SPACE ALLOCATING STRATEGIES FOR IMPROVING IMPORT YARD PERFORMANCE AT MARINE TERMINALS

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Abstract: This paper focuses on the organization of the import storage yard at container port terminals. Three new stacking strategies are introduced which take into account the containers’ arrival and departure rates and the storage yard characteristics. A mathematical model based on probabilistic distribution functions is developed to estimate the number of rehandles required to manage an import container yard. The model is applied to the three proposed stacking strategies. Results show that the optimal strategy depends on stacking height and the relationship between vessel headway and container dwell time.

1. INTRODUCTION

Maritime transportation currently represents over 80% of world freight trade. Container trade is estimated to have increased by a factor of 5 during the last 20 years, which is equivalent to an average annual growth rate of 9.8%. This trade is forecast to double by 2016 and further increase by 2020 to exceed 371 million TEUs (Twenty Equivalent Units). Due to container trade growth, ports and terminal managers are having to increase terminal productivity and are trying to achieve the optimum terminal capacity.

The container terminal is considered to be a system made up of four subsystems, whose effectiveness and productivity affect the performance of the next subsystem. These subsystems can be considered as independent processes but their operation is influenced by the global system as a whole. The four main subsystems are: ship to shore, transfer, storage, and delivery/reception.

Likewise, one of the main problems of container terminals is their lack of space for storing goods. The difficulty in extending the premises combined with the increase in freight volumes transported by container ships makes it necessary to increase the terminals’ productivity and efficiency. One of the most common solutions is to apply multi-level stacking of containers, increasing the yard storage productivity and density, although overstacking has some negative effects regarding additional rehandling moves (reshuffling) of containers during the retrieval process, thereby increasing the turnaround time of trucks in the terminal and the operating cost.

The stacking problem is considered to be quite complex because of the uncertainty regarding which container will be needed first. Import container operations are especially uncertain because the information available on the departure time is unknown while containers are stacked, since trucks’ arrival time at the terminal to pick up the containers is random. Container stacking affects the time needed to retrieve the containers already in the yard as well as future container moves.
In light of this, this paper focuses on the organization of import bays by evaluating several different stacking strategies aimed at using the storage space efficiently in order to minimize unproductive moves and their associated operating costs.

The strategies developed in this study involve both a static and a dynamic stage aiming to eliminate the wasted space in the yard after applying mixed and segregation strategies. The methodology developed here will allow determining which strategy generates the fewest number of rehandles, which is the primary objective of this paper.

2. IMPORT STORAGE STRATEGIES

Each strategy has two stages: in the first stage, the containers from different ships are segregated (static strategy); and in the second stage, each strategy has its own procedure to mix the containers from different vessels, trying to make efficient use of the storage space by applying a combination of both static and dynamic strategies. In the second stage, each strategy can be described as follows:

- **Strategy 1 (S1).** The first strategy consists in starting to fill the oldest group of sub-blocks of the storage yard (the one composed by the containers that have been at the storage yard for a longer time), that is, stacking new containers on top of the ones that are already stored in the yard and belong to the oldest group of containers.

- **Strategy 2 (S2).** The second strategy follows the same operative as the first strategy did, although the filling order in the import block is just the opposite: it starts mixing those groups of containers with a shorter time at the terminal with those that have just arrived, in other words, the last group that has been stored in the terminal with the new inbound containers.

- **Strategy 3 (S3).** The third strategy requires clearing movements and rehandles during the operational planning. It consists in replacing old containers that are still in the terminal when new cargo is ready to be unloaded in the terminal. These new containers will be stored in those bays with fewer remaining containers, which in turn have the highest probability of leaving the terminal.

3. METHODOLOGY

The methodology consists on developing a mathematical model to calculate the expected number of rehandles over the time a container remains in the storage area (dwell time).

Assumptions:

- Ships’ interarrival time is constant.
- The number of containers is constant for all ships.
- The dwell time in the storage area follows a Weibull distribution. Other authors such as Watanabe (2001) assumed an exponential distribution to characterize the containers’ departure process. This exponential distribution function is a specific case of the Weibull distribution.
- The import block is divided into $K$ groups of bays (sub-blocks) and each sub-block has the same capacity.
- The maximum stack height is limited.
- It is not allowed to mix containers from more than two different ships in the same sub-block.
It is assumed that the time-planning horizon is cyclical.
Secondary rehandles have not been taken into consideration in the model.

### 3.1 A numerical case

The import storage yard has five sub-blocks (K=5) with the same capacity, which equals the number of containers per vessel. Each sub-block is divided into ten slots (length) and six rows (width). Containers are stacked up to three or five tiers high, where h=3 represents a container terminal with moderate volume, while h=5 represents a terminal operating close to its maximum capacity (congested). The terminal will be operated by rail-mounted gantry cranes (RMG), which have a maximum operative stacking height of six containers.

The arrival time of each containership is determined by the long-term schedule. It is assumed that the arrival rate of import containers follows a cyclic pattern equivalent (in terms of time) to seven ships arrivals, that is, the capacity of the import storage yard is designed to accommodate, at least, the unloaded container volume from seven ships (N=7). The amount of unloaded import containers per ship is 180 (n) when the stacking height is three tiers and 300 (n) when it is five tiers high.

The ship interarrival time $\Delta T$ is assumed to be constant. Different scenarios have been defined by increasing $\Delta t$ from 0 to 4.5 days. We assume that the dwell time in the storage $t$ follows a Weibull distribution with parameters $c$ and $\lambda$, whose values are: $c=1, \lambda=0.230$ (scenario (a)) and $c=1.5, \lambda=0.073$ (scenario (b)).

In the case of $c=1$, the dwell time, $t$, follows an exponential distribution. The terminal departure rate ($\lambda$) has been calibrated so that the dwell time reaches 4 or 5 days (the normal values for this type of freight in these terminals).

As an example of optimal strategies, in the following figure the optimal strategy for each specific value of $\Delta T/E(t)$, h=3 and scenario a is shown.

![Optimum strategy depending on $\Delta T/E(t)$ for scenario (a) and stacking height 5 (h).](image)
4. CONCLUSIONS

This paper has analyzed the performance of different storage strategies aiming to reduce the number of unproductive moves in the import container storage area. These strategies have been evaluated using the methodology described in this paper. The model that was developed enables the quantification of the expected number of rehandles (vertical rehandles and clearing moves) that result from combining containers with different departure probabilities in the same stack.

The main contributions of this paper are the following:

This model takes into account the different probabilities of leaving the terminal with regard to the time at which each container arrives. Therefore each container has a different probability of departure depending on time. This enables us to quantify the number of rehandles that result from having a mix of containers with different probability of departures in the same stack. This approach differs from previous studies which assumed that all containers have the same departing probability.

Three new storage strategies were defined for inbound containers, allowing the operations to be analyzed more in depth than the strategies developed in previous contributions. Castilho and Daganzo (1993) followed by Kim and Kim (1999) only considered two cases for import: segregation and non-segregation.

More specifically, we can observe that strategies S1 and S2, which are comparable to the non-segregation strategy, are recommended for terminals with a short average stacking height and a ship headway-to-container dwell time ratio less than 0.5, or when container dwell time is high. In contrary, for terminals with a small storage area and high traffic volume (when storage capacity must increase by way of higher container stacking), strategy S3 becomes preferable for inbound yard management, requiring fewer rehandling moves and thus demonstrating the advantage of dynamic strategies in these situations.

In this study, an analytic methodology based on probabilistic distribution functions was developed. This allows us to evaluate each strategy in a stochastic context and avoiding excessive computational calculations.

REFERENCES

