

The Influence of the Storage Strategy on the Complexity of the Container Selection Procedure

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Abstract. The paper deals with the practically and theoretically important problem of the container selection from the stacks of the container yard. This problem to a great extent determines the operational efficiency of the modern specialized maritime and dry container terminals. The severe ecological pressure exposed on the terminals ruled out the extensive way of the terminal development by the territory expanding. The permanent growth of the container flows leaves the only dimension to expand, to go high. In the same time, the increase in the operational height of container stack causes another big problem, that of container selectivity. With the growth of the number of tiers in the stack, the number of non-productive moves is also bigger, thus deteriorating the operation efficiency of the container yard. The results of the study shows that this problem could be fought by the changing the operational strategy of the box allocation in the container blocks of container yard. The benefits resulting from the changing of the strategy from the traditional horizontal filling of the empty space cell by cell and tier after tier to the vertical allocation of the boxes in sequential columns and rows are displayed on the concrete samples. This problem cannot be solved by the analytical mathematical techniques and should be treated with computer simulation.

1. Introduction

Containerization today is the dominating technology of the industrial goods' transportation, which leaves for the break bulk transportation ever narrowing niche [1,2]. The development of the international trade causes permanent growth of cargo volumes handled in container ports and terminals, while the correspondent growth of vessel sizes aggravates the demands for the operation efficiency in peak surges of shipload storage. The ecological pressure put on container terminals usually excludes any extensive development, since the port territories and water areas approach the boundaries outlined by the regional master plans [3,4].

Under these circumstances, the focus of this pressure falls on the most area-demanding element of every terminals, i.e. its container yard [5]. With the territory allocated for this site limited, the growth of the operational demands for container yards (playing the role of a buffer element in the technological chain of container handling system) is inevitably translated into the demand for the increase of the one-time storage capacity. In its turn, this factor becomes a driver for the increase of the stacking density, measured in number of containers stored on area unit. Today, the advanced



terminals display the values of this indicator around 1000 TEU per hectare, which assumes the utilization of highly productive and expensive technological equipment[6,7].

At the same time, the standard geometrical dimensions and very strict safety rules restrict the blueprint area of the stack foundation, leaving for the growth only one direction – vertical, demanding for the equipment with a bigger stacking height.

Solving the problem of increasing the stacking density, this approach creates a new problem, even more important from commercial and financial point of view. This is the problem of the container selectivity.

The bigger stacking height is, the bigger also will be the probability that a container claimed by the client (called “hot box”) would be blocked by other containers atop of it (“cold boxes”). In order to provide the access to the hot box, the cold boxes should be shifted to empty positions of the stack, which increases the labor input of operations and the servicing time. Whatever productive the equipment would be, these non-productive moves could ruin the economic foundation of container handling at the terminal.

A common stack of the container yard usually stores several cargo parties. Newly arrived “cold boxes” usually land over the previously arrived “hot boxes”. The latter ones gradually “sink” to the bottom of the stack. When there comes a request for a hot box, it is necessary to “dig” it out of the stack [8,9]. It is not possible usually to predict a moment when a container will be ordered from the stack, so the operational procedure practically is described by pure combinatorial schema

In order to fight the damnation of combinatorics, the container operators have developed several empirical strategies, which usually deal not with a single container, but concern general principles of the stack structure’s formation. These empirical strategies inevitably form a foundation for the next level of operational strategies aimed to reduce the non-productive expenses for box handling in the stack.

The goal of this study is to verify details of the basic combinatorial schema which form the operational tactics and strategy of container handling, to analyze them critically and offer some recommendation for their alternations. The ultimate goal is to develop more effective general strategy of container yard management.

2. Methods and materials

2.1. General description of the problem

The standard marine shipping container has right parallelepiped shape and strict geometric dimensions. The possibility to stack them one atop another provides the formation of the stacks which keeps the conformity of the cargo unit itself, i.e. the container. In other words, in any container handling system practiced by the terminal, the container stack forms a parallelepiped or a block of containers built by several tiers and rows. The cross section of containers in the stack (placed side to side and top to bottom) is a rectangular which is called a bay or section. This is illustrated by Fig. 1.

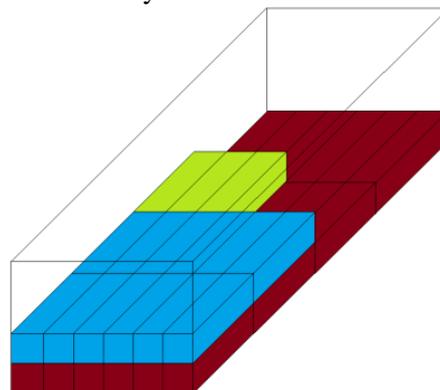


Figure 1. General configuration of the container block

The group of the most advanced and productive equipment providing the maximal stacking density is gantry cranes, rail mounted (RMG) and rubber tired (RMG). The construction of these cranes includes a massive still portal travelling over the container stack (block). In the span of the portal the trolley moves crosswise along the upper beams of the structure, equipped with the special box-catchment device, the spreader. The spreader put on a container can automatically catch it, lift and move to any location in the section of the stack or alongside of it. The transportation between different bays usually takes longer time since it involves travelling of the whole crane structure and precise positioning in a new location. Accordingly, practical reasons encourage avoiding these movements and performing all operations in one location over the same bay.

Accordingly, the problem of container selection as the first approximation (rather sufficient for practical purposes) can be regarded as two-dimensional task of operations in one rectangular cross-section of a block.

2.2. Formal description of the problem

The referenced cargo flow Q with a given cargo dwell time T_{dw} at the terminal allows to evaluate the size of one-time storage capacity of the container yard $E = Q \cdot \frac{T_{dw}}{365}$.

This volume, taking into account some external factors, is divided into a certain number of blocks $E = \sum_{k=1}^K E_k$. Every block has its width (number of rows w), length (number of bays l) and maximal height (number of tiers H).

The operational features of the vessels handling at the terminal enables us to evaluate an average volume of the cargo party, thus determining the average share of this party allocated for a block. Knowing the length of the block, it is possible to determine the average volume of the party V allocated for one bay of the block.

The external commercial environment of the terminal operation determines not only the cargo dwell time T_{dw} , but also the mean interval between party arrivals T_{int} . The ration $\frac{T_{dw}}{T_{int}}$ defines the amount of parties n with the average volume V to be stored in one section of the block. The total amount of the stored containers $n \cdot V$ divided by the area of the block $w \cdot l$ (measured in terminal ground slots) gives the average stacking height $h = \frac{n \cdot V}{w \cdot l} = \frac{T_{xp} \cdot V}{T_{um} \cdot w \cdot l} < H$.

The task is to evaluate the dynamic behavior of this variable against the static average value, the number and the total transportation distance of all moves needed to operate the block under given conditions.

2.3. Necessity and goals of the simulation

The problem of the random selection of elements from a set traditionally belongs to a mathematical branch called combinatorial analysis or combinatorics. The difficulty of this problem is in a very high sensitiveness of the solution to the initial state. Moreover, every move performed for selection of a current element strongly affects the relevant branch space of the problem solution tree.

Additionally, this problem is not a pure mathematical one, since the allocation of arriving parties could follow different rules, as well as the relocation of blocking elements at every step does.

Eventually, the solution of this problem requires to identify not only dependences of the number and distance of the moves on the numeric values – number of parties, average height, but also from the strategy of the initial allocation and shifting of the boxes at every step of the handling procedure.

Traditionally, the strategy of the arriving containers allocation assumes keeping the minimal surface elevation (“flat relief”). Under this strategy every arriving container is placed in the lowest free position (slot) in the block. If there are several equal positions, the nearest one to the already formed massive in the tier is selected. The resulting strategy bears the character of epithelial growing of stratum after stratum, as Fig. 1 shows.

The similar strategy is used also for the removal of the blocking “cold boxes”: the upper one is shifted to the lowest position in the section; if there are several alternatives positions, the closest is selected. The same procedure is repeated for every next blocking container.

Fig. 2 shows the example of the epithelial (horizontal) allocation procedure for initial allocation and operational shifts of blocking containers.

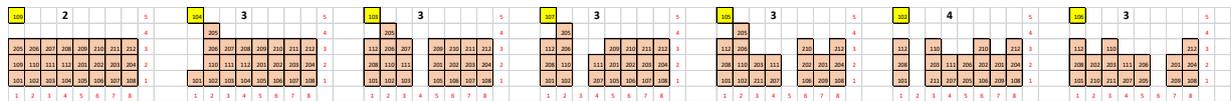


Figure2.Horizontal allocation and operation strategy

The figure displays the current structures of the block, the box selected at the step and number of moves requires to dig it out.

At the same time, it is possible to offer another strategy that seems to be paradoxical from the first glance. This strategy assumes a dense allocation of the arriving containers in a compact block of the maximal height, thus providing the same epithelial allocation procedure, but vertically oriented (Fig. 3).



Figure3.Vertical allocation and operation strategy

As one can see from this figure, the amount of moves at every step of the procedure drops significantly in respect to the horizontal strategy.

The preliminary simulation experiments, similar to the ones shown by Fig. 2 and 3, with different block dimensions and numbers of parties, gave the reduction of total moves per selected container in the range of 20-30%, which is quite a significant value.

At the same time it also has been proved that the methodological reasons discussed above exclude any other tools for the study except for the simulation: the analytical toolkit of mathematics really turns out to be powerless for this kind of problems.

3. Results

The results given by the simple models of basic combinatoric dependencies enable to conclude that the primal mechanisms responsible for the operational complexity seem to be studied insufficiently. The reduction of the number of moves for 20-30% is too significant value to deprive these basic mechanisms of additional fundamental studies.

Simultaneously, in order to conduct the studies of this kind it is necessary to develop the software tools to make massive and different experiments, explore a wide variety of managing strategies. The development of hidden trends and lows also assumes that this software complex include an equally powerful methodological apparatus for statistical data acquisition and interpretation.

The discussed results permit only to define a general direction for this study, to state the hypothesis and evaluate the perceptiveness.

4. Discussion

Even if the full-scaled experiments would show the expected convergence of the results, this will be only the first step in the indicated direction of the study. The transfer from the sections to the blocks, block groups and the whole yard levels could not preserve these promising results.

Many practical restrictions (e.g. aimed to avoid occasional “towers” of containers in the stack, demanding to form “slopes” at the periphery of the blocks, taking into account client ownerships etc.) could also blur the “pure theoretical” effect observed in the modelling experiments.

On the other hand, the degree of these pessimistic assumptions could be assessed only by the further studies and introduction of more adequate models, which in its turn would affect greatly the operational technology of container terminal planning and control.

5. Conclusions

1. The mathematical problem of combinatorial complexity of operations over the simple section of container block is studied.
2. It is proved that the suggested solution depends not only on the geometrical characteristics of the studied segment, but also on the sequence of the previous operations and the strategy of shifting of blocking containers.
3. It is shown that this problem cannot be solved by the analytical mathematical techniques.
4. The goal and tasks for the simulation procedure are discussed.
5. The simulation results have revealed a significant reduction in number of non-productive moves with abandoning traditional strategy of stack planning.
6. The results of the study are critically analyzed to state the goal of the further study.

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