A Comparison of Layouts of Reefer Containers in Automated Container Terminal

HYUNG RIM CHOI, BYUNG JOO PARK, HAE KYOUNG KWON, DONG HO YOO
Dong-A University University, 840 Hadan2-dong, Saha-gu, Busan, KOREA

NAM KYU PARK
Tongmyung University, 535 Yongdang-dong, Nam-gu, Busan, KOREA

Abstract: - For managing reefer containers more efficiently, it is important to optimally determine the block size and the layout of reefer containers in the early design phase. Work balances among blocks of a yard have a significant effect on the productivity of container handling activities in automated container terminals (ACTs), and thus, the productivity of the whole terminal highly depends on the layout of reefer containers in the yard. This paper proposes various layouts of reefer containers, which are based on the basic plan of Gwangyang ACT in Korea. The simulation was used to find the optimal layout of reefer containers.

Key-Words: - Automated Container Terminal, Reefer Container, Simulation, Layout, Productivity

1 Introduction

For designing the yard layout of an ACT, the layout of reefer containers is a very important issue. ECT (Europe Combined Terminal) in Rotterdam has dispersed reefer containers over all the automated blocks, whereas, in CTA(Container Terminal Attenwerder) of Hamburg, only three blocks among 22 automated blocks are designated as reefer container blocks. The difference in the layout of reefer containers results in different operational procedures.

Although there may be numerous ways to locate reefer containers, this paper proposes three different layouts as follows: centralized layout in which all the reefer containers are located several centralized blocks; alternating layout in which one every second block is designated as a reefer block; distributed layout in which every block has bays reserved for reefer containers. All three layouts have their own merits and demerits. For example, the centralized layout of reefer containers may cause longer delays in travels of AGVs (Automated Guided Vehicles), whereas workers conducting the plugging operation for reefer containers in the yard may travel shorter distances than distributed layouts.

Emphasizing the importance of the layout of reefer containers in the yard, Beemen [1] said in his study, "When planning storage positions of reefer containers in automated container terminal, one has to strike a balance between two conflicting requirements. In order to reduce travel distances for reefer mechanics, one would like to concentrate the reefer positions in one location. On the other hand, if all reefer containers are concentrated in one location, one would not have sufficient stack handling capacity available when loading the large reefer bays of large container ships."

We propose the minimization of the make-span of loading and unloading operations as the ultimate objective function for the layout problem for reefer containers. A simulation study is conducted to evaluate various layouts of reefer containers. By using the simulation method, it is possible to consider realistic and stochastic distributions of ship arrivals, the number of containers for loading and discharging, and equipment service time.

2 Suggestion of Optimal layout for Reefer Containers

Before suggesting the optimal layout of reefer containers, the definition of the parameters in the yard layout should be given. Also, to seek important factors in finding out a meaningful layout method, the composition factors of the total loading times including reefer container-related loading times should be analyzed.

The purpose of seeking the optimal layout is to minimize the total working times. Total working times consist of QC(Quay Crane) work-time, QC and AGV connection work-time, AGV moving time, AGV and ATC(Automated Transfer Crane) connection work-time, ATC moving time, ATC work-time, reefer container plugging time, and work-time caused by confusion.

To find out a better layout method, the following two steps have been taken.

(1) First decide whether to adopt a concentrated lay out method or a decentralized method.
(2) When adopting a decentralized method, we have to decide whether to select every block arrange ment, every other block, or every third block.

In the first step, the merit of centralized layout is to reduce the plugging hours of reefer containers, but its demerit of long working hour stems from waiting time caused by congestion of AGVs. And the work hour of other jobs is to vary depending on an environmental situation. Therefore, it will be decided by simulation. Likewise, in the decentralized layout, the work hour of each job is to be decided by simulation.

In an effort to find out a better model, this paper has the following assumption.

(1) All yard layout is to be made vertically against the quay.
(2) Job processes under the test are confined to inbound containers.
(3) It has 7 blocks per one berth.
(4) Each block has the capacity of 10 rows and 4 stack heights.
(5) The length of one block is 321.3m.
(6) The number of containers loaded in a ship ranges from 120 to 300.

The reasons for above-mentioned assumption are as follows:

(1) The vertical arrangement is generally used to seek job balance and to avoid AGV job confusion. ECT of Netherlands and CTA of Germany have also adopted this method.
(2) The specific size of the block has been given to make our mock tests more practical. This paper is based on the real case of Gwangyang ACT in Korea [2].
(3) The reason to adopt one ship carrying 120-300 containers is that in the case of a ship of 3,000 TEU, the rate of reefer containers to total ones is usually ranging from 4% to 10%.

This study has suggested four layout patterns: concentrated layout pattern, every block pattern, every other block pattern, and every third block pattern. The yard storage capacity varies as each pattern. The handling capacity of one berth is assumed 400,000 TEU. If 3% of this capacity is occupied on average, it will be 12,000 TEU on a yearly basis. Therefore the TGS based on 12,000 TEU can be 61 TGS.

61 TGS is composed of 10 rows and 6.1 bays, and accordingly, the length of reefer container block becomes 268.5m (321.3m – 52.8m). One bay of reefer container is 20ft. of container length + space for plugging job. It is about 8.65 meter. If these criteria are applied to the four layout patterns, their layouts are as shown in Fig. 1.

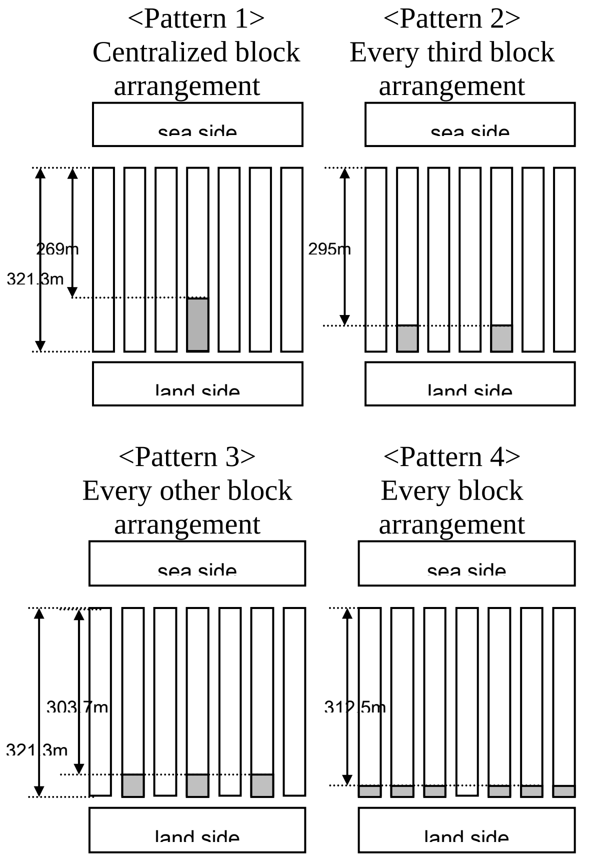

Fig. 1. Reefer Container Block Arrangement Patterns

3 Simulation Modeling for Reefer Container layout

As mentioned above, the simulation method is very effective in seeking the optimal layout. For our simulation modeling, the following three steps have been taken.

(1) The scope and objects of simulation are to be decided, and their resources are also to be defined.
(2) Simulation models for each object are to be built.
(3) Tests and results analysis for each model are to be done to draw a conclusion.

This study has used the simulation package ARENA Ver. 5.

3.1 Scope of Simulation and Resources of Simulation Objects

This simulation covers one berth and seven blocks. Also it includes all the unloading job of an inbound ship: QC work, QC and AGV connection, AGV transfer, AGV and ATC connection, ATC movement, ATC work, and plugging. The environmental parameters of automated block simulation model are as follows:

Table 1. Environmental parameters in the automated block simulation

Section	Contents
Number of block (block)	7
Block type	10 rows, 5 stacks
Full block length (m)	321.3
Reefer block type	10 rows, 4 stacks
Reefer block length (m)	52.8 – pattern 1 26.3 – pattern 2 17.6 – pattern 3 8.8 – pattern 4

In the case of layout pattern 1, the yard travel distance of general containers ranges from 6.5 m to 268 m based on the TP (Transfer Point) of the sea side, and that of reefer containers ranges from 268 m to 321.3 m. Other layout patterns also have the same yard travel distance.

And the environmental parameters of unloading equipment simulation are shown in the Table 2.

Table 2. Environmental parameters of unloading equipment simulation

Equipment	Section	Contents
ATC	Number of unit	7 (one per block)
	Travel speed	average 3 m/s
	Pick-up time	30 sec
	Loading time	30 sec
	Job assignment rule	FIFO
AGV	Number of unit	21 unit
	Travel speed	average 6m/s
	Travel time	vary as blocks
	Job assignment rule	Random
C/C	Number of unit	3
	Job handling	1 Van/min

(1) A ship has three QCs, and it takes one minute to handle one container.
(2) One berth has 21 units of AGV, which travel 6m/s. Containers are randomly assigned to AGV. Traveling time is to be decided by the route distance between QC and container blocks.
(3) Each block has one ATC, which travels 3m/s on average. Pick-up and unloading time is 30 second respectively. The order of job is based on FIFO. The travel time of ATC will be based on the container location in the yard.
(4) The workman in charge of reefer containers is one person who travels 8m/s on average.

3.2 Simulation Modelling

Based on the above-mentioned values of environment, now the simulation model for reefer container layout is to be built. To this end, the first thing we need to do is the preview of our simulation results. That is, prior research has to be made about the possible results of simulation model.

The conclusion we want to reach is to know whether there is any difference in the make-span according to the layout patterns or not. On the other hand, we also want to know whether the difference of work hour according to the rate of reefer containers to total ones to be handled has any direct relationship with our four layout patterns.

It is necessary to raise a matter of simulation scope. Of course, if all the factors related to the total make-span are included in the simulation, the best results can be obtained. However, for convenience' sake this paper has separately dealt with the job of plugging and the job of unloading equipment such as QC, AGV, and ATC. The following are the steps taken for building simulation model.

(1) Before simulation, the environmental parameters have been set based on the four layout patterns. AGV travel time, ATC travel time, QC-AGV connection work time, and QC-ATC connection work time vary as four patterns.
(2) After setting the environmental parameters, the data on the containers ought to be given. This paper has assumed that the ship has 3,000 containers, and that it has respectively 4%, 6%, 8%, and 10% reefer containers to total ones. The simulation results will be derived from each one of them.
(3) A ship has three QCs, and each QC handles the same number of containers.
(4) Then QC picks up containers and puts them on AGV. The modeling of this job uses normal distribution (60, 0.5).
(5) When QC picks up a container, it should be confirmed whether it is a reefer container or a general container. If it is a reefer container, random-based block slot assignment rule and environmental parameters will be applied according to the layout pattern. A general container also uses random-based block slot assignment rule and environmental parameters.
(6) The transfer time required of average travel distance between each QC and each block is to be applied to the AGV transfer work.
(7) AGV-ATC, just like QC-AGV, uses the environmental parameters corresponding to layout patterns.
(8) In case of ATC transfer time, the environmental parameters are separately applied to the general containers and reefer containers.
(9) The 30 seconds of ATC loading time has been fixed.
(10) The make-span of unloading of containers and the plugging time for reefer containers are to be calculated separately, and then added for make-span.

4 Test Results and Analysis

4.1 Unloading Time by Reefer Container Ratio and By Layout Pattern

Based on the ship loaded with 3,000 containers, the make-span of unloading has been measured, and tests were conducted 10 times. The make-span by reefer container ratio and by pattern are shown in Table 3.

Table 3. Average make-span by reefer container ratio and by pattern (unit: second)

Reefer con. Ratio / Layout Method	4% (priority)	6% (priority)	8% (priority)	10% (priority)
Pattern 1	724440(4)	1046401(4)	1188664(4)	1178668(4)
Pattern 2	705702(2)	728427(2)	898650(2)	959749(2)
Pattern 3	723677(3)	757023(3)	908039(3)	960228(3)
Pattern 4	673728(1)	689727(1)	715084(1)	720423(1)

The results of simulation show that pattern 4 takes the least time, thus coming first, pattern 2 comes second, pattern 3 comes third, and pattern 1 takes the longest time, thus coming last. This order has not changed if the reefer container ratio increases from 4% to 10%. Notably, when the reefer container ratio is 10%, the difference in the unloading time become wider than the ratio of 4%. This means that the difference in the unloading time by pattern becomes far wider when the reefer container ratio rises higher. This trend is shown in Fig. 2.

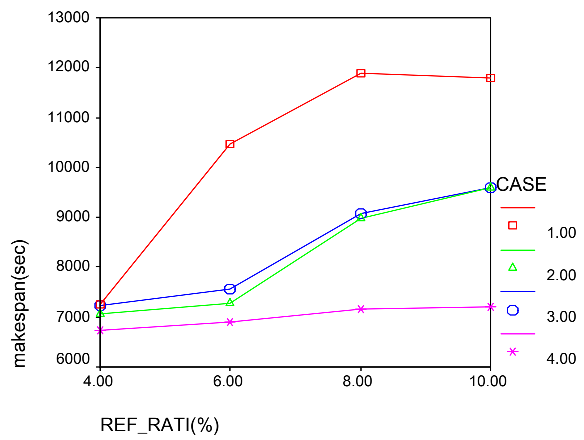

Fig. 2. Make-span by reefer container ratio and by pattern

When we have checked the wait time of each pattern, the pattern 4 has the least wait time. So we have found out that the more reefer container blocks are scattered, the more likely the wait time of reefer container is to reduce. This is shown in Table 4.

Table 4. Average wait and transfer time in case of reefer container ratio of 4% (unit: sec)

	Average wait time		Average transfer time	
	general con.	reefer con.	general con.	reefer con.
Pattern 1	754.93	947.48	69.58	110.59
Pattern 2	717.17	873.26	69.17	108.17
Pattern 3	887.46	894.03	69.4	113.12
Pattern 4	621.68	374.65	68.5	114.51

The results of two-way ANOVA have shown that the changes in the layout pattern and reefer container ratio have a direct effect on the make-span at the 5% level of significance. According to our test analysis, the pattern 4 has brought the best result under any circumstance.

4.2 Total Processing Time for Reefer Container Layout

To evaluate the reefer container layout pattern, we have checked total work time including plugging job. The total work time is shown in Table 5.

Table 5. Total processing time for reefer container layout

Layout Method \ Reefer Con. Ratio	4%	6%	8%	10%
Pattern 1	753489.5	1089851	1246513.5	1250918
Pattern 2	734956.5	772081.5	956704.5	1032204
Pattern 3	753136.5	800882.5	966298.5	1032888
Pattern 4	703802.5	734201.5	773958.5	793697.5

The results of two-way ANOVA have shown that the layout pattern 4 takes the least work time under any situation. Therefore, we have reached the conclusion that the decentralization of reefer container layout is more desirable. It holds true, in particular, in case of a large ship with higher reefer container ratio.

5 Conclusion

This study analyzed various layouts of reefer containers at an automated container terminal, and came to the conclusion through the simulation study that the distributed layout, in which reefer containers are distributed over all the blocks, of reefer containers is more effective in reducing the make-span of unloading operations than the centralized layout, in which all the reefer containers are stacked only in several blocks.

Accordingly, considering the current trend that the reefer container ratio is steadily increasing (in Busan port, the ratio of the number of reefer containers to that of all the containers was 3.1% in 2002), the study on the layout of reefer containers is significantly meaningful. Moreover, in order to respond actively to this trend, it is necessary to conduct further research on planning ship operations and various equipment, managing reefer containers and inland trucks.

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