STUDY ON THE FUNCTIONAL DESIGN OF CONTAINER TERMINAL BASED ON THE ANALYSIS OF OPERATIONAL DATABASE

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Abstract

Container terminal is a nodal point linking the marine and land distribution. In the rapid increase of the container ship size, swift services in container logistics are required to minimize port stay of the container ship. Non stop activity of gantry cranes in container handling is required and container handling equipment can be introduced excessively to keep activity of gantry crane. When there are no synergies between cargo handling equipments, it will cause efficiency and way to avoid that is to reduce the number of an excessive deployment of other supporting equipment to keep minimum loading time and avoiding idle time. In this study, we developed a data analyzing system that handle the loading database for the acquisition of temporal information of cargo handling equipment and create functional design simulation based on the loading information. Furthermore, using the records, we consider the appropriateness deployment of chassis and transfer crane in order to keep gantry crane operation and not to cause a lot of waiting time during loading and unloading services. Simulation model by Petri Network is used to analyze the operation in discrete event system on each instrument introduced for container handling in the container terminal.

Keywords: *Container Terminal Simulation, Functional Design, Database Analysis, Petri Network;*

1. INTRODUCTION

Container terminal is a nodal point linking the marine and land distribution. Swift services of container logistics are required to minimize port stay of the container ship. When there are no synergies between cargo handling equipments and its excessive deployment inefficiency in loading time, traffic, and idle time for one or more equipment will increased. In this study, we developed a data logging system that handle the loading database for the acquisition of temporal information of cargo handling equipment and show the functional design of the container terminal by simulation based on the collected data. Consider as an example here is the recording of actual loading and unloading to confirm the reproducibility of the cargo handling from the simulation. Furthermore, using the information, we consider the appropriate deployment for the chassis and transfer crane so it minimize waiting time and idle time during loading and unloading services. Island City Hakata Container Terminal, located in Fukuoka Prefecture, Japan is choosed as the test case. In order to properly analyze the operation for equipments that used during container handling in the terminal, we construct simulation model using Petri Network.

2. INFORMATION ACQUISITION OF CONTAINER HANDING EQUIPMENT

2.1. Island City Hakata Container Terminal

Island City Hakata Container Terminal is a new container terminal opened in September 2003 as an effect of increasing container volume at Fukuoka Prefecture, Japan. This terminal is a medium sized terminal which have two principal quay berth, 680m quay length, both at 15 m and 14 m depth, gantry cranes equipped with latest technology (abbreviated as G/C), 5,284 m^2 area of container yards to store 19,296 TEU. The terminal recorded to handled 36.7 million TEU in 2010. The terminal also use the latest information technology and logistic system by implementing HiTS (Hakata Port Logistic IT System) and KACSS (Kashii Container Control System) which can be seen on the Leaflet of Hakata port Terminal Co.,Ltd. The container yard had designed to have 8 columns width. To serve that purpose, special design of transfer crane (T/C) has been developed. Flow concept in the terminal is a chassis premises (abbreviated as C/Y) to link the T/C and G/C as a connecting devices. To minimize waiting time, a gang concept have been introduced, where in 1 gang, 4 C/Y are deployed to serve 1 G/C, while T/C are deployed for all lines.

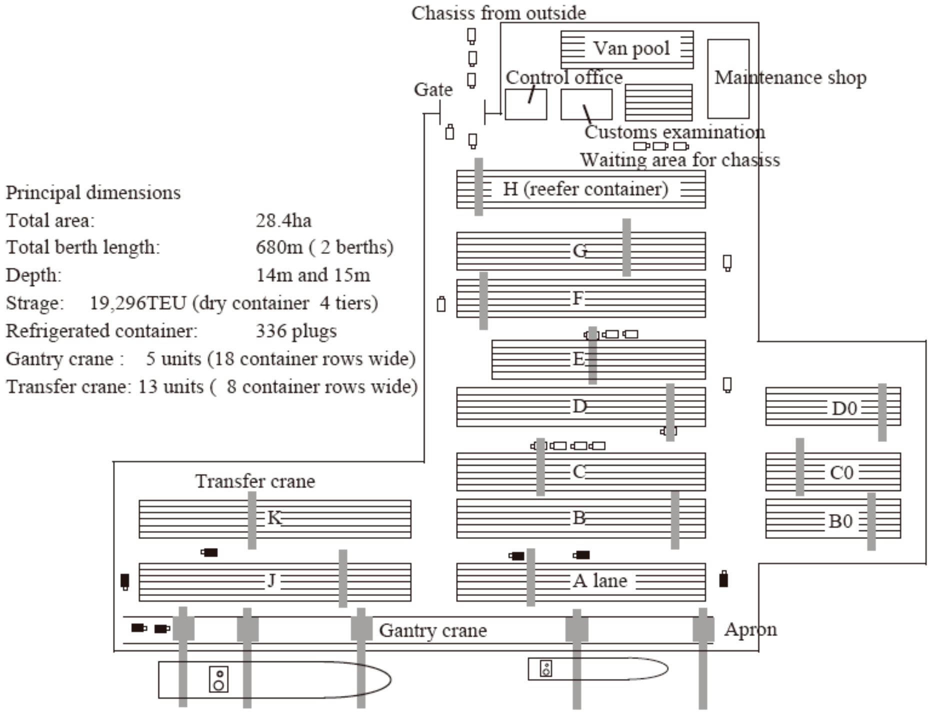
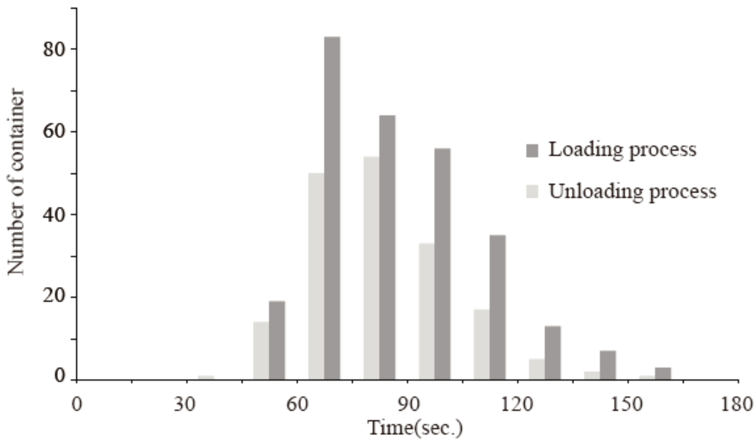


Figure 1. Illustration of Container Terminal Layout



2.2. Data Collection for Each Cargo Handling Equipment

Before constructing handling simulation model, information was obtained by measurement and analysis of the loading and unloading database in the field of operation for each cargo handling equipment.

(1) Gantry Crane (G/C)
To obtain the time information of G/C, a data logger was installed to a sequencer in the switchboard room which controlled the mechanical movement of G/C and measured the activity of the control signal. Figure 2 shows the frequency distribution obtained as the handling information. The average time from sequencer for unloading process is 84 second while for loading process is 88 second.

Table 1. Daily work report of container handling by transfer crane

Daily work report of Hakata Island City Container Terminal

[Transfer crane No.03] [Completed work data on 19:07, 01 / Aug / 2007 (Wed.)]

No.	Operation	G/C	Container No.	Size	From	To	Stock address	Accept. work time	Completed work time	Comments	Flag
37	Ship to Stock	I3	****6698051	40	CY013	C115-4-4	C115-2-3	11:02:19	11:13:49	Reserved	O/C
38	Receipt		****8050570	40	C121-1-2	C121-4-2		11:03:41	11:14:31	Reserved	O/C
39	Rehandling		****1316020	40	C121-1-1	TM004		11:16:50	11:19:42		O/C
40	Delivery		****6057208	40	C113-5-2	C113-4-2		11:15:27	11:21:24		O/C
41	Delivery		****9410917	40	C113-5-1	IW005		11:15:28	11:25:13	Reserved	O/C

Remark ; The abbreviation of O/C means ordinary completed.

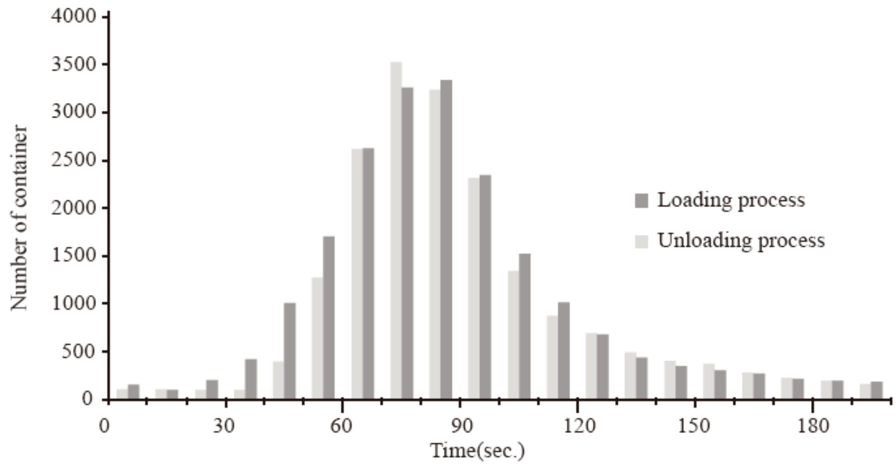


Figure 3. Average work time of transfer crane in loading and unloading process.

(2) Transfer Crane (T/C)

Daily report were required to get the information of T/C operation (Shinoda et al., 2007). T/C's daily handling operation is stored as text in CSV (Comma Separated Values).). Example of daily report is shown in Table 1, which are numbered from the starting tasks of T/C in a day, showing types of operation, container number handled by T/C, container origin and destination in container terminal, and completed working time. From this database, time analysis was performed to extract the needed information. Figure 4 shows an example of analyzed data that were extracted from approximately 40,000 CSV data, indicating the average working time of T/C for both loading and unloading process. The average time for unloading process is 90 second while for loading process is 87 second.

(3) Chassis (C/Y)

Two ways to collect information from the chassis were conducted, which is direct measurement by accompanied every movement of chassis during operation, and using video monitor, installed in front of driver's seat to recorded all activity. The measurement had created recording sheet based on the activity of the C/Y, arrival time to apron, travel time, number of waiting C/Y, waiting time for the receiving and removing container, end time of handling, etc. Figure 4 shows the average working time for all the chassis movement from apron to CY and otherwise, for each lane and for both loading and unloading activity. Longer waiting time was recorded for line H which is dedicated for reefer container and located at the furthest distance to the apron as can be seen in Figure 1. Figure 5 shows the waiting time of C/Y at the apron during the loading operation. In some cases of waiting time above 90 seconds, C/Y must wait for other C/Y based on container receiving sequence from G/C.

3. CONTAINER HANDINLING SIMULATION

3.1. Petri Net Model

Shiizuka (1992) mentioned that petri network which calculate each work process can be used for the cargo handling simulation. Figure 6(a) shows the components of the petri network, where transition (T) shows the operation of the transition state of the process, place (P) shows the activity in the process, arc (input and output) indicates the flow of work, and current status of process is represented by a token. Here, in order to control the flow of the process due to idle time or default action, an information place was designed and placed in the petri network as triangles shown in the figure 6.

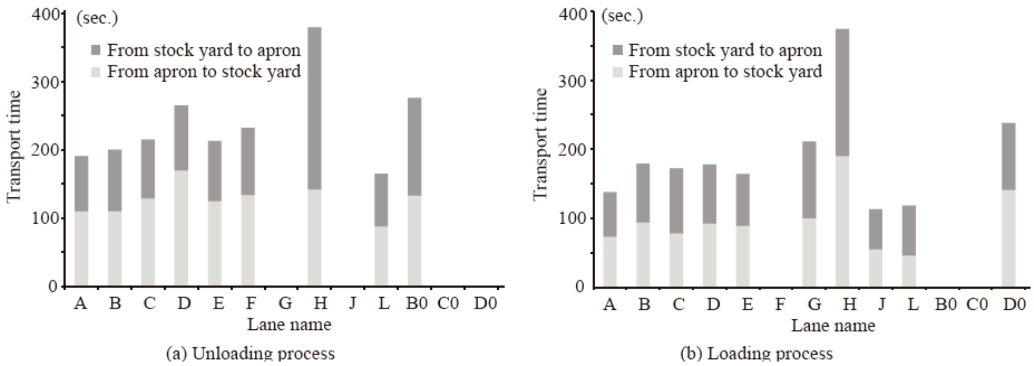


Figure 4. Average work time of transfer crane in loading and unloading process.

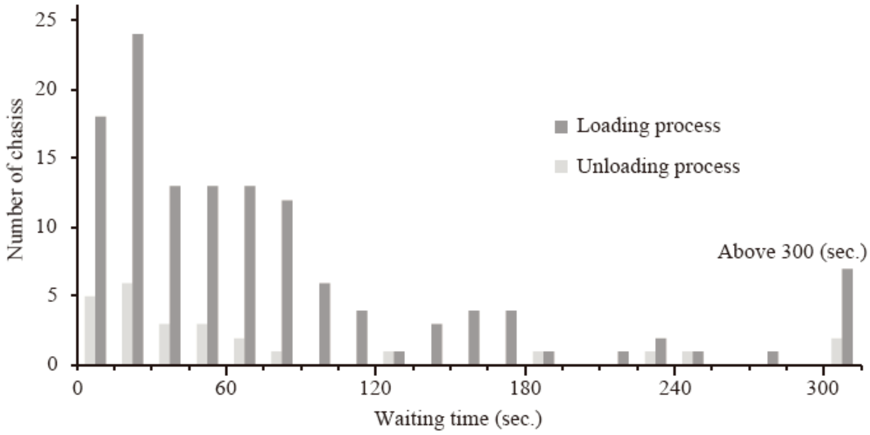


Figure 5. Chassis idle time at apron waiting for container supply from gantry crane

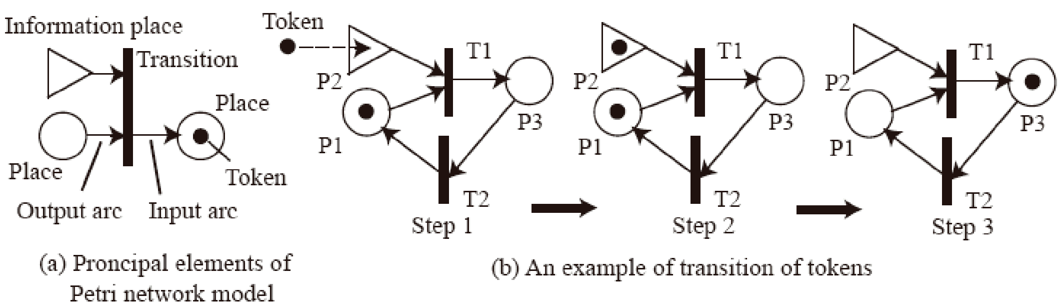
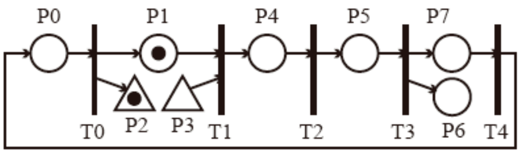


Figure 6. Petri network model and explanation of its process



Place No.	Expression
P0	End of moving spreader at apron
P1	Waiting at apron
P2	Information of end of moving spreader at apron
P3	Information of satisfying condition for transferring from C/Y
P4	End of transferring

Place No.	Expression
P5	End of moving spreader above storage position in ship
P6	End of storage in the hold
P7	End of releasing contaienr

Transition No.	Expression
T0	Transmission of information of end of moving spreader at apron
T1	Start of loading container
T2	Start of moving spreader above storage position in ship
T3	Start of releasing container
T4	Start of moving spreader to the apron

Figure 7. Handling process model for gantry crane by petri network

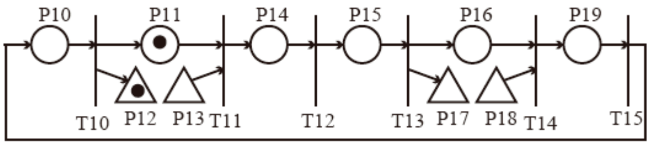
Figure 6(b) shows the flow of a simple process to explain the petri network. As shown in Step 1, put a token in place P2 and sends instructions to process information to fire the transition T1, as shown in Step 2. Next, token were moved to P3, as shown in Step 3 as the continuity of the process. Thus, by introducing the information place, it is possible to control the transition firing conditions such as previous work instructions. In addition, we introduced timing in petri network to allow time to firing process (Timed Petri net). Here, after the firing of the transition, time model is used to delay the firing to next place in a certain time. Computer program was created by the C programming language to tested and run the model. The definition of time used in the model is the recorded working and idle time for each equipment.

3.2. Container Handling Simulation

Since each equipment working and idle time had known by measurement as explained in chapter 2, First, handling simulation is merely conducted to reproduce the working and idle time, thus compared and testing the reliability of the model with the actual working and idle time. Second, an evaluation of functional design for equipment deployment in the container terminal is implemented. The simulation based on the C/Y deployment to serve desgnated G/C and T/C in the terminal. Petri net model for each C/Y were construted and combined to model the entire movement in the handling process. Figure 7 shows the constructed petri net to model the handling process of G/C, while Figure 8 shows the petri network model for C/Y. Explanation for each model were included in the table below each figure. T/C handling model also constructed with petri network but will not be shown in this paper. Handling equipment used in simulation are 3 G/C, 12 T/C, and initially 15 C/Y. Then we gradually increased the number of C/Y deployed to 45, 180 and 225 units. In the first test, The deployed chassis are based on fixed chassis system, which means the C/Y designated to each G/C is fixed including its moving sequence as shown in Figure 9(a).

Second option were provided for chassis deployment system, by introducing free chassis system and combined fixed-free chassis system as shown in Figure 9. In free chassis system, all ready C/Y are moving freely to the next available G/C regardless of designation and sequence, while combined fixed-free chassis system defined as a combination of free movement for some C/Y and a fixed movement of the other C/Y in a gang.

To connect the G/C and C/Y model, an Interchange unit of Information place is used. This is to give order priority by control program for each ready-to-receive C/Y to go to available G/C in the container terminal. For example of explanation, in Figure 8, P11 had set for chassis waiting activity on the apron as well as P1 for G/C waiting activity in Figure 7. Then waiting information will be processed in the interchange unit. If each unit equipment are ready to operate, then both information token from G/C and C/Y will be sent by control program to each equipment to start the next operation.



Place No.	Expression	Place No.	Expression	Transition No.	Expression
P10	End of moving at apron	P15	End of moving at the storage slot	T10	Transmission of information of end of moving at apron
P11	Waiting at apron	P16	Waiting at the storage slot	T11	Start of transferring container to G/C
P12	Information of end of moving spreader at apron	P17	Information of end of moving at the storage slot	T12	Start of moving to the storage slot
P13	Information of satisfying condition for transferring from C/Y	P18	Information of satisfying condition for transferring from T/C	T13	Transmission of information of end of moving at the storage slot
P14	End of transferring	P19	End of transferring	T14	Start of transferring
				T15	Start of moving to the apron

Figure 8. Chassis movement model by petri network

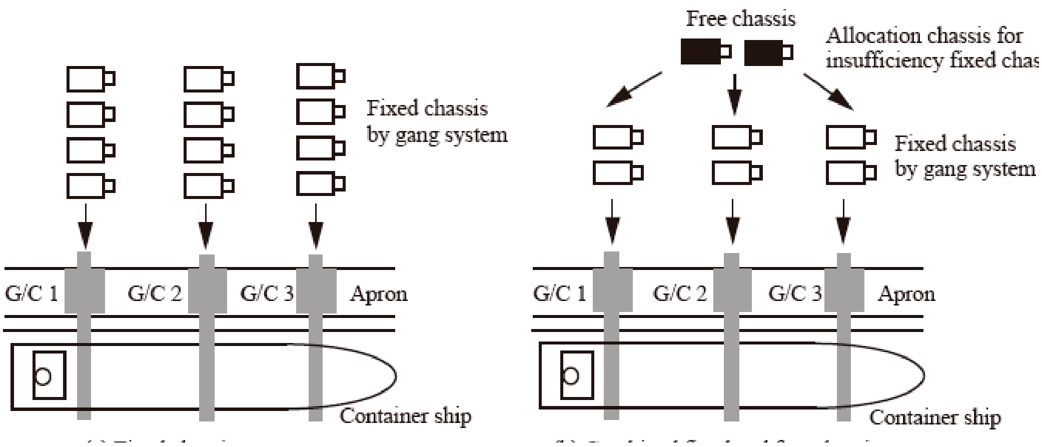


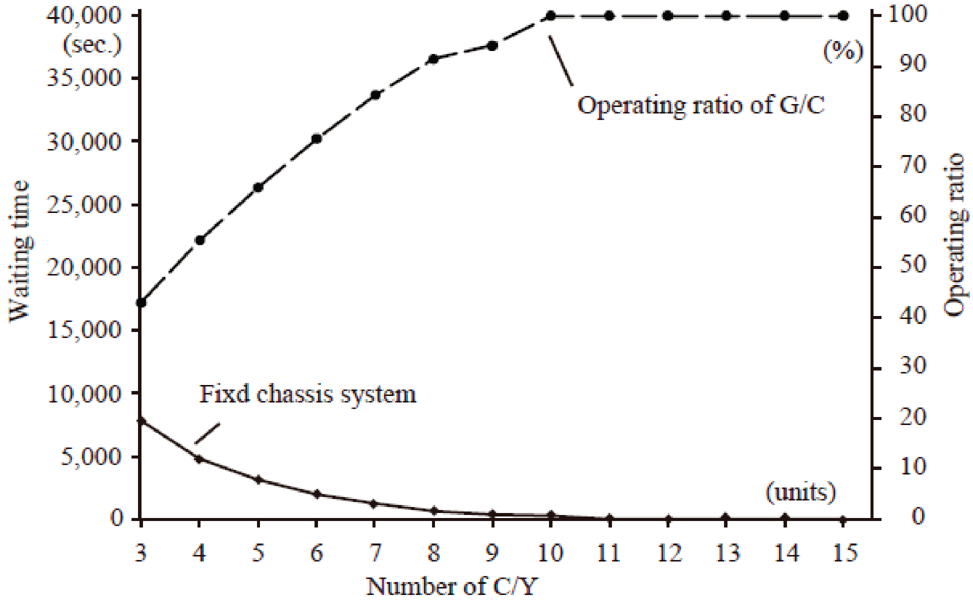
Figure 9. Chassis movement model by petri network

3.3. Handling Simulation Results and Future Remarks

(1) Improvement of functional design by appropriate C/Y deployment
Container handling simulation with fixed C/Y system by petri network produced similar result for C/Y waiting time compared to that which was measured in chapter 2, i.e. 12 C/Y deployed for 3 G/C in a fixed C/Y system (see Figure 11). So we can be confidence that the simulation model can represent real situation in the container terminal which is 1,695 second for each C/Y which is equal to 30% of C/Y operating time of 5.720 second for each G/C.

(2) Potential improvement of functional design by equipment re-deployment
By proper study of deployed C/Y into container handling process in container terminal, with fixed C/Y system (4 C/Y configuration to serve each G/C) as shown in Figure 9(a) and introduction of all free movement C/Y or combined fixed C/Y as shown in Figure 9(b) we knew which kind of configuration produce minimum idle time for entire system. Analysis result of G/C's idle time in figure 10 shows that to reach maximum operating ratio of G/C, number of C/Y deployed may be reduced from 12 to 10 C/Y, and while considering trade off between waiting time and operating ratio, optimum deployment is recommended to be between 9 to 10 C/Y for entire system.

C/Y idle time analysis is shown in figure 11. In free C/Y system, by gradually giving free movement order to more deployed C/Y, we can reduce the number of C/Y in a gang. Introduction of all free movement of C/Y may reduce C/Y's idle time in apron, but it is not recommended to give a free movement ability to all C/Y for an anxioucity of C/Y collision (safety factor).



(b) Details of number of combined fixd and free chassis system

Num. of C/Y	4	5	6	7	8	9	10	11	12	13	14	15
Num. of Free C/Y	1	2	3	1	2	3	1	2	3	1	2	3
Num. of Fixed C/Y	3	3	3	6	6	6	9	9	9	12	12	12

Figure 10. Idle time of gantry crane, waiting for chassis readiness in loading process

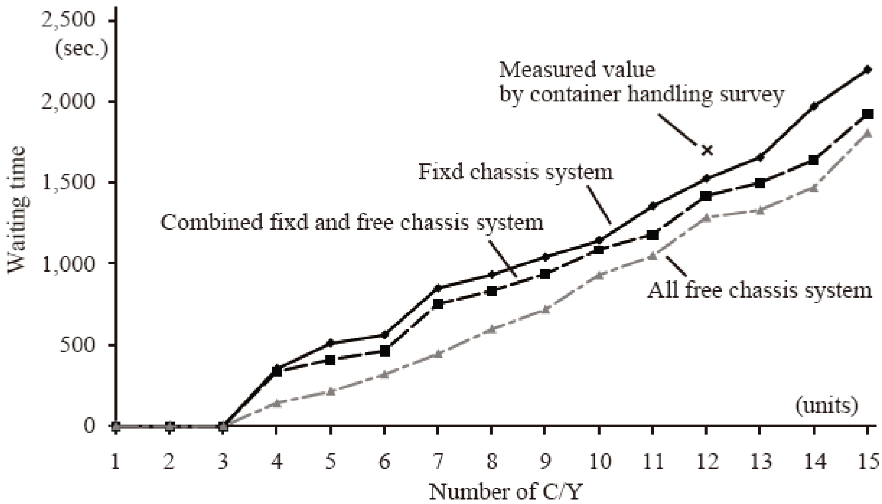


Figure 11. Idle time of chassis at apron, waiting gantry crane readiness in loading process

Thus, by reducing the number of deployed C/Y the equipment idle time during loading operation can be reduced to 34% compared to real and current situation. Additional 6% reduction gained by introduction of combined fixed-free chassis system. As for unloading operation, similar result also can be found.

4. CUNCLUSION

We developed a database and logging system for obtaining information on loading and unloading time in container terminal operation. In addition, we construct a simulation model using petri network and use the collected information to review the functional design of handling system in the container terminal. We have examined the appropriate deployment of the chassis to support container handling activity by petri network simulation and produce the optimum chassis to be deployed with minimum idle time to fit its functional design. Also, by introducing combined fixed-free chassis movement to the gang terminology in chassis deployment, we manage to show large reduction in chassis idle time. In the future, the authors will examine this measurement with stowage plan consideration and see its correlation in order to create more efficiency in container handling at container terminal.

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