# Estimation of the Number of Equipment for a Temporary Storage Yard in Automated Container Terminals

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***Abstract***— **In order to improve the level of customer service in automated container terminals, this study suggests the operation of temporary storage yard which is located between a gate and marshalling yard. The interface between outside trucks and unmanned container handling equipment can be easier through temporary storage yard. Cooperation of container handling equipment and outside truck invite complexity. Performance is also highly dependent on operational policy. Therefore it is difficult to study the system through an analytical approach, such as queuing theory. The response surface methodology using simulation is adopted to estimate the number of equipment for a temporary storage yard. Experiment illustrates the proposed procedure of estimating the number of AGVs and yard cranes needed to satisfy the target waiting time of outside trucks.**

***Keywords***— ***Container Terminal, Temporary Storage Yard, Simulation, Response Surface Methodology***

## I. INTRODUCTION

One of most difficult operations of automated container terminals is how to receive or deliver a container from/to outside trucks. It is very difficult to control the precise position of outside trucks for receiving and delivery operations due to a variety of outside trucks' conditions. Also, if outside trucks enter a marshaling yard, which the route of trucks and the AGV path overlap each other in some places, the collision of automated movers and outside trucks can incur the breakdown of entire system [1-3].

The installation of a temporary storage yard between a marshaling yard and a gate complex to resolve these difficulties can be considered. Though the situation of Kozan's study is different from that of this problem, it provides useful ideas in terms of the transfer efficiency [4]. He proposed that an efficient transportation requires that interfaces between different modes of transport are provided which minimize costs while meeting customer requirements for reliability of service delivery. In a temporary storage yard, manned yard cranes or remote controlled yard cranes receive an export container from a truck or deliver an import container to a truck.

However, this system requires more transfer, equipment, and spaces than the current system, in which outside trucks are directly served by yard cranes in a marshaling yard. While the primary objective of a temporary storage yard is to ensure the interface between outside trucks and unmanned equipment, ATC (Automated Transfer Crane), it can be engaged in smooth of workload of ATCs in a marshalling yard, the reduction of waiting time of truck, and efficient storage of outbound container. When the temporary storage yard is installed, the service level for outside trucks has to be considered. Delay time of receiving and delivery operations is one of important factors that should be considered in the evaluation of the customer service level of a container terminal.

The objective of this study is to determine the number of equipment to minimize the cost of equipment for a temporary storage yard providing the adequate service level. The service level for trucks is assumed to be the average waiting time of trucks at a temporary storage yard.

In this study it is proposed how to operate the temporary storage yard in automated container terminals as interface between automatic equipment and outside trucks. Also, an efficient methodology is illustrated to determine the number of equipment of temporary storage yard using response surface methodology.

## II. TEMPORARY STORAGE YARD

### A. *Motivation in Automated Container Terminals*

In order to reduce the space requirements for export containers, Taleb-Ibrahimi et al. studied a "rough-pile" (a temporary storage area separate from marshalling area) for early-arrival containers [5].

Let's make sure of the unique characteristics of container terminals in order to establish how to utilize the temporary storage yard. Fig. 1 depicts the general pattern of the cumulative export arrivals for a container ship. The bold line shown in Fig. 1 represents the actual cumulative export arrivals and the dashed line means estimated cumulative export arrivals while the slender line represents the assigned storage space for estimated cumulative export arrivals. Let's $t_0$ and $t_2$ denote the starting time and the ending time of free dwell interval, respectively. Free dwell interval refers to the interval when containers are placed into a yard without pay. $t_3$ denotes the time when the loading operation of a ship is finished.

Though the amount of the containers is few during initial arrival of export container, the difference between the actual amount of the containers and the estimated amount of the containers is much. So, this feature incurs that the storage efficiency and the productivity of ship operations are decreased.

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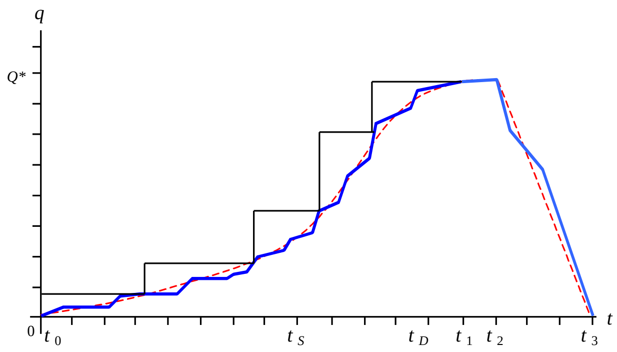


Fig. 1. Export container arrival and departure pattern for a ship

Fig. 2 shows the arrival pattern of truck in a container terminal during a day. There is a lot of outside trucks in the daytime but the number of arriving outside trucks decreases at night. This pattern is not made by the terminal operators but by the shipment agent. Conventional container terminals may cope with the unbalance of workload between the daytime and the night by allocating workers flexibly but the similar effect is not expected in an automated container terminal.

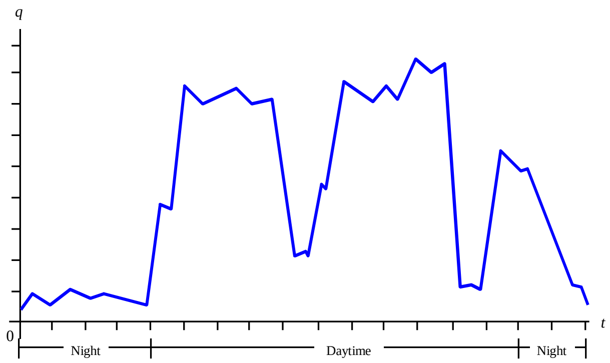


Fig. 2. Arrival pattern of outside trucks during a day

The characteristics of export containers arrival and truck arrival imply that utilizing temporary storage yard provide additional functions, such as workload balancing, efficient storage planning.

### *B. System Description*

In a temporary storage yard, two types of equipment, AGVs and yard cranes (gantry cranes) perform the receiving/delivery operation. AGVs transport the containers between a marshaling yard and a temporary r yard, and containers are unloaded from outside trucks or loaded on outside trucks by yard cranes.

The assumptions in this study are as follows.

- AGVs are dedicated to transfer operation between a marshalling yard and a temporary storage yard. The AGV, which finished the transfer operation, waits at the last transfer point in a marshaling yard or a temporary storage yard.
- The transfer point where outside trucks and AGVs stop and loading/unloading is performed are corresponding to the yard-bay of a temporary storage yard in one to one.
- A yard crane has no overlapped working area so as to avoid the interference with each other.

In an automated container terminal with a temporary storage yard, it is assumed to transfer the received containers, which are stacked at a temporary storage yard, in the daytime for balancing workload or at the initial free dwell interval, from a temporary storage yard to a marshaling yard. For applying storage planning efficiently, until the time, $t_S$ in Fig. 1, when the adequate amount of export containers arrive at a container terminal, they are accumulated in a temporary storage yard and next they are transferred from a temporary storage yard to marshalling yard.

Workload of gate-out operation can be distributed as gate-in operation. If terminal operators receive the precise information of import containers from shipment companies through EDI, they can prevent the congestion of workload by transferring some import containers from a marshaling yard to a temporary storage yard in advance. However, now, the import container for gate-out operation can be confirmed in container terminals. When both of the loaded AGV and the corresponding public-way truck are ready to perform a gate-out operation at the transfer point in a temporary storage yard, a yard crane transfer the container from the AGV to the truck.

The operations, which are modeled in this study, are as follows.

- Direct receiving operation: A yard crane receives a container from a truck and directly delivers the container to the corresponding AGV.
- Delivery operation: A yard crane receives a container from an AGV and delivers the container to the corresponding truck.
- Receiving operation: A yard crane receives a container from an outside truck and stacks it at a temporary storage yard.

Fig. 3 roughly depicts the operations of yard cranes in a temporary storage yard. Supposing that the above direction in figure indicates a marshaling yard and the below direction in figure indicates the gate complex, the left yard crane is performing gate-in operation, the middle yard crane is performing direct gate-in operation or gate-out operation, and the right yard crane is remarshaling.

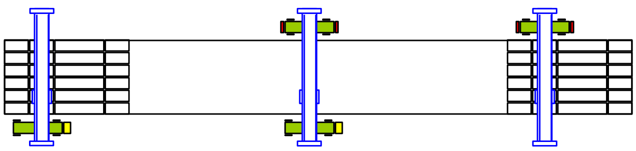

Fig. 3. Operations of yard cranes in a temporary storage yard

### *C. Operational Policies*

The following rules are applied for equipment dispatching in the system under this study.

- AGV dispatching rule: when a truck arrives at gate complex or an AGV becomes idle, the dispatching rule is triggered. Jobs are assigned to an AGV on a First-Come-First-Served (FCFS) basis. AGVs, which is waiting at a temporary storage yard, have priority over other AGVs for jobs of a direct gate-in operation.

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AGVs, which is waiting at a marshalling yard, have priority over other AGVs for jobs of a gate-out operation.

- Yard crane dispatching rule: when a truck arrives at the assigned transfer point in a temporary storage yard or a yard crane becomes idle, the dispatching rule is triggered. Jobs are assigned to a yard crane on a FCFS basis.

## III. ESTIMATION OF THE NUMBER OF EQUIPMENT

### *A. Simulation*

Various approaches, such as mathematical programming, queuing networks, computer simulation, have been proposed for the design and control of material handling systems. The usefulness of any of these tools depends on the nature of the problem. Equipment dispatching rules affect design elements in case of material handling system, such as container terminals [6-8]. Thus, an operational policy, implemented during shop operation, should be integrated to the design state to maximize the overall system performance.

Also, cooperation of equipment in a temporary storage yard and public-way truck invite complexity. As complexity increases, it is difficult to study the system through an analytical approach. Therefore this study will estimates the number of container handling equipment for a temporary storage yard through simulation. In this study, the simulation model shown in Fig. 4 simplifies the flow of containers and the activities of equipment.

Simulation, which can easily model the complexity, are often found to be time consuming. Although the speed of processing of the computers has increased considerably, paving the way for the use of simulation as a methodology for solving complex problems more realistically, use of efficient experimentation technique in conjunction with simulation would make the approach even more attractive.

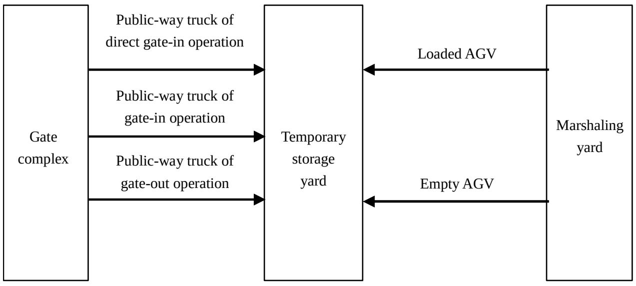


Fig. 4. Configuration of simulation model

### *B. Response Surface Methodology*

Response surface methodology is generally used to optimize “the performance of an unknown system (or a model of the system) that is subjected to controllable, uncontrollable and unknown variables”. Response surface methodology seeks to approximate the response function be a lower-order polynomial [9]. Denoting the criterion of effectiveness by $\eta$ and the decision variables as $X_1, X_2, \ldots, X_k$, the system can be modeled by $\eta = f\,(X_1, X_2, \ldots, X_k\ ;\ s)$ where $s$ is a random variable of mean zero and of variance $\sigma^2$, regardless of the decision variables. Application of response surface methodology for a first-order experiment involves a two-step procedure:

From an initial condition, known as the base point, a first order experiment is conducted to develop an estimate of the gradient direction. Using a $2^k$ factorial design or $k$-dimensional simplex design, it is possible to estimate the linear equation

$$\hat{\eta} = a_0 + \sum_{i=1}^{k} a_i X_i$$

where

$\hat{\eta}$ = an estimate of the system response under study.

$a_0$ = the response of the system at the base point.

$X_i$ = value of the $i$-th controllable variable.

$a_i$ = regression coefficient of the $i$-th controllable variable.

The second step involves moving from the current base point to a new point and performing the experiment again.

Termination usually takes place according to a criterion suitably defined for the system. Response surface methodology offers the twin advantages of optimization of unknown systems and efficient experiment

Some of the characteristics of the system under study have to be taken into account before the application of response surface methodology. Since the independent variables are integers in this experimentation, the response surface resembles a wire mesh with the lattice points representing the integral values. When moving from one base point to another, only the lattice points are considered.

The procedure is as follows:

Step 1. Identify an appropriate experimental region and set an initial base point by conducting $2^k$ factorial experiment.

Step 2. Fit a first-order regression equation from the regression observed.

Step 3. Find the combination of decision variables, whose estimate is more than 0 and closest to target waiting time, from the regression equation. Set it a new base point. In this study, the increment of $X_i$ is 1.

Step 4. Conduct an experiment after updating $X_1$ and $X_2$. If average waiting time of the experiment is less than target waiting time, then go to step 5. Otherwise, set an experiment region for a new base point, conduct an experiment and go to step 2.

Step 5. Identify the combination of independent variables that gives the satisfying waiting time in the most recent experiment, as the best solution.

## IV. EXPERIMENT

The simulation experiments are conducted so as to illustrate the estimation of the number of equipment through response surface methodology. As shown in Fig. 5, the simulation model is developed using simulation software ARENA and the experiment is conducted.

Table I shows the input data and parameters for simulation experiment. The simulation of the system was performed for 1000 public-way truck completion. A warm-up run of 100 job completions was used initially to minimize the effect of the ‘idle and empty’ condition. The design point for AGVs and yard cranes is ranged from (2, 2) to (8, 6). The average waiting times of full combinatorial experiments are represented in Fig. 6.

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TABLE I. INPUT PARAMETERS AND EXPERIMENTAL CONDITIONS FOR AN ILLUSTRATION

| Item | Value (unit: minute) |
|---|---|
| Interarrival time of trucks | Exponential distribution (2.5) |
| Ratio of operation (direct gate-in : gate-in : gate-out) | 10 : 40 : 50 |
| Traveling time of a truck from gate to transfer point in a temporary storage yard. | Uniform distribution (1,5) |
| Traveling time of an AGV from a marshaling yard to transfer point of a temporary storage yard | uniform distribution (4,10) |
| Traveling time of an AGV from a temporary storage yard to a marshaling yard | uniform distribution (2,8) |
| Traveling time of a yard crane per bay in a temporary storage yard | 0.2 |
| Target waiting time | 10 |

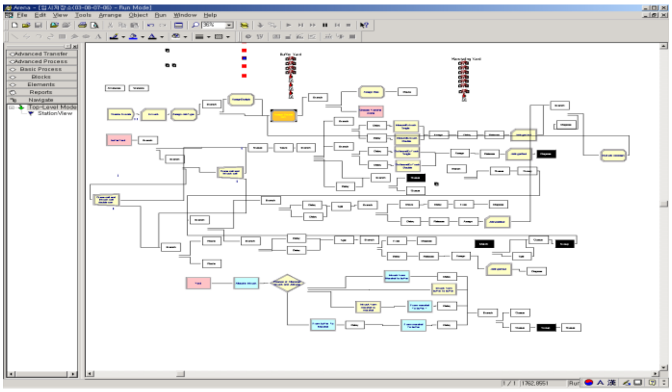

Fig. 5. Simulation model developed with ARENA

The regression coefficients and the average waiting times for each iteration of response surface methodology procedure are summarized in Table II. From the result of the experiment, the combination, that the number of AGVs is 5 and the number of yard cranes is 4, is seem to be the best combination satisfying the target waiting time.

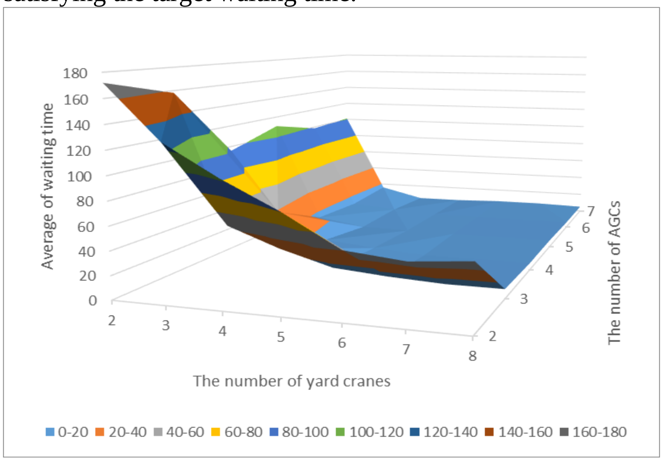


Fig. 6. Full combinatorial experiment

TABLE II. REGRESSION COEFFICIENTS FOR BUFFER STORAGE BLOCKS

| No. | Base point | | Waiting time at base point | Regression coefficients | | | Best solution | | |
|---|---|---|---|---|---|---|---|---|---|
| | $X_1$ | $X_2$ | | $a_0$ | $a_1$ | $a_2$ | $X_1$ | $X_2$ | *Waiting time* |
| 1 | 3 | 3 | 44.05 | 332.98 | -41.16 | -37.79 | 4 | 4 | 14.08 |
| 2 | 4 | 4 | 14.08 | 94.71 | -9.32 | -9.39 | 4 | 5 | 9.64 |

## V. CONCLUSION

In this study, we discuss how to operate a temporary storage yard in an automated container terminal, which will be used for resolving the difficulties to which the interaction between external manned trucks and internal unmanned equipment led. The operations, which are conducted in temporary storage yard, are analyzed and the equipment dispatching rules are proposed. The determination of the number of container handling equipment, such as AGVs and yard cranes is an important issue in designing of a temporary storage yard in automated container terminals. This study proposes simulation to evaluate the performance of a temporary storage yard considering the operational policies. By using response surface methodology for efficient experimentation, the best combination of design parameters under applicable operational strategies is obtained.

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