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Study on the Optimalization and Development of Tanjung Emas Container Terminal in Semarang Using Powersim Dynamic Model Simulation

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ABSTRACT

Objective of the study is to provide the management with the tool to control the services of its performance. It can predict and reflect the effect of terminal's improvement to the services performance.

Service's performance of the terminal are affected by many factors such as equipment, manpower, system and procedure, number and size of ship, and many others. To represent the relation between those factors to the services, a system dynamic approach is used. The approach will show the effect of any changes of those factors to services performance, to the whole performance and to the performance of the specific factor.

To run The System Dynamic Approach, a computer simulation application program called Powersim and the cost analysis model are used. The variables used for the model are the piloting and tugging time for incoming and outgoing ships, cycles time for each container handling equipment (i.e. Container Crane-CC, Rubber Tired Gantry-RTG, Top Loader-TL, and Side Loader-SL), Head-truck's headway at each equipment, container loading-unloading volume per ship per type (full container/empty container), container receiving and delivery in container yard, operation cost and invesment of each equipment. These input data are formatted in a distribution function. The result of the research will be the optimal configuration of the whole container handling equipment.

To meet the forecasted container demand of year 2000 to 2010, the optimal equipment configuration and the facilities required will be the basic of the container terminal development program.

INTRODUCTION

Indonesian Port Corporation III is one of state-owned companies of the Ministry of Communications which aims to support the economic development and earning the profits to the company, by conducting port services and other related businesses.

The company provides port facilities and services to support the flow of ships, goods, passenger embarkation and debarkation as well as other businesses related to the port services. As one of state-owned companies providing a general port in Indonesia, the company have the task to provide excellent service of port affairs concerning safety, security, reliability, and convinience of the users. As a company, IPC-III gives a contributions generally to the country's economic development and especially to the revenues, either directly or indirectly, and earns profits based on the management principles.

However, in several recent years the company's faces some difficult condition due to the national monetary crisis, so that in order to be able to identify business opportunities, challenges, and tendencies for strategic areas, the branch directors are demanded to have any creativity (*Sumardi, President Director of the IPC-III*). Looking at the container flows where the trend is increases between 4 % up to 55 % per annum during 1987 up to 1997 or in average of 27 % per annum, also the room sizes and the draft of the ships served which tend to increase, it is necessary to anticipate the optimum facilities and equipments required for container handling at Tanjung Emas Container Terminal in Semarang.

The main problem faced by the management is that there hasn't been any analysis instrument of service capacity which is based on the real condition of Tanjung Emas Port, so that there should be any adjustment if the changes of internal and external conditions happen.

The appplication of dynamic model is expected to be able to predict the requirement of port facilities and equipment which change dynamically following the container demands fluctuation.

This study aims to provide management tools which able to:
1. control performances of each service sub systems and all systems which are easilly adjusted to the changes of demand level;
2. predict the effect of performance improvement on service sub systems to all systems, if the management wants to decide a performance improvement object for a service sub systems;
3. support in making a decision for facilities and equipment development.

SCOPE OF WORK

Looking at the wide scope of facility and equipment problems in Tanjung Emas Port, the research scope is limited to the container terminal which specifically handles container loading-unloading with the wharf length of 345 meters (2 berths) being able to serve 2 ships at once with the criteria condition as follows:
1. The numbers of operated Container Crane (CC) depends on the container stowage plan;
2. The ship loading-unloading process can be through two ways, those are, firstly by unloading containers from ships unup to the end, then loading them to the ships, secondly, by container loading-unloading from and to the ships at the same time.
3. The demand forecasted will be limited up to year 2010.
4. The dynamic model is constructed with Powersim 2.0 software.

The scope of research object comprises:
1. The service sub system from the anchorage to the wharf, and at inverse from wharf to the anchorage;
2. The container loading-unloading process sub system in the wharf, consisting of unloading process from ships to the wharf and loading process from wharf to ships;
3. The container transport service sub system from wharf to container yard and vice versa;
4. The container transport service sub system from container yard to the gate and vice versa.

Facilities and equipment included in the dynamic system program are:

1. Pilot Boat that functions as pulling/piloting ships into the berth with the information of number and speed of pulling ships;
2. Wharf as an infrastructure for container loading-unloading activity with the information of wharf length and areas;
3. Container Crane (CC) that functions as lifting or unloading container from ships to the available head-trucks or vice versa with the information of cycle number and time;
4. Rubber Tired Gantry (RTG) that functions as taking containers from container yard to head-trucks or vice versa with the information of cycle time and number;
5. Top Loader (TL) that functions as taking containers from Container Yard to head-trucks or vice versa with the information of cycle time and number;
6. Head-trucks (HT) that functions as transporting containers from apron to container yard or vice versa with the information of cycle time and number;
7. Container Yard (CY) that functions as a place for container piling with the information of an areas and capacity.

DESCRIPTION OF MODEL

Waiting time of vessel at port is influenced by loading and unloading turn over. The time of loading and unloading process is influenced by the capability and capacity of its equipment, or in other word, capability and capacity of equipment influenced the period of loading and unloading process.

The necessity of loading and unloading cycle time of each containers from vessel to the quay and vice versa by container crane is influenced by capability of human resources, technology and specification of container crane used. While the process of container transportation from the quay to the container yard and vice versa by head-truck is influenced by capability of human resources and head truck technology, which used itself. The necessity of cycle time for moving process of container from head truck to the container yard and vice versa by rubber tired gantry is influenced by capacity of human resources and technology instrument used.

The process of loading and unloading of containers from vessel to the container yard and vice versa used three instruments assistance, that is container crane, head truck and rubber tired gantry by working in a synergy, so sooner or later the process of loading and unloading of each container from vessel to the container yard and vice versa depends on harmony of three equipment that mentioned before. This problem is caused the difference of cycle time of that equipment, of course would compose the composition of necessity the amount of each ideal equipment to give optimal synergy.

More faster of loading and unloading process of container will influence sooner or later the vessel take berthing time in the quay (Berthing Time, BT), and then will influence the occupancy rate at the port (Bert Occupancy Rate, BOR) and waiting time of vessel at the port (Turn Round Time, TRT). From the high occupancy level of the quay will influence the amount of availability quay which ready to be anchored by the ship. Based on the limits of the availability of the quay and high turn round time will influence the waiting time of vessel (Waiting Time, WT) and get service at the port and then will influence to the total of ship call. The form of linkage each other between that element will be showed in Figure 1.

Based on activity mechanism like diagram above is arranged a simulation model by computer to calculate how far the capability of equipment available, and which elements can be intervened to optimize the ability of equipment available.

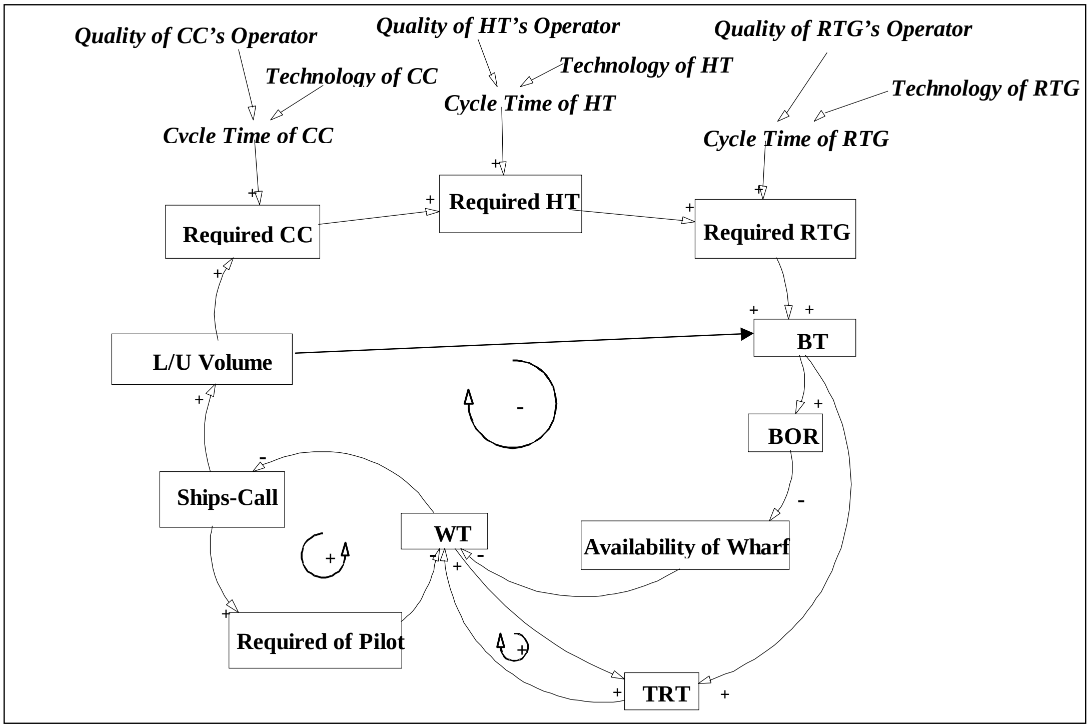

Figure 1. Causal loop diagram of dynamics system of the research object

After the simulation model can be validated to describe the real situation, and then be analyzed intervenes efforts concerning elements that have influence significant toward quality of its activity to anticipate the situation in future. By forecasting that the total ship call will increase, of course the total of container, which will arrive, or departure from Port of Tanjung Emas will increase too. It needs anticipation of the equipment available, whether in total or its composition.

Several assumption are adopted in constructing and implementing the program for Tanjung Emas Container Terminal:

- Three scenario of the demand forecasting up to year 2010 i.e. **pessimistic**, **moderate** and **optimistic**.
- Three scenario of the one week ship-call pattern i.e. **5 days** per week, **6 days** per week and **7 days** per weeks.
- The variables of the equipment's operator and the equipment's technology are not included in the program.

The equipment configuration scenario used are:

- **Scenario I (SI)**, existing condition i.e. 4 CC, 3 RTG for CY Export, 3 TL and 2 SL for CY Import, and 24 HT. Intervention is done in total of Head-truck with using condition are 16, 20, and 28;

- **Scenario II (SII)**, CY export and import become one, with combination of 4 CC, 6 RTG, 2 SL, and 24 Head-truck. Intervention on total of Head-truck with using condition is 16, 20, and 28.
- **Scenario III (SIII)**, to add 2 unit of new RTG, with combination of 4 CC, 8 RTG, 2 SL, and 24 Head-truck. Intervention is done on total of Head-truck with using condition are 16, 20, and 28.

EXAMPLES OF THE OUTPUTS FROM THE MODEL

As an example of the simulation output, we consider the working time of the equipment at peak condition demand where the container terminal serve only 5 days per week due to the ship-call pattern using the moderate projection as shown in Figure 2. The figure reflect that scenario I of the equipment configuration is not able to serve operational activity in 2003 because its working time is more than 21 hours (maximum working time per day). Hence head-truck is needed to add to 24 units (scenario I with configuration 4) in order to decrease working time become 19,05 hours. Without scenario II and directly to develop scenario III with configuration 3 i.e. 8 RTG's and 20 head-trucks , its capability is only stand to 2007.

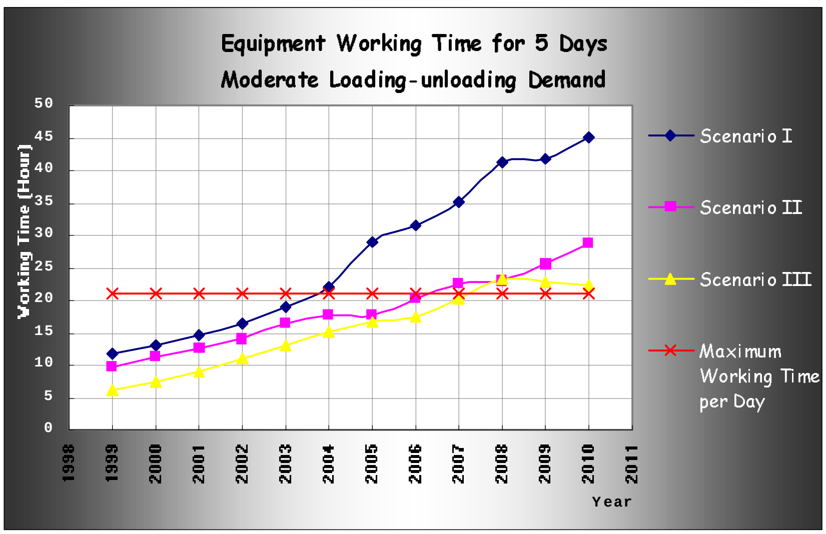

Figure 2. Equipment working time for 5 days moderate loading-unloading demand

ANALYSIS OF SIMULATION OUTPUTS

Execution of dynamic model simulation during 24 hours (1 day) will give an information about production of each handling equipment configuration for one day relating to the ship-call distributions. Table 1. as follows describes equipment production capacity that is obtained from execution of dynamic model for 24 hours.

Simulation execution on each optimum equipment configuration scenario using all combinations of loading-unloading container demand yielded information on capability of port services, namely equipment productivity (box/crane/hour), idle time, equipment working time, mooring time and ship waiting time. The results of simulation execution were used to calculate total cost.

Total cost for each component (facility cost, equipment cost, mooring cost, commodities capital cost and ship cost) was calculated based on the classic formula and using all of component of time resulted from the simulation execution as well as the unit of total cost.

Table 1. Output of simulation execution for 24 hours scenario configuration

Scenario	Configuration (CC-HT-RTG-SL-TL)	Notation	Production capacity of Loading-Unloading (Box/day)	Productivity (BCH)
I	(4-16-3-2-3)	SI-1	938	11.16
I	(4-20-3-2-3)	SI-2	932	11.69
I	(4-24-3-2-3)	SI-3	910	10.84
I	(4-28-3-2-3)	SI-4	1112	13.24
II	(4-16-6-2-0)	SII-1	1299	15.46
II	(4-20-6-2-0)	SII-2	1270	15.12
II	(4-24-6-2-0)	SII-3	1163	13.85
II	(4-28-6-2-0)	SII-4	1294	15.40
III	(4-16-8-2-0)	SIII-1	1184	14.09
III	(4-20-8-2-0)	SIII-2	1214	14.46
III	(4-24-8-2-0)	SIII-3	1541	18.35
III	(4-28-8-2-0)	SIII-4	1379	16.41

Moreover, total cost per box for each equipment configuration scenario was analyzed in order to gain the minimum total cost of the three RTG addition scenarios (Scenario I, Scenario II, and Scenario III). The minimum total cost was gained by choosing the smallest total cost per box from the four equipment configuration scenarios based on head-truck addition.

As an example of total cost analysis, Figure 3. presents the calculation of total cost per box based on peak condition of ship-call pattern that can be described as follows:

1. Optimistic estimation

   Equipment scenario I, II and III at the highest demand level generally will undergo the increasing total cost per box along with additional demand from year 2000 to year 2010. However, the operation of scenario II and III can press the improvement of significant total cost compare to scenario I.

2. Moderate estimation

   At the moderate demand level, only scenario III can reduce total cost per box to the minimum in year 2001. On the other hand, the operation of scenario I and II will tend to increase total cost per box up to year 2010. The operation of 8 RTG's is an optimum scenario in view of improvement total cost per box every year.

3. Pessimistic estimation

   At the relatively low demand level, total cost per box will reduce up to year 2002 for scenario III and year 2004. Whereas the equipment operation with scenario I and II will increase total cost per box from year 2000 to year 2010.

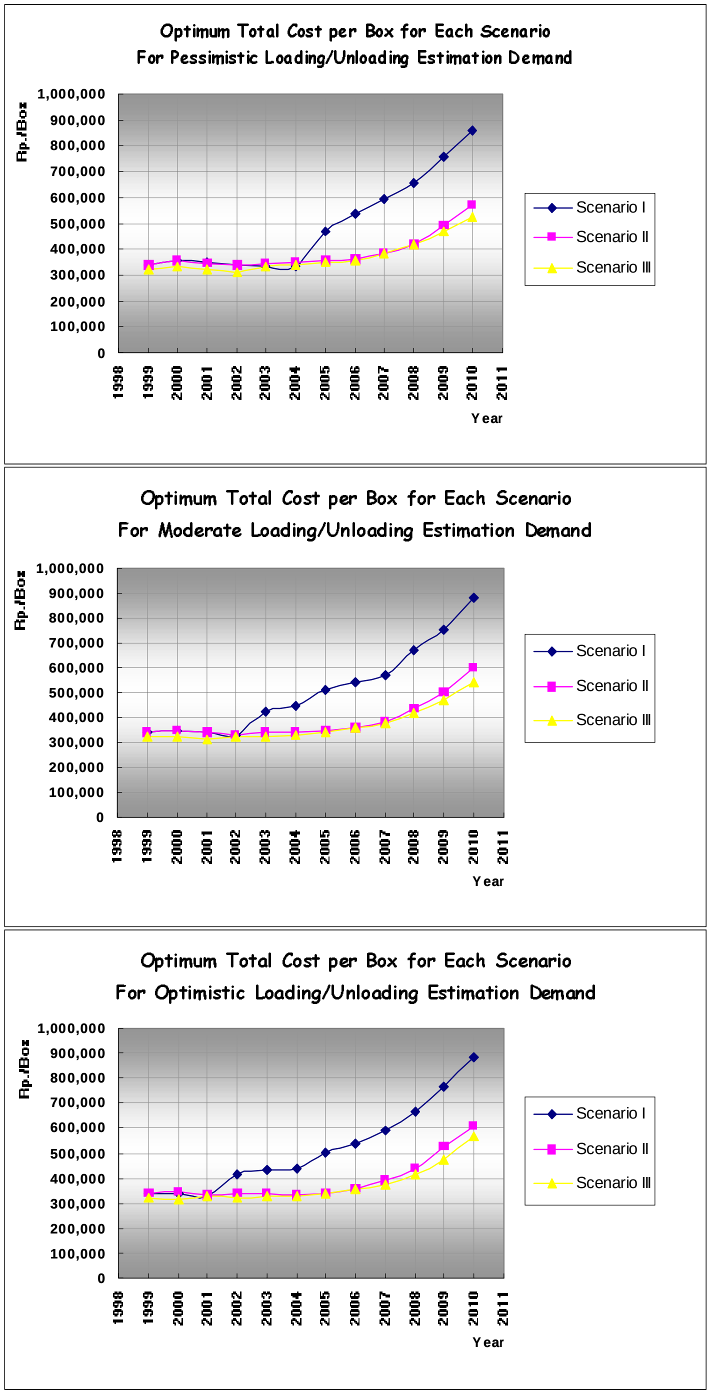

Figure 3. Total cost per box graph according to the assumption of 5 days calling ships per week pattern

At the highest level with 5 days calling ships per week pattern, the three equipment scenarios tend to yield the increasing total cost per box from year 2000 to year 2010. It is caused by the operation of equipment which almost reach its production capacity so that the waiting time become longer. If the demand pattern reduce a little (moderate and optimistic) only scenario III will yield the reduction of total cost up to year 2001. Equipment scenario III is a scenario which will give an optimal condition for both minimum total cost and improvement of total cost every year.

Temporary conclusion which can be derived from the result of the three computation of total cost per box are stated as follows:

- Equipment scenario III, namely the operation of 8 RTG's is an optimum scenario which will give minimum total cost per box for whole demand pattern.
- From all of the demand pattern, the improvement of demand will accelerate the achievement of minimum total cost. Optimum condition in view of minimum total cost per box move from year 2004 at the lowest demand (pessimistic, 7 days/week pattern) to year 2000 at the highest demand (optimistic, 5 days/week).
- If scenario III is applied at the highest demand level (optimistic, 5 days/week pattern), the optimum condition in view of total cost per box will only reach up to year 2000, it means it can not fulfil the existing demand.

To find the optimum equipment configuration, we consider to the balance between total cost per box and equipment productivity capacity. An optimum equipment configuration is a configuration with the least total cost per box with highest production capacity. Results of production capacity calculation shown in Table 1 and total cost per box container for each equipment configuration in various daily loading-unloading demand year 1999 to 2010 are uses as a base of analysis optimum equipment configuration.

The result of the analysis show that the equipment configuration of Scenario III-3 (4CCs, 24 Head-trucks, 8 RTGs, 2 SLs) has the biggest capacity with average productivity of 18.34 box/crane/hour. Meanwhile, the minimum total cost per box analysis indicate that the least total cost per box is produced by Scenario III (usage of 8 RTGs) for every container loading-unloading demand pattern.

From those analysis, it can be concluded that Scenario III-3 is the optimum configuration. So, the loading-unloading equipment package for Tanjung Emas Container Terminal is determined by Scenario III-3. This package of equipment is the basic of equipment additional program.

Meanwhile, to calculate the facilities required, the Berth Occupation Ratio will be the basic for calculating the required wharf and the container demand will be the basic for calculating the required container yard.

ADDITIONAL FACILITIES AND EQUIPMENT REQUIRED

To illustrate the analysis of additional facilities and equipment required from year 2000 to 2010, we present the scenario of moderate demand according to 3 ship-call pattern i.e. average condition (7 days), middle condition (6 days), and peak condition (5 days).

1. Average Condition (7 days)

   To anticipate moderate demand in peak condition (7 days), scenario I year 1999 in actual condition (at the time of survey), equipment and facilities compositions are 2 units of berth, 4 units of CCs, 16 units of head-trucks, 3 units RTGs, 2 units of Side Loaders, and 3 units of Top Loaders. This composition give BOR of 36,20 %. Based on simulation results, optimum value for scenario I fourth configuration, it needs additional head-truck to 28 units, so, BOR value can be pressed to 33,29 % and the need of CY is only 3,69 Ha (from the total of 7 Ha available).

   In the following years, along with the demand improvement, the optimum composition of scenario I, it only stands up to year 2004, with BOR value 65.59 %. Therefore, scenario II was developed so that BOR value can be pressed to 56.62%. On the other hand, the need of CY can not be fulfilled anymore (7,81 Ha > 7 ha). The next step, it was developed scenario III by adding RTG to 8 units. With this scenario, BOR value in year 2005 can be pressed to 53.16 % and it can stand up to year 2007. For the next year (2008), it is developed by adding 1 unit of berth including 1 package of equipment composition, so that BOR value reduce to 45.06 %, and it can stand up to year 2009. For further anticipation, it needs to add 1 more unit of berth in year 2010, so that BOR value can be pressed to 49.13 %.

   Based on equipment and facilities compositions owned in year 1999, the need of equipment and facilities addition to anticipate pessimistic estimation demand with average condition calling ships (7 days) as stated in Table 2.

Table 2. Additional equipment and facilities required for moderate estimation and average condition (7 days)

Facilities/ Equipment	Unit	Y E A R					
		1999	2000	2001	2002	2003	2004
Berth	Unit	-	-	-	-	-	-
CC	Unit	-	-	-	-	-	-
HT	Unit	-	12	-	-	-	-
RTG	Unit	-	-	-	-	3	2
SL	Unit	-	-	-	-	-	-
TL	Unit	-	-	-	-	-	-
CY	Ha	-	-	-	-	-	0.42

Facilities/ Equipment	Unit	Y E A R					
		2005	2006	2007	2008	2009	2010
Berth	Unit	1	-	-	1	-	1
CC	Unit	2	-	-	2	-	2
HT	Unit	12	-	-	12	-	12
RTG	Unit	4	-	-	4	-	4
SL	Unit	1	-	-	1	-	1
TL	Unit	-	-	-	-	-	-
CY	Ha	1.22	1.42	1.67	1.97	2.32	2.74

2. Middle Condition (6 days)

   Optimum configuration of scenario I (fourth configuration), can only stand up to year 2003, with BOR value 66.05 %. Therefore, in year 2003 it is developed scenario II so that BOR value can be pressed to 57.02 %. This scenario can only stand to year 2004 with BOR value 66.24 % and CY had not been able to accommodate the need, since it reaches 7.81 Ha. Therefore, it needs additional CY of 0.81 Ha.

The next step, it is developed scenario III by adding RTG to 8 units. By this scenario, BOR value in year 2004 can be pressed to 53.51% and it can stand up to year 2005, since BOR value has reached 62.19 %. Therefore, in year 2006 it needs to add 1 unit of berth including 1 package of equipment composition. This causes the reduction of BOR value to 41.46 % and it can stand up to year 2008 with BOR value 65.59 %. For the next anticipation, it needs to add 1 more unit of berth at the same year, so that BOR value can be pressed to 49.20 % and it can stand up to year 2010 with BOR value 67.24%.

Based on the equipment and facilities composition owned in year 1999, the necessity of equipment and facilities addition to anticipate pessimistic sstimation demand with the middle condition calling ships (6 days) pattern, can be seen in Table 3.

Table 3. Additional equipment and facilities required for moderate estimation and middle condition (6 days)

Facilities/ Equipment	Unit	YEAR					
		1999	2000	2001	2002	2003	2004
Berth	Unit	-	-	-	-	-	1
CC	Unit	-	-	-	-	-	2
HT	Unit	-	12	-	-	-	12
RTG	Unit	-	-	-	3	2	4
SL	Unit	-	-	-	-	-	1
TL	Unit	-	-	-	-	-	-
CY	Ha	-	-	-	-	-	0.42

Facilities/ Equipment	Unit	YEAR					
		2005	2006	2007	2008	2009	2010
Berth	Unit	-	-	1	-	1	-
CC	Unit	-	-	2	-	2	-
HT	Unit	-	-	12	-	12	-
RTG	Unit	-	-	4	-	4	-
SL	Unit	-	-	1	-	1	-
TL	Unit	-	-	-	-	-	-
CY	Ha	1.22	1.42	1.67	1.97	2.32	2.74

3. Peak Condition (5 days)

BOR value of scenario I configuration is 68.30 %, it can stand up to year 2002, with BOR value 64.88 %. Therefore, in year 2002, it needs to be developed scenario II with RTG addition of 6 units, so that BOR value can be pressed 58.96 %. This scenario can only stand for 1 year, with BOR value in year 2003 reaches 68.43 %.

The next step, it is developed scenario III with RTG addition 8 units. With this scenario, BOR value in year 2003 can be pressed to 55.31 % and can only stand for 1 year that is year 2004 with BOR value 64.21 %, therefore, at the same year it needs addition of 1 unit berth including 1 package equipment composition. This causes reduction of BOR value to 42.81 % and can stand up to year 2007 with BOR value reaches 67.46 %. Therefore, it needs to add 1 more berth at the same year, so that BOR value can be pressed to 50.60 % and can stand up to year 2009 with BOR value reaches 68.97 %.

Based on the equipment and facilities composition owned in year 1999, the necessity of equipment and facilities addition to anticipate moderate estimation demand with the peak condition calling ships (5 days) pattern, can be seen in Table 4.

Table 4. Additional Equipment and Facilities Required for Moderate Estimation and Peak Condition (5 days)

Facilities/ Equipment	Unit	Y E A R											
		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Berth	Unit	-	-	-	-	1	-	-	1	-	1	-	1
CC	Unit	-	-	-	-	2	-	-	2	-	2	-	2
HT	Unit	-	12	-	-	12	-	-	12	-	12	-	12
RTG	Unit	-	-	3	2	4	-	-	4	-	4	-	4
SL	Unit	-	-	-	-	1	-	-	1	-	1	-	1
TL	Unit	-	-	-	-	-	-	-	-	-	-	-	-
CY	Ha	-	-	-	-	-	0.42	1.22	1.42	1.67	1.97	2.32	2.74

CONCLUSION

Along with the increasing container traffic in Tanjung Emas Port, which reaches about 2.7 % annually, it has been anticipated by conducting the research in order to find out the optimum equipment usage and to formulate the need of equipment and facilities required up to year 2010;

In this research, Powersim simulation model was used to find out optimum composition of CC, Head-truck, RTG, TL and SL facilities, based on maximum capacity and minimum total cost criteria. So that it was gained optimum configuration of the equipment with Scenario III-3 which consists of 4 unit of CCs, 24 unit of Head-trucks, 8 unit of RTGs and 2 unit of Side-Loaders.

Additional programs of optimum facilities and equipment up to year 2010 in order to meet the moderate demand forecast in the peak condition of ships call pattern (5 days per week) are as follows:

1. *Berth* : 1 unit in year 2003, in year 2006, in year 2008 and in year 2010;
2. *CC* : 2 unit in year 2003, in year 2006, in year 2008, and 2 units in year 2010;
3. *HT* : 12 unit in year 2000, in year 2003, in year 2006, in year 2008, and in year 2010;
4. *RTG* : 3 unit in year 2001, 2 unit in year 2002, 4 unit in year 2004, 4 unit in year 2006, 4 unit in year 2008, and 4 unit in year 2010;
5. *SL* : 1 unit in year 2003, in year 2006, 1 in year 2008, and in year 2010;
6. *CY* : 0.42 Ha in year 2004, 1.22 Ha in year 2005, 1.42 Ha in year 2006, 1.67 Ha in year 2007, 2.32 Ha in year 2009, and 2.74 Ha in year 2010.

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ATTACHMENT

ORGANIZATION OF THE RESEARCH TEAM

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