLING OPERATION OPTIMIZATION MODEL AT KOJA CONTAINER TERMINAL

3.1. Single Container-handling Operation Model

This model is currently operated at KOJA. In accordance with the literature above, the single model is a conventional method in which the container is unloaded first before the loading operation begins. In unloading operation, containers are unloaded based on the bay plan published by the shipping lines. The sequences of the operation are usually started on the port side in advance to avoid the slope of the ship's position.

In a single model, there are three common service operations carried out, for instance: berth operations, transport operations, and yard operations. This single model will focus on the operation of the berth first and then followed up with other operations.

3.1.1. Berth Operation

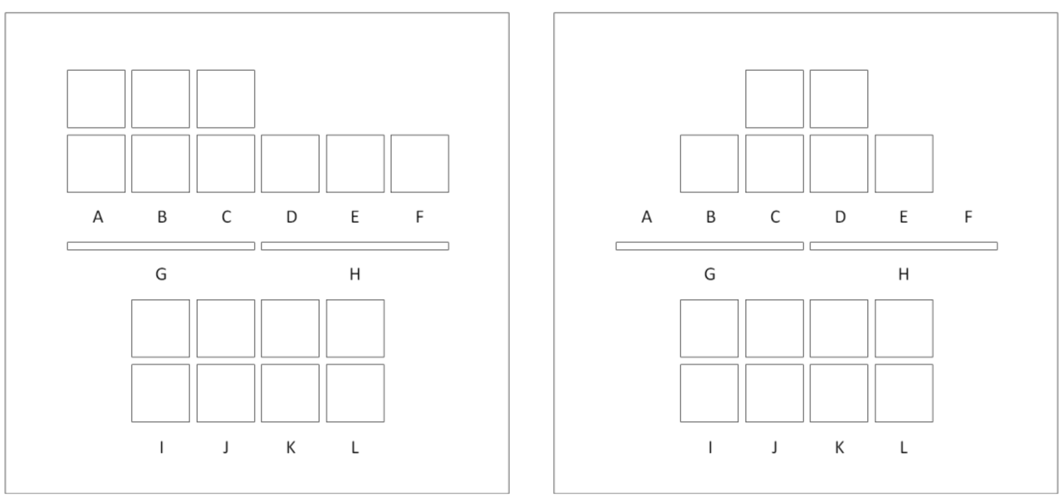
For berth operation where the focus of equipment that will be reviewed are quay cranes, the author will try to calculate how much time which is used by the quay crane to complete the loading and unloading operations in a single bay only.

In a destination port, the ship will unload its entire cargo when that port is a last port. To make easy of illustration and in accordance with the fact that KOJA Container Terminal is set as the last port, the author will only apply simulation based on the activities of unloading the entire cargoes and complete its activities with loading sequences later on.

Generally, container ships will put the structure of its cargoes placement based on its destination. The container with the last destination will be placed at the bottom.

However, the weight and size of containers is also a consideration in the placement of containers. The heavy-weight and the 20 feet-size of the container should be placed on the bottom also. Sometimes, the 20 feet-size is a light-weight thus will result a constraint in placement. To anticipate that, the ship will put the container in an unusual location and consequently it will cause the container-shifting activity at the last port. That activity is happened where containers are handled is not a container that will be unloaded. This leads to double handling or twice a cycle operation in which the container is unloaded to then be placed back to the ship after the container below is taken.

Due to assumption that KOJA is placed as the last port, all containers will be unloaded and then proceed to fit a single model of the loading operation. In this case, container-shifting activities will be eliminated. In the illustration below, the author will parse the single models from the number of cycles required in the operation of the berth.



(a) Unloading plan (b) Loading plan

Figure 6 Illustration of Ship Container Layout in a Single Bay

Source: Author

In the figure 6(a), in order to complete the unloading operation in n-location, the QCC's operator can perform totally U_n = 19 cycles. The Sequences of cycle can be done either from the starboard, the port-side or from the side which is safe to do. For this illustration, the author will attempt to start unloading operations from the starboard first and then proceed to the port-side. In this figure, it starts from A to H. For unloading operation under deck, in principle, the implementation of these operations are same as on berth operation after deck hatch removed. It starts from G to H then continue to I to L. However, this activity usually takes longer due to the adjustment of the spreader to the ship's position.

After completion of the unloading operation, the loading operation will be directly implemented. It also can be started from the starboard or port-side based on a loading plan. In figure 6(b), it will be started from the reverse of unloading sequence, L to I. Next operation is to put back the deck hatch and continue the rest operation. It start from G to H as deck hatch operation and completed from E to B. In total of loading operation in n-location, it can take L_n = 16 cycles including 2 cycles of deck hatch operations.

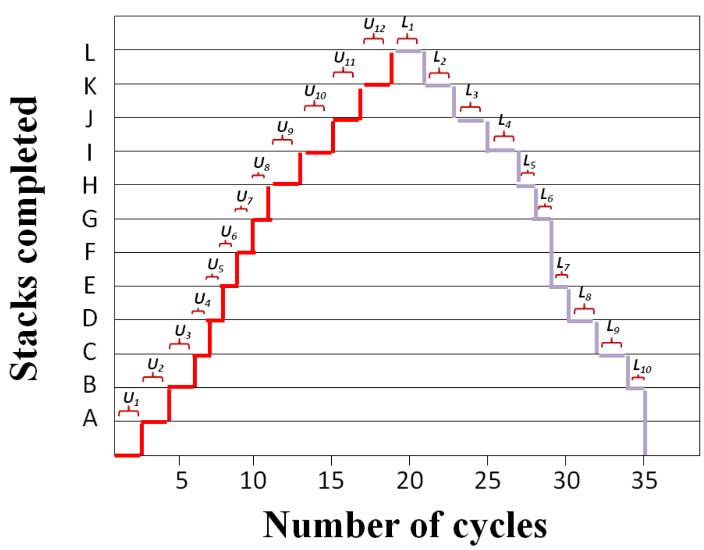


Figure 7 Cycle Sequence of Unloading and Loading Operation in Single Model
Source: Author

According to figure 7, total time of unloading operation can be calculated. If the average cycle-time of unloading operation is FU_n then it can take 19 times FU_n to perform total time of unloading operation in n-location, it shown as X_n. If the average cycle-time of loading operation is FL_n, then it can have 16 times L_n to complete loading operation, Y_n. Total operation to complete unloading and loading operation that can be calculated is 35 cycles. Here, we can take a conclusion that total cycle in a single model of berth operation is as same as total number of container to be unloaded and loaded plus deck hatch operation.

$$X_n = U_{n(\mathrm{A}\ldots\mathrm{L})} \times FU_n \tag{17}$$

$$Y_n = L_{n(\mathrm{L}\ldots\mathrm{A})} \times FL_n \tag{18}$$

$$W_n = X_n + Y_n \tag{19}$$

3.1.2. Transport Operation

Typically, container terminal operations currently carried out by the trailer system. KOJA Container Terminal implement this system in which the use of trailer to move containers to and from the berth. To support the berth operations, a lot of trailers are used in general will speed up unloading and loading operations. However, if at that time there were other ships that are berthed and also have the same service, then we can see how much chaos in shipping operations it will be.

In this case study, the authors see that the application of trailer used is not limited to specific equipment. For instance, a single quay crane will not only use a trailer with a particular specification, but it can operate with the support of any trailer to place themselves in the operation of quay cranes everywhere. Effects arising from this system are the trailers will cross among each other.

A lot of numbers of trailer are operated then it will cause longer time of trailer to reach one cycle-time. And vice versa, the fewer the number of trailers are used, the cycle time will be faster but it will affect to the increasing of waiting-time of quay crane. Therefore, it requires the optimal number of trailer used in order to make balance of quay crane and trailer's cycle-time.

3.1.3. Yard Operation

In this case, KOJA implement the RTG system where the equipment used is a rubber tyred gantry to move the containers to and from the trailer in a container yard. For the implementation of yard operations, the equipment is used by following the number of blocks or operated area.

Related to the fulfillment of cycle time, this RTG activity is different from the previous system. RTG cycle time does not depend on the quay crane or trailer because the RTG work on the specific block or area respectively. As has been known, container yard consists of several blocks or area to facilitate loading and unloading operations. The area is usually made up of export area, located on the starboard and the import area which is located behind the export area. In addition, there are other areas that are not less importantly, reefer plug area and area for empty containers.

Based on the observations, the use of RTG equipment is not accompanied by a proportionate number within every block where there is less number of RTG to be operated. Sometimes, trailers have to wait in a long time to be handled by RTG. Thus, their effect is the placement of containers that do not fit to the block that it should be.

This activity happens usually on unloading operation due to trailer's driver do not want to wait in a long time to be served. The impact is the increasing of trailers to be operated.

The time of RTG to complete the cycle-time is included in the trailer's cycle-time. Therefore, the longer RTG finish the cycle-time then the longer trailer to reach its cycle-time also. In the perspective of unloading and loading operation, RTG have the equal time to complete its activities.

3.2. Double Container-handling Operation Model

Compare with single operation model, this model tries to apply loading operation with unloading operation. For the implementation of this model, the authors feel the need to apply some assumptions as follows:

1. To facilitate the simulation, the process of loading and unloading operations is limited to a particular bay by using one quay crane operated.
2. The unloading operations are made entirely without taking any rehandles operation because of KOJA as the final destination port.

The author will attempt to start the simulation of double operation model application by making a basic model of the system at first and try to analyze the constraints that arise as a deck hatch in each bay.

3.2.1. Deck Hatch

Problem that arise in the application of this double operation model come from the placement of any deck hatch bay at ship. With a deck hatch, then the combination of loading and unloading process is hampered. The average width of deck hatch covers half of each row or third row of every bay at ship. To overcome this problem, several things into consideration in the application of this model are as follows:

1. Doing the unloading operation normally on the upper deck at first.
2. Replace the deck hatch after all the containers on deck are being discharged into the safe place. Normally, it is allocated in the outside of working area of quay crane or at the back-side of quay crane.
3. When the unloading operation has reached below the deck hatch, then the combination can be implemented.

3.2.2. Modeling Framework

As mentioned above, the authors will describe three forms in the service of loading and unloading operations. In this regard, illustrations of activities will be further elaborated with the layout of unloading and loading plan.

3.2.2.1. Berth Operation

As in the single operation model, berth operation focus on the operation of quay crane. The difference between single and double operation model is the need of combination activities in certain circumstances of unloading operation with loading operation. By using that specific combination activity, it can result in the increasing number of containers handled per unit time by a particular quay crane. However, in order to implement this double operation model, some preparation are needed both in the trailer line placement to avoid cross each other between the loading and unloading operation and the preparation of a proper management system.

In a simulation where KOJA as the last port, the container unloading activities will not have any changes in the amount of quay crane cycles. Therefore, the number of cycles are presented in unloading operations are equal to the number of containers itself. The thing that needs to be concerned in this double model is the placement of deck hatch on each bay. According to that reason, double model only can be provided to handle container operation in under deck.

In term of starting point in double cycle model, the operation planner generally has to decide where and when it starts. It is not only for the ease operation but it requires the safety operation for the ship itself as had already mentioned previously. Because of the various unloading and loading pattern and condition, it seems difficult to assign the starting point of double model.

In order to determine in which direction the sequence start and where the starting point begin, there are 3 considerations have to be made, such as maximum frequency of double cycle model, convenience of quay crane operators and other workers, and planning (Song, 2007). Therefore, the terminal operator has to analyze those considerations and define the optimum formula respectively.

To give more explanation about this model, the author will attempt to simulate the process of unloading and loading containers in a particular bay with 3 conditions that might be happened in the operation, as follows:

a. The sequence starts from port-side to starboard.
b. The sequence starts from starboard to port-side.
c. The sequence follows randomly.

Based on the container layout as shown in figure 6, the process of unloading containers on the upper deck is done in advance whether it starts from the port-side or starboard which is then followed by the placement of deck hatch. Quay crane's cycles are counted in this initial process is a pure cycle of unloading operation. After all containers on deck and followed by deck hatches are unloaded then containers under deck are ready to be unloaded.

Jung-Ho Song had provided the formula to find the optimum sequence of starting point in double model (Song, 2007), as presented:

$$w_i = \sum_{n=1}^{i} X_n - \sum_{n=1}^{i} Y_{n-1} - \sum_{n=1}^{i} W_{n-1} \ (i = 1,2, \dots, n) \tag{20}$$

$$W = \sum w_i \tag{21}$$

$$w_i \geq 0 \tag{22}$$

Where,

W = Total idle moves

w_i = Idle moves for each row

x_i = Loading moves for each row

y_i = Unloading moves for each row

i = Row index

According to the formula, in order to determine the sequence starting point, there are some key points that have to be considered base on Jung-Ho Song's formula, as follows:

1. The value of D_i-L_{i-1} except for D_1 is reaching a negative number.
   This situation means that the amount of imports container are less than export ones. The double model sequence is supposed to be started in advance before import containers as many as the difference between the two sums is unloaded.
   To analyze the optimum starting point, D_i-L_{i-1} has to be a positive value at first by adding the next formula, not the previous number (D_1), until it reaches a positive value. If it still has a negative value then the formula has to be abandoned.

If, D_2-L_1 < 0

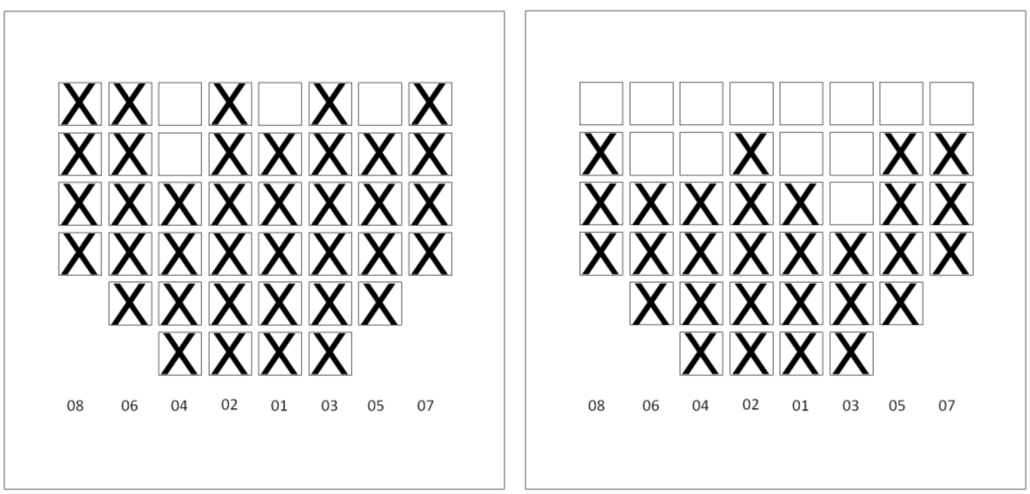
$$\{(D_2-L_1) + (D_3-L_2) + \dots\} > 0 \quad (23)$$

2. The value of D_i-L_{i-1} is a positive number

   This is an opposite situation that means the amount of imports container are higher than export ones. In this case, double model can be started after import containers as many as the difference between the two sums have been unloaded. In order words, this value should be added to the previous ones including the value of D_1.

3.2.2.1.1. The sequence starts from Port-side to Starboard

Based on the formulation, the simulation can be developed using a simple module. In this illustration, the double cycle will begin under deck or after the containers on deck are fully unloaded.



(a) Unloading plan (b) Loading plan

Figure 8 Illustration of Ship Container Layout Under-Deck in a Single Bay

Source: Author

From figure 8, it can be seen that the import containers are higher than export containers. In order to provide double cycle and from determining the sequence, starting point can be calculated by using the formula.

The result shows that the starting point begin at the 12^{th} import container is unloaded. In the 13^{th} sequence, quay crane is supposed to lift-on export container to be stack at the half way of quay crane cycle and deliver the import container at the last cycle. The frequency of double cycle can be determined also by 26 times. The calculation is presented, as follows:

Table 2 Formulation of Double Cycle Starting Point (Portside to Starboard)

Row Number	08	06	04	02	01	03	05	07
Unload Sum (D)	4	5	4	6	5	6	4	4
Load Sum (L)	3	3	4	5	4	3	4	3
D-L	2	1	2	0	2	1	0	
Starting Point Formula	W = D08 + (D06-L08) + (D04-L06) + (D02-L04) + (D01-L02) + (D03-L01) + (D05-L03) + (D07-L05)							
Starting Point (W)	4 + 2 + 1 + 2 + 0 + 2 + 1 + 0 = 12							
Frequency Formula	Unload Sum - W							
Frequency	26							

Source : Author, Adapted from (Song, 2007)

By 38 movements of import containers in total and it is higher than 29 movements of export, total cycle that can be applied for this double cycle model is maximum between unloading and loading operation added by the difference of loading operation and the frequency established. In other words, the unloading operation covers 26 times of loading operation. Total cycle is 41 times.

3.2.2.1.2. The sequence starts from Starboard to Port-side

By using ship container layout as same as shown in figure 8, the starting point of double cycle can be provided after the 12th sequence. It means that the loading operation can be performed on the sidelines of unloading operation at the 13th sequence. Detail calculation is shown, as follows:

Table 3 Formulation of Double Cycle Starting Point (Starboard to Portside)

Row Number	08	06	04	02	01	03	05	07
Unload Sum (D)	4	5	4	6	5	6	4	4
Load Sum (L)	3	3	4	5	4	3	4	3
D-L		1	1	-1	2	2	2	1
Starting Point Formula	W = D07 + (D05-L07) + (D03-L05) + (D01-L03) + (D02-L01) + (D04-L02) + (D06-L04) + (D08-L06)							
Starting Point (W)	4 + 1 + 1 + (-1) + 2 + 2 + 2 + 1 = 12							
Frequency Formula	Unload Sum - W							
Frequency	26							

Source : Author, Adapted from (Song, 2007)

By using the same formulation, total cycle that can be applied for this double cycle model is 41 times. It has similar starting point with the previous sequence.

3.2.2.1.3. The Random sequence

In order to determine the starting point of random sequence, with the same layout as shown in figure 8, Johnson's Rules can be implemented to find the optimal solution of the first sequence. The general idea about this rule is allocating the small operation at every row to be put in last sequence. The detail working rule to find the optimal solution can be described, as follows:

1. Listed all operations in every row.
2. Select the largest operation at first then follows by smaller operations. The largest operation means the difference point between export container and import in every row.
   a. If the largest operation lies on the first machine/work centre, the operation is placed at first sequence.
   b. If the largest operation lies on the second machine/work centre, the operation is placed at the end sequence.

   All operations must be completed at first before moving to the next sequence.
3. Once the operation is scheduled, then go to the next step.
4. Repeat the step number 2 and number 3 to the remaining operations, these activities are performed towards the centre of the sequence.

The starting point of double cycle with random sequence can be applied based on Johnson's Rule after 12th sequence. It means that the loading operation can be performed on the sidelines of unloading operation at the 13th sequence. Detail calculation is shown, as follows:

Table 4 Formulation of Double Cycle Starting Point (Random Sequence)

Row Number	**08**	**06**	**04**	**02**	**01**	**03**	**05**	**07**
Unload Sum (D)	4	5	4	6	5	6	4	4
Load Sum (L)	3	3	4	5	4	3	4	3
L-D	-1	-2	0	-1	-1	-3	0	-1
Priority (Larger Point)	3	2	7	3	3	1	7	3
Row Number (Priority)	**05**	**04**	**07**	**08**	**01**	**02**	**06**	**03**
Unload Sum (D)	4	4	4	4	5	6	5	6
Load Sum (L)	4	4	3	3	4	5	3	3
D-L	0	0	1	2	2	0	3	
Starting Point Formula	W = D05 + (D04-L05) + (D07-L04) + (D08-L07) + (D01-L08) + (D02-L01) + (D06-L02) + (D03-L06)							
Starting Point (W)	4 + 0 + 0 + 1 + 2 + 2 + 0 + 3 = 12							
Frequency Formula	Unload Sum - W							
Frequency	26							

Source : Author, Adapted from (Song, 2007)

In this random sequence, total cycle that can be applied for this double cycle model also has similar value with all the previous. It takes 41 times to complete all the operations.

3.2.2.2. Transport Operation

The difference can be seen in this system is that there is continuity in the activities of trailer to carry import container to be stacked in the container yard, followed by loading activities of export container to be delivered to the berth.

In order to support double cycle model, container terminal layout have to be considered. The layout influences to the movement of trailer where long distance of export and import will cause longer time to deliver.

Another aspect that has to be considered is allocating of unloading and loading path in order to avoid cross movement among those activities. Commonly, there are lines or paths under quay crane to ease the operation to separate each activities of quay crane used.

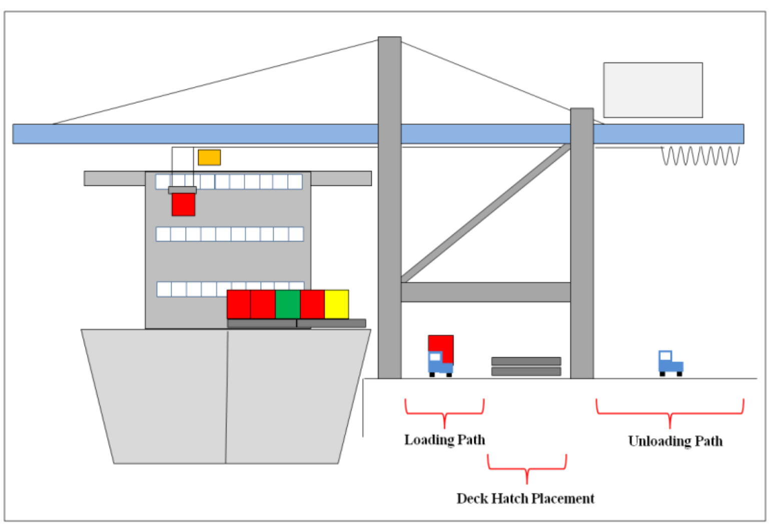


Figure 9 Unloading and Loading Operation Path
Source: Author

In figure 9, there is an illustration about operation path under quay crane. In double cycle model, author will try to present a simple path which can be used. There will be separation paths using deck hatch placement between unloading and loading operation in order to make easy to recognize the operation by the operator. Unloading operation is placed on the back-side of quay crane to make short the way and separate the queue line.

In overall activity, the location of export area is generally near from the ship's side while the import area is behind the export area. According to that, the movement of the trailer will become more complex because one trailer in this cycle can be attempted to load import and export containers. It can be seen in figure 9, as follows:

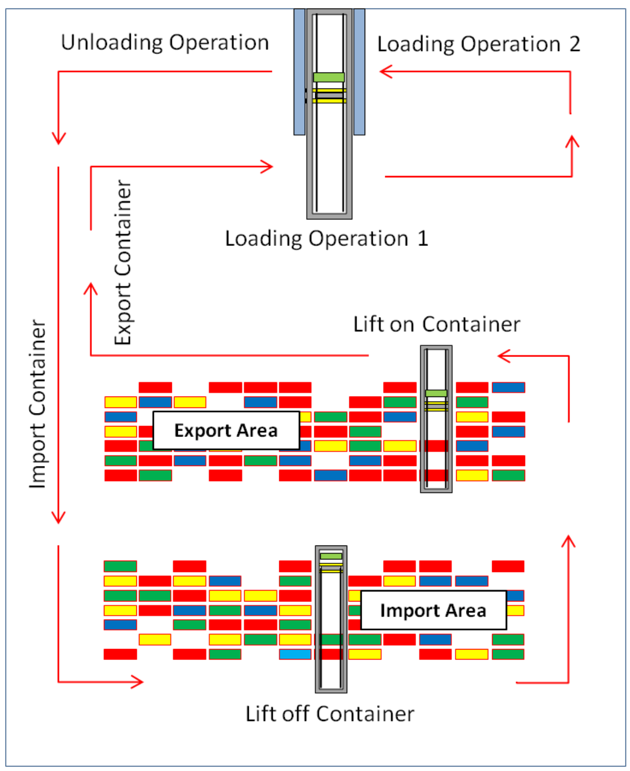


Figure 10 Vertical Trailer Operation Path
Source: Author

Based on figure 9, there are two loading operations that can be applied. The first operation is performing the loading activity in the back area or back-reach of quay crane to determine unloading and loading operation. This is done to facilitate the operator in identifying every movement. The second operation is applying loading activity in the same path of unloading activity. This requires accuracy in determining the trailer's movement in the queue.

However, there is another way to make trailer's movement faster. When export and import area are allocated on a line, the unloading and loading operations by trailers can be done directly. In other terms, this type can reduce the trailer's operation path. The detail description can be shown in figure 11, as follows:

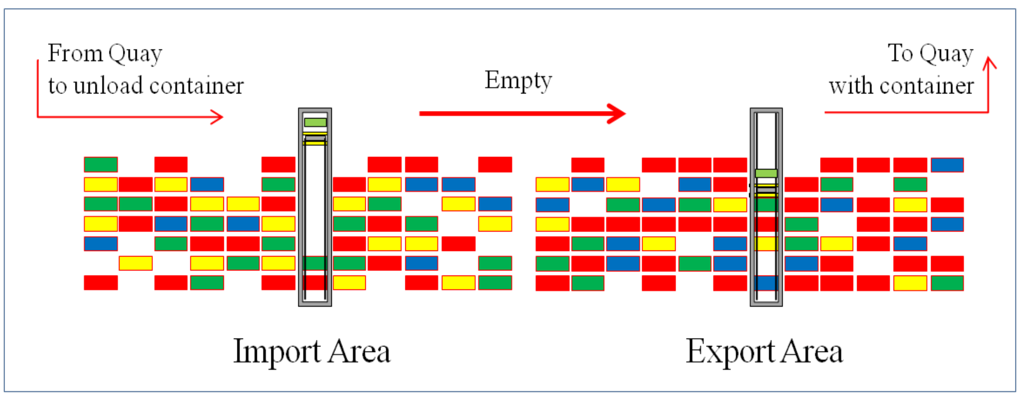


Figure 11 Horizontal Trailer Operation Path
Source: Author

To allocate the appropriate operation path to accommodate double cycle model, terminal management have to consider which path is suitable depend on the availability of its equipment and the existing container yard. Because, double cycle model is required an adequate amount of equipment placed in each area indirectly.

3.2.2.3. Yard Operation

By using the RTG system, yard operations in the double-cycle model in principle is not much different from the single-cycle model. The thing that has to be concerned is the use of RTG's as the container yard equipment at the same time. Thus, when a container terminal is equipped with limited RTG, then the double cycle model will take a lot of difficulties to be applied.

Limitations on equipment owned by a container terminal, it is required container stacking arrangement to be able to carry out the double cycle model. Stacking imports and exports container should be placed on specific areas based on the allocation of each vessel. Against the different types of containers are handled, for instance reefer containers and empty containers, the author suggests to allocate in a vertical stacking of containers.

Chapter 4 DATA COLLECTION AND ANALYSIS

4.1. Data Requirements

To analyze the right form of the operation model, it takes some data to be analyzed. This operating model focuses on the berth operation in a particular condition that requires more data on the quay crane operation. The other data that will be the next consideration is the haulage data or movement of containers from or to berth by trailer and also container data movement lift-on lift-off which is performed by RTG.

Form of data in general is provided as a cycle-time. It is measuring in time of a container movement from or to berth. This data will be described further by the authors into the three forms of the cycle-time, such as quay crane's cycle-time, trailer's cycle-time and RTG's cycle-time. The results of data collection will be analyzed generally in the diagram to make it easier for the average movement of containers in each treatment.

4.1.1. Container Arrival's Rate

Container arrival rate is calculated from the time trailers arrives at berth to receive import containers or delivery export containers in one quay crane's location. The arrival rate can specified as a quick or not depend on the number of trailers used.

Based on the research, data collected (h) is presented at 1,328 of container's move. Therefore, the frequency can be calculated, as follows:

a. Determining the bins (k),

$k = 1 + Log_2 1{,}328$ = 11,375

b. With the maximum number of data observed is 3.98 and minimum number of data is 1.07, then determining the bins width (h),

$$h = \frac{3.98 - 1.07}{11,375} = 0.26$$

After the bins and its width are known, then the result can be presented in Table 5 as follows:

Table 5 Distribution of Container's Arrival Time

Bin	Cycle-time (minute)			Frequency
1	0.00	-	0.62	0
2	0.62	-	1.24	19
3	1.24	-	1.86	136
4	1.86	-	2.48	155
5	2.48	-	3.10	199
6	3.10	-	3.72	268
7	3.72	-	4.34	228
8	4.34	-	4.96	172
9	4.96	-	5.58	97
10	5.58	-	6.20	39
11	6.20	-	7.10	15
Average	3.15	minutes		1328

Source: Author

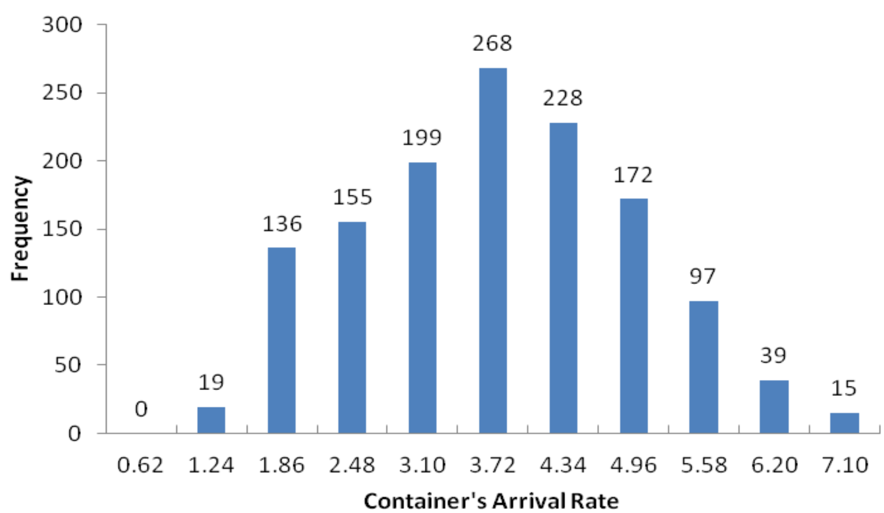


Figure 12 Histogram of Container's Arrival Rate
Source: Author

4.1.2. Quay Container Crane's Cycle Time

Quay crane's cycle-time is counted from the first time of spreader moves from berth-side to ship and rolls back to berth-side whether to unload or load container. It can take a short or a long time to handle depends on the specification of quay crane itself or the skill of operator instead of other condition, such as the readiness of container to be handled and supporting equipment at port. This cycle-time consist of the time quay crane moves and wait for trailer.

During the research, data collected (h) is only provided at 1,328 of quay crane cycle-time. It covers a half of all quay crane operation under deck in one particular ship at that time. Therefore, the frequency can be calculated, as follows:

According to the bins and its width, the result can be presented in Table 6 as follows:

Table 6 Distribution of Quay Crane's Cycle-time

Bin	Cycle-time (minute)			Frequency
1	1.07	-	1.33	38
2	1.33	-	1.59	259
3	1.59	-	1.85	310
4	1.85	-	2.11	96
5	2.11	-	2.37	48
6	2.37	-	2.63	141
7	2.63	-	2.89	189
8	2.89	-	3.15	32
9	3.15	-	3.41	39
10	3.41	-	3.67	79
11	3.67	-	3.98	97
Average	2.13	minutes		1328

Source: Author

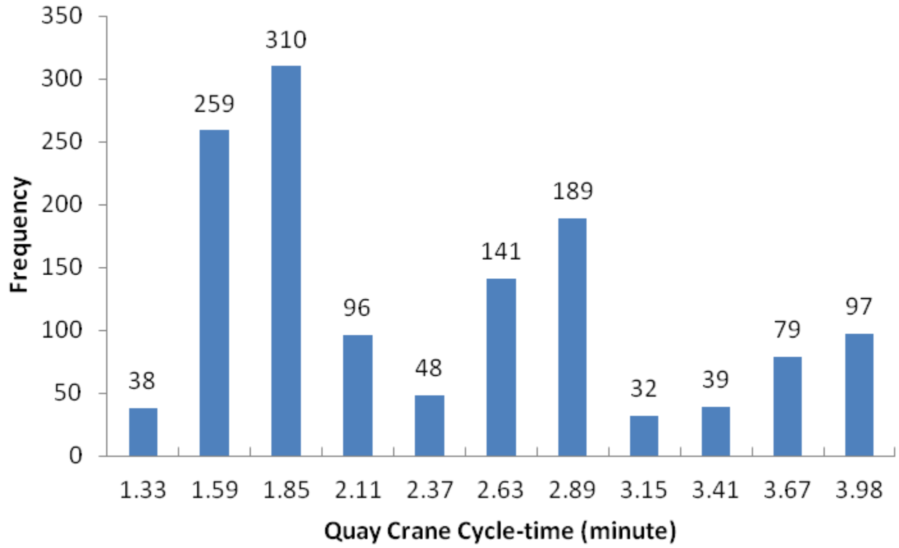


Figure 13 Histogram of Quay Crane's Cycle-time
Source: Author

4.1.3. Trailer's Cycle Time

Trailer's cycle-time is measured from the time trailer transfer a container from berth to yard or vice versa. This cycle-time consist of the time trailer moves and wait for container. In double model, there will be unloading and loading operation where trailer's movement are continuously operated from berth to import area and goes to export area and finally back to berth.

During its operation, trailer sometimes have to wait at long to receive import or export container. It can be caused by large amount of trailers used that it does not equivalent with the quay crane's or RTG's operation.

Therefore, number of trailer used effect on the time of trailer to complete its cycle. In other chapter, it will explain further about the proper number of trailer used based on the queuing theory provided in previous. To determine the frequency using the same number of data observed, the formula used is as same as quay crane cycle-time frequency which is presented:

Table 7 Distribution of Trailer's Cycle-time

Bin	Cycle-time (minute)			Frequency
1	10.03	-	11.43	114
2	11.43	-	12.83	89
3	12.83	-	14.23	88
4	14.23	-	15.63	121
5	15.63	-	17.03	156
6	17.03	-	18.43	136
7	18.43	-	19.83	191
8	19.83	-	21.23	113
9	21.23	-	22.63	103
10	22.63	-	24.03	70
11	24.03	-	25.97	147
Average	17.19	minutes		1328

Source: Author

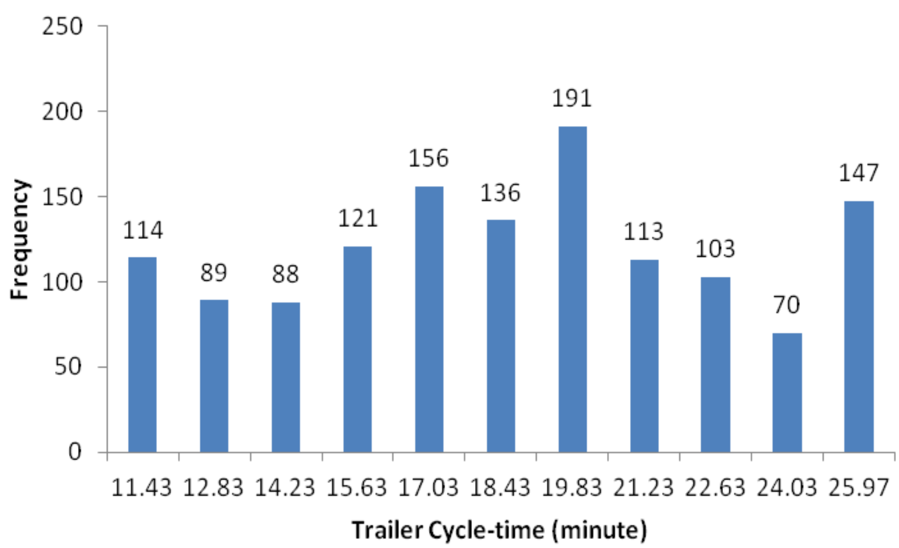


Figure 14 Histogram of Trailer's Cycle-time
Source: Author

4.1.4. Rubber Tyred Gantry's Cycle Time

As same as quay crane, RTG's cycle-time is calculated from the time RTG lift container to be stacked in a specific yard area and then back to previous position or the opposite moves to lift container from yard area to be stacked into trailer. This cycle-time consist of the time RTG moves and wait for trailer as same as quay crane's cycle-time.

Table 8 Distribution of RTG's Cycle-time

Bin	Cycle-time (minute)			Frequency
1	1.10	-	1.44	75
2	1.44	-	1.78	91
3	1.78	-	2.12	65
4	2.12	-	2.46	168
5	2.46	-	2.80	175
6	2.80	-	3.14	135
7	3.14	-	3.48	184
8	3.48	-	3.82	176
9	3.82	-	4.16	96
10	4.16	-	4.50	62
11	4.50	-	4.98	101
Average	2.83	minutes		1328

Source: Author

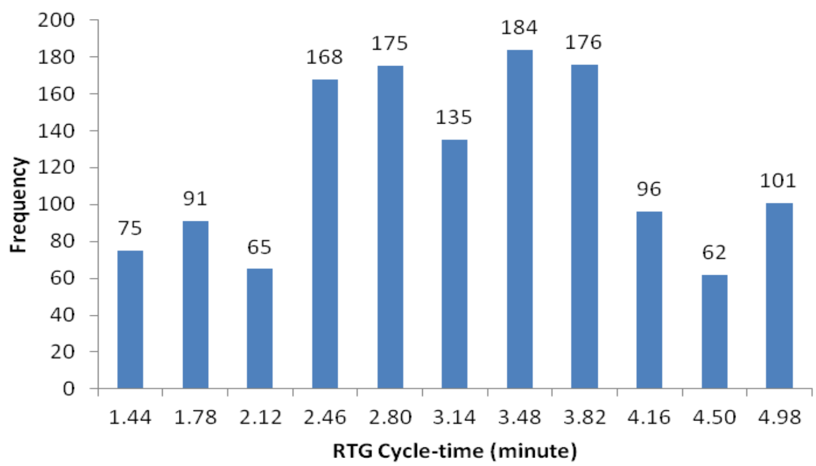


Figure 15 Histogram of RTG's Cycle-time
Source: Author

4.2. Operational Method Analysis

After all cycle-time data are being collected then in order to determine the optimum operation, a simulation based on starting point formula will be used. In field research at KOJA, the author will attempt to simulate double cycle within one ship as a whole operation. The simulation will be generated into each bay for unloading and loading operation.

The data that is presented in the simulation will be further analyzed using the formula that has been described in chapter 2 and 3. The analysis consists of the following subject:

a. The distribution test of arrival and service time pattern.
b. Analysis of queuing model for loading/unloading operation, receiving and delivery.
c. Analysis number of equipment used.

4.2.1. Simulation of Double Container-handling Operation Model

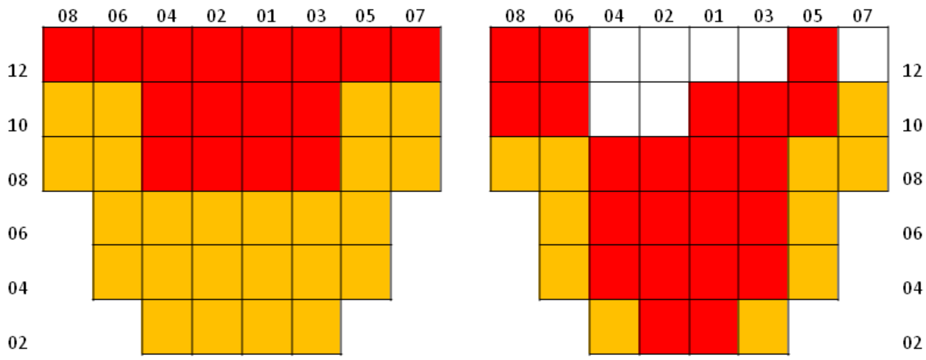
Using formula as mention in chapter 3, total number of cycle required can be analyzed. During the research, the author only can provide the simulation under deck operation while on deck operation cannot be applied for double cycle model. Therefore, the number of cycle on deck is counted as same as the number of containers itself.

The research takes 25 bays with 1305 boxes of import containers and 1249 boxes of export containers. Because the double cycle model can only be run under deck level, then the simulation will only discuss the implementation of double cycle model at these locations. Some rules that have to be considered in this simulation are stated as follows (Song, 2007):

1. In the case that the result of all D_i-L_{i-1} , except for D_1 , is a negative value, then:
    a. The negative value should be added to the next ones ((D_3-L_2) + (D_4-L_3) +...), not to the previous value (D_1), until the value becomes a positive,
    b. If it still have a negative value until the last sequence, then the double cycle is abandoned or can start at a reverse sequence,
    c. But, at the moment that a negative value becomes a positive after it is being added to the next value, then it have to be added directly to the first value (D_1) in order to stop the sequence.
2. In other words, a positive value means the total of import containers is more than export containers. Therefore, double cycle model should be applied after some import containers are unloaded.
3. When the result presents a minus value, it means the total of import containers is less than export containers. Therefore, double cycle can be applied in advance before the import containers are unloaded.

For this simulation, the author will present the whole container-handling operation in one container ship berthed at KOJA. In this case, it took MV Patricia Schulte as one example that berthed on May 5th 2012. By analyzing its bay plan, it can be determined the number of cycle required.

The sequence is assumed to be started in random sequence because of ship balance's consideration. Some container ship cannot provide to adjust its balance as faster as it required, therefore the terminal operator have to decide which sequence is better to use. There is one sample of double cycle model calculation according to the research data provided. The bay layout and the calculation can be presented in the figure 16 and Table 9, as follows:



(a) Unloading Plan (b) Loading Plan

Figure 16 Container Layout at Bay no.11(10)
Source: Unpublished MV.Patricia Schulte Bayplan

In figure 16, it shows the import containers that have to be unloaded are 40 boxes and export containers are 33 boxes. In this case, it presents a positive value which means after certain numbers of import containers are unloaded or starting point, then double cycle can be started. According to the formula, the starting point can be calculated and presented as follows:

Table 9 Double Cycle Starting Point at Bay 11(10)

	08	06	04	02	01	03	05	07
Unload Sum (D)	3	5	6	6	6	6	5	3
Load Sum (L)	3	5	4	4	5	5	5	2
L-D	0	0	-2	-2	-1	-1	0	-1
Priority	6	6	1	1	3	3	6	3
Row Number	08	05	06	07	04	03	02	01
Unload Sum (D)	3	5	5	3	6	6	6	6
Load Sum (L)	3	5	5	2	4	5	4	5
D-L	2	0	-2	4	2	1	2	
Starting Point (W) after	12							
Frequency	29							

Source: Author

In table 9, it shows that the starting point start after the 12th of unloading activities, which is started at row 06. Total double cycle frequency is 29 times, therefore total of cycle resulted from this model is 45 cycles. In single cycle, it requires 73 cycles to complete whole operation at bay 11(10).

From the calculation, it can figure out that using double cycle model takes 15.58% differ from single cycle. In total cycle required with comparison of each model at one ship can be presented, as follows:

Table 10 Comparison of Container-handling Operation Cycle

No	Bay Location	Containers On Deck			Containers Under Deck			
		Single	Double	Deviation	Single	Double	Deviation	%
1	Bay no. 01	25	25	-	9	9	-	
2	Bay no. 03 (02)	35	35	-	28	19	9	32.14%
3	Bay no. 05	20	20	-	18	13	5	27.78%
4	Bay no. 07 (06)	39	39	-	49	32	17	34.69%
5	Bay no. 09	6	6	-	24	21	3	12.50%
6	Bay no. 11 (10)	56	56	-	73	45	28	38.36%
7	Bay no. 13	1	1	-	47	47	-	
8	Bay no. 15 (14)	96	96	-	96	60	36	37.50%
9	Bay no. 17	-	-	-	68	38	30	44.12%
10	Bay no. 19 (18)	94	94	-	104	64	40	38.46%
11	Bay no. 21	-	-	-	33	33	-	
12	Bay no. 23 (22)	82	82	-	100	63	37	37.00%
13	Bay no. 25	3	3	-	36	36	-	
14	Bay no. 27 (26)	81	81	-	113	64	49	43.36%
15	Bay no. 29	24	24	-	74	74	-	
16	Bay no. 31 (30)	97	97	-	93	56	37	39.78%
17	Bay no. 33	2	2	-	49	49	-	
18	Bay no. 35 (34)	100	100	-	103	66	37	35.92%
19	Bay no. 37	-	-	-	23	19	4	17.39%
20	Bay no. 39 (38)	110	110	-	108	60	48	44.44%
21	Bay no. 41	1	1	-	20	16	4	20.00%
22	Bay no. 43 (42)	102	102	-	60	46	14	23.33%
23	Bay no. 45	5	5	-	-	-	-	
24	Bay no. 47 (46)	124	124	-	-	-	-	
25	Bay no. 50	123	123	-	-	-	-	
					1,328	930	398	29.97%

Source: Author Calculation

According to the result at Table 10, double cycle model can reduce the number of cycle existed in single cycle model for about 29.97% in total average. The impact for this reduction is decreasing the ship's berthing time which can reduce its berthing cost at port directly.

KOJA as a subsidiary from Indonesian Port Corporation II is following tariff regulation of ship services. It had regulated that berthing time tariff is cost USD$ 0.111 per GRT per etmal. The calculation of tariff reduction can be described in the illustration as follows:

a. Cycle required in each model		
- Single cycle model	cycle	2,554
- Double cycle model	cycle	2,156
- Deviation	cycle	398
- Percentage		15.58 %
b. Average of quay crane's cycle time	minute	2.13
c. Number of QCC used in assumption	unit	3
d. Total time resulted in each model		
- Operation waiting time (before and after)	hour	2
- Loading preparation time (in single cycle model)	hour	1
- Total time using single cycle model	hour	33.22
- Total time using double cycle model	hour	27.51
e. Berthing time tariff (per GRT per etmal)	USD	0.111
f. GRT of MV. Patricia Schulte	Ton	28.592
g. Simulation berthing time tariff		
- Using single cycle model	1.5 etmal	USD 4.760,57
- Using double cycle model	1.25 etmal	USD 3.967,14
- Deviation		USD 793.43
- Percentage		16.67 %

In order term, by implemented double cycle model, the quay crane performance can increase 18.46%. With average quay crane's cycle-time and assumption of QCC used is 3 units, then the QCC performance can be calculate as follows:

a.	Total Boxes Handled	boxes	2,554
b.	Number of QCC used in assumption	unit	3
c.	Total time using single cycle model	hour	30.22
d.	Total time using double cycle model	hour	25.51
e.	QCC performance:		
	- Single cycle model	b/c/h	28
	- Double cycle model	b/c/h	33
f.	Deviation percentage		18.46%

4.2.2. Distribution Test

In this session, the author would like to find how is the availability of container-handling equipment at KOJA recently by using queue theory that had explained in chapter 2. In order to determine which queuing theory that is applicable, distribution test of data collected has to be calculated at first. Distribution test will analyze arrival and service pattern with assumption of poisson or exponential distribution.

As it already stated in chapter 2, arrival and service patterns are assumed to use an exponential distribution. By using Kolmogorov Smirnov Goodness of fit test (K-S test) to test the frequency distribution, the following steps can be presented:

a. Building a hypothesis that the population distribution of service time is following the exponential distribution:

H_0 : the population distribution of cycle-time $F_{(x)}$ is equal to $F_{0(x)}$

H_1 : the population distribution $F_{(x)}$ is not equal to $F_{0(x)}$, $F_{(x)} \neq F_{0(x)}$

b. Calculating the critical value (D_α) with level of significance (α) is assumed 95% and number of sample is 1,328 data.

$$D_{0.95} = \frac{1.358}{\sqrt{1,328}} = 0.0373$$

c. Determining the cumulative distribution for each cycle-time, as follows:

Table 11 Cumulative Distribution of Container's Arrival Rate

Interval Range	X_i	X_i / n	$F_{n(x)}$
0.00 - 0.62	0	0 / 1,328	0.0000
0.62 - 1.24	19	(0+19) / 1,328	0.0143
.... -	....	....	....
6.20 - 7.10	15	(0+19+...+15) / 1,328	1.0000

Source: Author's Calculation

d. Determining the probability density function (pdf) for each cycle-time, as follows:

Table 12 Probability Density Function of Quay Crane's Cycle-time

Interval Range	e	m	t	T	$f_{(t<x\leq T)} = \lvert e^{-t/m} - e^{-T/m} \rvert$	
0.00 - 0.62	2.7182818	3.15	0.00	0.62	$2.72^{-0} - 2.72^{-0.19}$	0.1788
0.62 - 1.24			0.62	1.24	$2.72^{-0.19} - 2.72^{-0.39}$	0.1468
.... -			...	...	...	...
6.20 - 7.10			6.20	7.10	$2.72^{-1.97} - 2.72^{-2.26}$	0.0347

Source: Author's Calculation

e. Calculate the cumulative probability density function (pdf),

f. Determine the absolute difference and complete the calculating for all bins, as shown in table 13:

Table 13 Distribution Function of Container's Arrival Rate

Cycle-time (minute)	Frequency	Probability	Cum. Prob Fn(x)	Probability	Cum. Prob Fo(x)	Different
0.00 - 0.62	0	0.0000	0.0000	0.1788	0.1788	-0.1788
0.62 - 1.24	19	0.0143	0.0143	0.1468	0.3257	-0.3113
1.24 - 1.86	136	0.1024	0.1167	0.1206	0.4462	-0.3295
1.86 - 2.48	155	0.1167	0.2334	0.0990	0.5453	-0.3118
2.48 - 3.10	199	0.1498	0.3833	0.0813	0.6266	-0.2433
3.10 - 3.72	268	0.2018	0.5851	0.0668	0.6933	-0.1083
3.72 - 4.34	228	0.1717	0.7568	0.0548	0.7482	0.0086
4.34 - 4.96	172	0.1295	0.8863	0.0450	0.7932	0.0931
4.96 - 5.58	97	0.0730	0.9593	0.0370	0.8302	0.1292
5.58 - 6.20	39	0.0294	0.9887	0.0304	0.8605	0.1282
6.20 - 7.10	15	0.0113	1.0000	0.0347	0.8952	0.1048
	1328	1.0000				

Source: Author's Calculation

g. Determine the maximum value of absolute difference, which is 0.3295.

h. Based on the result, 0.3295 as the maximum difference is higher than the critical value 0.0373. Therefore, the assumption of population distribution is not following exponential distribution. Conclusion, the population distribution is shown to be followed as a poisson distribution.

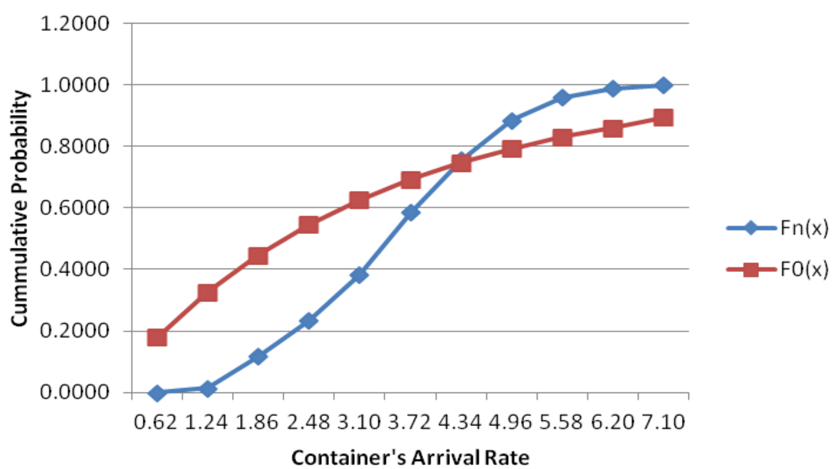


Figure 17 Distribution Function of Container's Arrival Rate
Source: Author

According to the calculating result in table, distribution test of trailer's cycle-time and RTG's cycle-time can be determined. The result can be figured in Table 14, as follows:

Table 14 Distribution Function of Arrival Rate and Service time

Description	Sample	Average	Different	D(α)	Distribution
Container's Arrival Rate	1328	3.15	0.3295	0.0373	Poisson
Quay Crane's Cycle-time	1328	2.13	0.5492	0.0373	Poisson
Trailer's Cycle-time	1328	17.19	0.6628	0.0373	Poisson
RTG's Cycle-time	1328	2.83	0.4942	0.0373	Poisson

Source: Author

4.2.3. Queuing Model

According to the result of distribution test, the queuing model can be determined by using M/M/1(∞) Queuing system. Based on the literature, M/M/1(∞), this queuing model can run on the following assumption, as follows:

a. Single server is used, for instance: the queuing theory at one quay crane
b. Containers arrival pattern is random, following poisson distribution
c. Service time, such as: trailer's cycle-time or RTG's cycle-time, is random
d. Queue length is infinite
e. Queue discipline is following free-in free-out
f. There is an infinite population

By using M/M/1(∞), the average number of trailers to support the quay crane operation can be calculated with the following assumption:

- Average container's arrival rate is 3.15 minutes, then average containers will arrive at a single server is 19 units.

- Average quay crane's cycle-time is 2.13 minutes, then average the quay crane serves in one hour is 28 units.

According to that assumption, the queuing system can be determined as follows:

a. Utilization of quay crane

$$\rho = \frac{\lambda}{\mu} = \frac{19}{28} = 67.86\%$$

b. Probability of the machine when it is idle

$$P_0 = 1 - \rho = 1 - 67.86\% = 32.14\%$$

c. Average number of trailers in the quay crane area

$$L = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu - \lambda} = \frac{19}{28-19} = 2 \text{ unit}$$

d. Average number of trailers waiting in the queue line

$$L_q = \frac{\rho^2}{1-\rho} = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{361}{252} = 1 \text{ unit}$$

e. Average time trailer spent in the quay crane operation

$$W = \frac{1}{\mu - \lambda} = \frac{1}{9} = 0.68 \text{ hour} = 6.67 \text{ minute}$$

f. Average waiting time in the queue line

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{19}{252} = 0.075 \text{ hour} = 4.52 \text{ minute}$$

According to the result, it is shown a high utilization of QCC. It means QCC operates two-thirds from its time and performs 28 boxes per hour. The shortage of container's arrival will impact on the higher of QCC's performance. But, when container's arrival reach more than QCC's cycle-time, then number of trailers waiting for operation or in the queue line will also increased. In consequence, the proper number of equipment used to support the QCC's operation has to be determined.

With 28 boxes can be served by QCC per hour and 17.19 minutes of average trailer's cycle-time, the existing trailer's used can be determined. By 17.19 minutes, one trailer can take approximately three times of delivery operation from berth to yard or vice versa. Based on trailer's rotation, it requires at least 10 trailers to be used to handle QCC's operation where number of boxes per hour is divided by number of cycle for a trailer in one hour.

Using double cycle container-handling operation which perform 33 boxes per hour and with the same average trailer's cycle-time, the number of trailers have to be used are 11 units. Even it requires more units than previous model, total time which is provided by double cycle model 18.46% faster. The container terminal layout also has to become an important consideration as well, while longer time of delivery operation will impact on high trailer's cycle-time.

Chapter 5 CASE STUDY AT KOJA CONTAINER TERMINAL

5.1. Company overview

KOJA Container Terminal is located in Tanjung Priok Jakarta. It is one of jointly operation between Indonesia Port Corporation (IPC) and Hong Kong-based leading port operator Hutchison Port Holdings to handle the daily operation of the terminal. Among other container terminal in Jakarta, KOJA also serves as national hub port and have a function as a gateway to industrial hinterland of West Java commonly.

KOJA is committed to provide quality services to achieve customer satisfaction. In order to aim that commitment, KOJA strive the best container handling services in 24 hours a day, all year round.

5.1.1. Terminal Facilities

Nowadays, KOJA Container Terminal has approximately 21.8 hectares of container yard area in total and 650 meters of berth length with 9-14 mLWS depth (http://www.tpkkoja.co.id) as shown in figure 18.

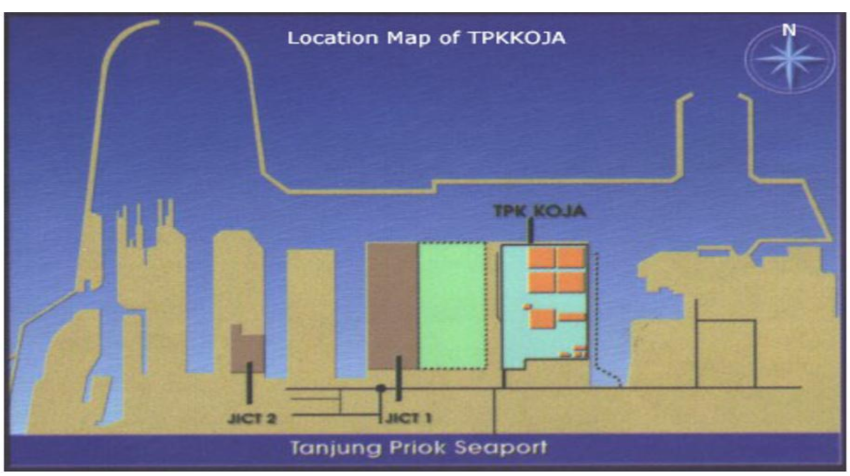


Figure 18 KOJA Container Terminal Layout
Source: (http://www.tpkkoja.co.id)

KOJA is designed to handle a throughput of 620 thousand TEUs (Twenty foot Equivalent Units) of containers per year. Therefore, it equipped its terminal handling facilities with brand new equipments as presented in table 15.

Table 15 Terminal Facilities and Equipment

	Description	Unit
I.	Infrastructure	
	Berth Length	650 m
	Berth Width	40 m
	Depth	-14 m LWS
II.	Container Yard (CY)	
	Area	21.80 ha
	CY Import Capacity	7.560 TEUs
	CY Export Capacity	6.696 TEUs
	CY Reefer Capacity	100 Plugs
III.	Equipments	
	Post-Panamax type Quayside Cranes (QCC)	3 units
	Panamax type Quayside Cranes (QCC)	3 units
	Rubber-Tyred Gantry Cranes (RTG)	21 units
	Head Trucks	40 units
	Chassis	49 units
	SuperStacker	1 unit

Source : (http://www.tpkkoja.co.id)

5.1.2. Traffic Flows

During this year, KOJA is trying to achieve 800.000 TEU's container-handled in total (http://www.tpkkoja.co.id). With limited area, the management has to establish the proper operational system to avoid congestion and stagnation which can be happened.

In the past 9 years, container traffic growth in KOJA has increased for about 5.07% per year as presented in Figure 19. But, as we all know that the world economic decreased in 2009, this also has carried a big impact on container traffic at KOJA. During that period, loading and unloading operation decreased to -13.34% from the previous year. In 2010, the traffic increased sharply to 20.97%.

No	DESCRIPTION	2003	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10	2010/11	Average
1	Import Container										
	- Boxes		6.87%	3.38%	1.04%	22.08%	1.67%	-12.62%	18.91%	9.12%	**6.31%**
	- TEU's		5.87%	2.47%	1.51%	20.55%	3.63%	-11.43%	20.04%	9.08%	**6.46%**
2	Export Container										
	- Boxes		-10.75%	2.70%	1.53%	27.67%	-5.94%	-14.19%	23.39%	7.01%	**3.93%**
	- TEU's		-9.75%	4.86%	-0.86%	26.24%	-5.37%	-12.66%	23.38%	7.68%	**4.19%**
	TOTAL										
	- Boxes		-2.23%	3.06%	1.27%	24.72%	-2.00%	-13.34%	20.97%	8.13%	**5.07%**
	- TEU's		-2.16%	3.60%	0.37%	23.25%	-0.74%	-12.00%	21.58%	8.43%	**5.29%**

Figure 19 KOJA Container Terminal Annual Throughput
Source: Unpublished KOJA Annual Report 2012

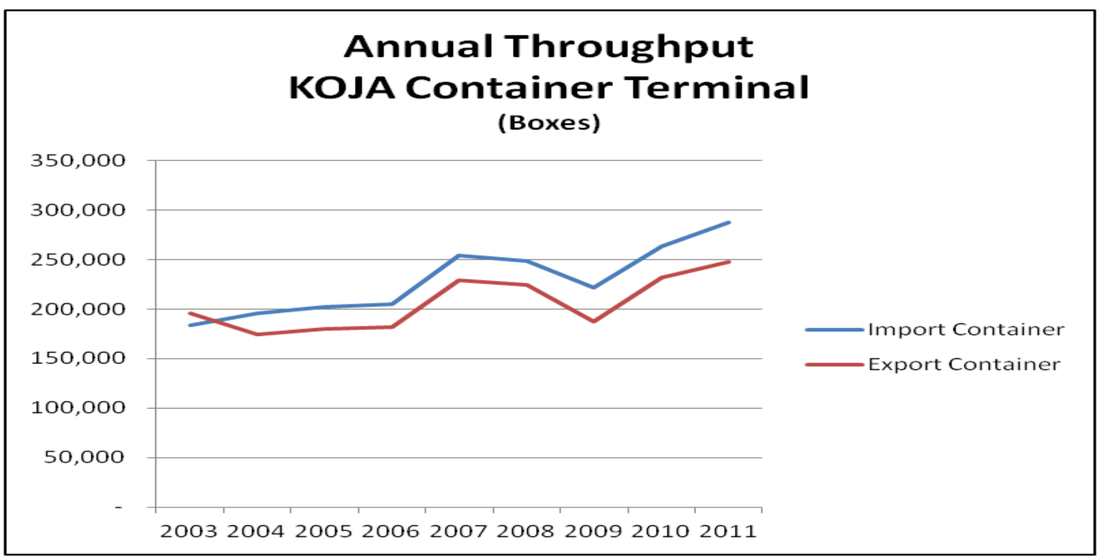


Figure 20 The Graph of KOJA Throughput
Source: Unpublished KOJA Annual Report 2012

This improvement unfortunately did not follow by ideal proportion of loading and unloading operation. In KOJA, import containers are still handled more than export ones as shown in Figure 20. Therefore, it influence to the layout of container terminal where import area is larger than export area.

5.2. Current Situation and Challenges

During the research, the author determines some obstacles and challenges that occur in the loading and unloading operations. In general, the current situation and challenges can be described as follows:

5.2.1. Container Handling Operation

For all these years, loading and unloading operation at KOJA has been done on the system still followed to a single container-handling operation model. One of the problem arises in the implementation of double container-handling system is determining a loading plan issued by the shipping lines. In daily operation, KOJA set a restricted time for containers to enter the terminal due to prevent traffic jam and in order to decide container-handling arrangement faster.

In the implementation of daily operations, ship lines will cooperate with the planner to decide final plan whether unloading or loading operations. Before the import container will be unloaded, the terminal will applied the men and equipments properly. Deciding numbers of equipment used including men allocating, such as the operators, drivers, etc, has to be considered with the shipping lines.

When container terminal has been providing services faster, but not followed by the preparation of the containers to be served especially export containers, all operations will be disrupted directly. The detail operations in container terminal can be described as follows:

a. Preparing the quay crane based on its availability or its number before the container ship is berthed at a berth.
b. When container ship has arrived, then the stevedoring operation starts. It can be implemented by using quay crane or other container-handling equipment. Import container will be unloaded at first and be put onto trailer that had wait in the queue line under the quay.
c. After a trailer receives the import container, then it will goes to export yard area and the container will be lifted off and stacked in the yard. All this operation is known as transport operation or haulage.
d. In yard area, import containers will be stacked by using RTG. It can be put in reefer area while it requires reefer plugs or put in empty area if it is empty.
e. All the stage is known by unloading operation.
f. While the ship arrives with export containers, the loading operation will start after all import containers are unloaded. It can take approximately one hour to consolidate all the process within the terminal operator and the shipping lines.
g. After all the preparation is complete, then the loading operation can be started with the opposite sequence with unloading operation.
h. In yard area, there is another operation known as receiving/delivery operation. It only deals with the operation after containers are stacked from the ship or when containers are arrived to be stacked from outside of terminal.

From detail operations, the implementation of the loading is performed on average one hour after the unloading operation is completed. This causes a problem for the terminal and the ship where all the loading and unloading equipment stopped to operate. The impacts arising from this problem is increasing the idle time on the ship at berth which means additional cost and low performance for the terminal.

To support the operation, KOJA had implemented N-Gen System. It can directly give an work order to the operator and driver. As a joint operation company where KOJA is under Hutchinson Company, N-gen system is required to be implemented.

This system is running depending on the particular network with featuring the work order of equipment as one of the advantages. But in practice, there often come problems caused by the blank spot so that the equipments have to wait for orders in a long time. According to these problems, the author will not review it further because all the elements in the model to be applied are in a normal situation.

5.2.2. Challenges

Some problems that are considered to be challenges faced by KOJA in general are limited facilities and infrastructure include: land area and loading and unloading equipment.

With limited area existed in which to present handling operations, it had exceeded the maximum TEUs that it should be. Then, the speed of container-handling operation has to be speed up. Another way to cope with land problem is reducing the dwelling time. Through double container-handling operations, unloading and loading operations is expected to be handled faster from the quay side to the yard area or vice versa.

Observing the low availability of equipment, it can be said that the primarily equipment used for all the operation especially QCC and RTG is already in old condition and sometimes frequent damage. The impact of the age factor is the speed of the equipment to lift containers and it need the operator's skill to control the equipment during operation carefully.

For transportation equipment such as trailers, the number of total head and chassis truck that is able to operate about 34 units per shift. When the ship is handled at amount of 2 units, then the comparison of the use of trailers will be served by quay crane is not worth so much. It arise the quay crane's to hang its wire in order to wait for trailer or waiting for container to be loaded.

5.3. Possible Alternative of Container-handling Operation Model

To some of problems that arise in yard operations, the authors feel to try to apply the appropriate operational models in order to reduce the impact of the problems mentioned above.

When using single container-handling operations is still being operated, then these problems will be over and over happened again without any solution. Ship unloading operations will be served at first and then wait for the determination of loading plan with an average waiting time for 1 hour. After setting is completed, loading operations can be performed using limited equipment.

Through some calculations above, the application of double container-handling operation through a simple simulation model brings an impact on the unloading and loading operation time in relatively short. However, some things need to be concerned to the implementation of this model so it can be more accurate, such as:

a. Determination of loading plan by the ship
b. The role of planning and control division
c. Availability of all equipment
d. Alertness of the operator in any situation

By knowing the difference of single and double model, it will be known easily whether the system can work effectively or not.

Based on the analysis, it is figured that using double model can reduce operation time with appropriate equipment used. In this model, the availability of all equipment is necessary. Therefore, to implement this into reality with limited existing equipment especially RTG will be hard to apply. When there comes more than one ship at berth, this double model of course will require more RTG to be applied because all import and export area will be operated.

In order to handle this condition, one possible activity is trying to allocate every import and export containers in one specific location based on its ship handled. So, when double cycle wants to be performed then there will be less equipment movements from one area to another area. This can be done by planner staff cooperate with shipping lines simultaneously.

In order to support double cycle model, simple solution against limited equipment existed is increasing the availability of equipment by investing new ones or repairing including total refurbish.

5.4. Advantages and Disadvantages

Before the system is applied, some aspects can be considered as advantages and disadvantages of each system. To find each of these aspects, the author will describe as follows:

5.4.1. Advantages

As common operation, Single container-handling operation model is familiar with the operator and driver to operate the equipment. The time for ship at berth can be calculate easily by multiplying the number of containers handled with average cycle-time of quay crane and plus waiting time.

The need of equipment used is also can be determined and meet what the shipping lines required. This model can present less number of equipment especially the RTG for yard operation. Therefore, this model can be applied to the terminal which has low availability of its equipment. For instance, the terminal can decide to use at least two quay cranes for unloading operation at berth combining with several trailers and supporting by RTGs in which only operate at import area.

The simple method about the operation is to spend the entire import containers at first then continue with loading the export containers after the loading plan is confirmed by shipping lines. Therefore, it will be a leg time between unloading and loading operation. During the research, the leg time is taken approximately no more than one hour.

When there are more than one ship berthed, trailers can change their order from serving a particular quay crane onto another quay crane. It does not only serve one quay crane to transport containers. Whenever it is available line in the queue then the trailers can take the order. Therefore, the control of terminal operation will be easily in general.

Applying double container-handling operation model, it will cut the number of cycles typically in the quay operation. High performance will be resulted in the form number of boxes handled per hour. When it takes less time to handle the operation, it will reduce the ship cost at berth significantly. According to the analysis, it reduces the cycles in

15.58 % or safe at least 16.67 % ship cost at berth. For the terminal, it cause a good impact to the port performance because high number of boxes per hour.

5.4.2. Disadvantages

For disadvantage of single container-handling operation model, author only can analyze the operation time resulted. Using this model, it takes a longer time to complete whole operation rather than double cycle model. With simple calculation as mentioned previously, the high number of containers to be unloaded and loaded will cause higher time required.

In double container-handling operation model, it is required more attention and skill of the operators and drivers because there will be combination activities among the operations. They have to be informed as soon as possible whenever it is a time to run the double cycle model on the sidelines of unloading operation.

In the quay operator, to change the ordinary job order have always to be guided whether by manually or using the system such as N-gen system. But for transport operation, the use of N-gen system will be more helpful rather than manually control because the driver just follow at the job order on the screen to show where they should be go. For RTG operation, it does not bring any changes except only follow the job order on the screen.

Another aspect that might be considered as the disadvantage of this double cycle model is the need of high equipment's availability. Hence, the number of equipment's used is more considerable manner. For trailer operation, it requires 10% more trailer to be operated and increase to the operational cost indeed. It also had been analyzed that high number of RTG is supposed to be operated.

In general view, advantages and disadvantages of each model can be presented in Figure 21 as follows:

No	Description	Single Container-handling Operational Model	Double Container-handling Operational Model
1.	Advantages	a. Application method is simple b. It can be operated in low availability of equipment	a. It reduce operational time b. Increasing productivity
2.	Disadvantages	a. It takes longer time to complete whole operation b. Ordinary productivity	a. Application method is more complicated b. It requires high availability of equipment

Figure 21 Comparison of Single and Double Cycle Model
Source: Author

Chapter 6 SUMMARY

6.1. Conclusion

In this research paper, the author presents the optimization of container-handling operation. Double cycle model is concluded as the effective operation to optimize the operation and increase the terminal performance. In order to run this model, it required high availability of all operational equipment and the readiness of ship's bay plan.

Through a simple formula, the difference among single cycle model with double ones can be figured out. For an example, the author makes a simulation of double cycle model using a real ship's bay plan published by shipping lines. In this case, it is MV Patricia Schulte which berthed at KOJA. In double cycle model, the combination operation can only be presented under deck location of a ship because there is a hatch problem that detains the combination movements. The container ship which is divided in each bay carries import and export containers and will be analyzed the cycle required.

According to the result, if double cycle model is applied and compared with single ones then it shows that the cycle required by double cycle model is 15.58% less. It means that this model can reduce the time of ship at berth which saving at least 16.67% of berthing cost directly. It also calculates the current situation at KOJA and the prospect situation if double cycle model is applied.

In current situation, quay crane productivity is reaching 28 boxes per hour while in double cycle model can reach 33 boxes per hour or 18.46% increases. But, double cycle model requires high availability of equipment such as quay crane itself, trailers and RTG. In double cycle model, there is no waste movement whether in quay crane area or trailers. Number of trailers also can be provided which required 10 units for single and 11 units for double cycle model.

6.2. Author's Recommendation

As already mentioned previously, double cycle model requires high availability of equipment where this is having a crucial problem for the terminal which have a lack of its equipment availability. In current situation, KOJA have new number of trailers but older quay cranes and RTGs. This reducing the speed of container-handling operation even it have well trained operator. If the investment that was already stated goes according to the plan, then the possibility of double cycle model can run is higher.

In order situation, determination of loading plan by shipping lines always becomes a serious problem. Container terminal management should have to decide the fix closing-time to shipping lines for the common good. If the ship is operated as fast as it should be, then benefit of low operational cost and the increasing of port performance can be reached.

If KOJA Container terminal can have newest equipment with well trained operator and better operational management, then double cycle model should have to be applied in order to give a good service to the customers.

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