Research of the Main Storage Area of the Container Terminal

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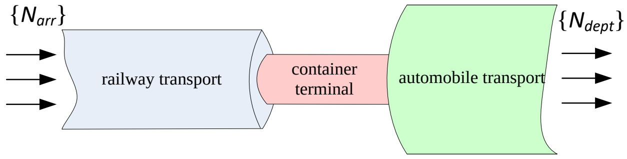
ABSTRACT---The research is aimed at finding rational values of container terminal parameters. Lifting and transport machines are compared with each other from the position of storage area capacity. The results allow estimating the terminal throughput capacity depending on the technical equipment of the site and the storage period of containers. The aim of the research is to improve the search for rational values of the container terminal parameters. Due to the given research mathematical models of the interrelation of the fundamental values of parameter sites of the basic storage of the container terminal equipped with reach stacker offered by Kalmar companies. Dependencies of a platform capacity on length of a storage site are resulted. Also in research results of processing ability of the container terminal in a year are resulted.

Keywords: container terminal, hoisting-and-transport cars, throughput capacity, shelf life, reach-stacker, portal auto-loader, gantry pneumatic-tired crane, gantry container crane.

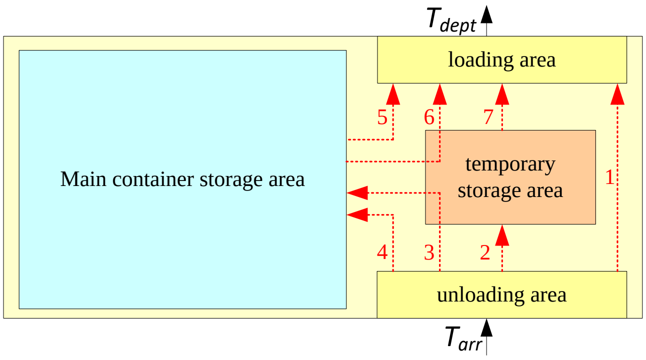
I. INTRODUCTION

Container transport plays an important role in international transport. The level of development of cargo transshipment terminals is one of the determining factors in freight transport. To date, one of the most significant factors that have a negative impact on the timely transformation of container flows is the capacity of cargo terminals. The purpose of the container terminal is to convert the container flow parameters with the least cost of basic resources. It should be noted that technical and technological solutions play an important role in increasing throughput capacity. Usually, when calculating the capacity of the entire supply chain elements, the following factors are taken into account:the number of lanes of the highway, maximum speed resolution, road load factor, number of main tracks on the runways, type of traffic schedule, number of stationary receiving and unloading tracks, technical equipment of loading and unloading sections of the container terminal, type of the used hoisting and transport machines and many other factors. As can be seen in Figure 1, the container terminal is still a bottleneck and the capacity of the entire supply chain is set up along it.



Picture 1: Conditional flow diagram of supply chain elements: $\{N_{arr}\}$, $\{N_{dept}\}$ - container flow parameters on arrival and departure, respectively

If you consider a container terminal as a technical system, all systems should have a clear structure with elements and the relationship between them (see Picture 2).



Picture 2: Container terminal structure: T_{arr}, T_{dept} - arrival and departure transport, respectively; 1-7 - in-terminal transport

The rational arrangement of the terminal's process areas affects throughput, but this study has had a more limited objective of showing the impact of the handling machines on throughput. Below are the advantages and disadvantages of the most used machines in the main storage area.

II. BRIEF ANALYSIS IN THE AREA OF CONTAINER TERMINAL CAPACITY

In the conditions of continuous growth of container flow on the railways of Uzbekistan, a significant problem is the increase in the capacity of container terminals. This problem is related not only to the rational design or reconstruction of the terminal but also to the increased use of loading and unloading machines, container allocation and throughput capacity.

In the present research, it is proposed to solve the issue of site capacity by studying the relationship between the main parameters of the container terminal, transport container

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(container) and portal loader.

In the literature sources, the study of container terminal capacity is also related to the participation of water transport. In [2] [Chen, L., Lu Z. [2012] considers the issue of container placement, the first step is to determine the approximate number of container seats in each tier. More precise container capacity is determined at the second stage. The question of placement at the first stage is solved by means of linear programming, while for the decision of a question at the second stage, it is applied by transposition of containers. As noted in (3) [Cristina Serban, Doina Carp [2017] one of the strategies for managing container capacity in a terminal is the shelf life, with each incoming container assigned a priority class. The authors of the study (4) [Dekker R, Voogd P, van Asperen E. [2006] considered the issue of container stacking at an automated container freight terminal. In work variants of placing of containers on the categories offered in article are analyzed. The article (5) [Galle, V., Barnhart, C., and Jaillet, P. [2018] is related to the search for rational container placement, which minimizes the number of loading and unloading operations required for transshipment from marine to road transport. The authors Kim K.H. (Kim K.H.) and Kim H.B. (Kim H.B.) have developed mathematical models and solution methods to obtain an optimal solution for capacity utilization. It was suggested that newly arrived containers should not be stacked on containers that arrived earlier (6) [Kim K.H., Kim H.B. [1999]. In studies (7) [Luo J, Wu Y, Halldorsson A, Song X [2011] notes that over the last four decades there has been increased interest in the study of container terminal operations. For example, the article "Storage and stacking logistics problems in container terminals" analyzes and classifies the sources of literature on finding a solution to the problem of container capacity and location in the terminal (7) [Luo J, Wu Y, Halldorsson A, Song X [2011] set a goal to inform the scientific community about the capacity and functioning of the container terminal. In (9) [Steenken D, Voß S, Stahlbock R [2004] describes and classifies the main logistics processes and operations in container terminals and provides an overview of their optimization methods. The authors of the article (10) [Virgile Galle, Cynthia Barnharta, Patrick Jaillet [2018] considered the issue of optimization of handling machines in the placement and removal of containers from the terminal storage area. In (11) [Zhang C, Liu J, Wan Y-w, Murty K G, Linn R J [2003] investigated the movement of a material handling machine in the main container terminal storage area.

There is no uniform approach in the literature in determining the capacity of the container terminal, and studies are often aimed at the problem of interaction of water transport with land transport modes.

III. PROCESSING CAPACITY OF THE CONTAINER TERMINAL

The controlled parameter of the container terminal is the capacity of the main storage area R, determined by the number of containers placed in the width x, the length of the site y and the stacking height z.

Since there is a certain functional dependence between the variables R, x, y, z, and container turnover η, such that the processing capacity E and container terminal capacity R can be expressed through x, y, z and η, the task is to determine the rational values of these expressions. Then the task of optimizing the processing capacity of container terminal E can be formed as follows: for the given characteristics of the incoming container flow it is necessary to find such x, y, z and η, which would lead to the optimization criteria E to the maximum, that is:

$$E = f(x, y, z, \eta) \to \max, \quad (1)$$

the variables x, y, z and η must be restricted:

$$\left.\begin{aligned} x_{\min} \le x \le x_{\max} \\ y_{\min} \le y \le y_{\max} \\ z_{\min} \le z \le z_{\max} \\ \eta_{\min} \le \eta \le \eta_{\max} \end{aligned}\right\}, \quad (2)$$

The values of $x_{\min}$ and $y_{\min}$ are determined by the minimum capacity requirement for a certain container flow, taking into account the storage time τ of these containers, and the maximum values are determined by the area allocated by the regional, city or district administration. The value z depends on the technical characteristics of the handling machines. It follows from the physical meaning that $\eta_{\max} = 1$ day.

The method of directional enumeration of variables is the most appropriate for the integer variables. The algorithm of searching for the most rational values of terminal parameters consists of the following stages:

- definition of the minimum allowable values of parameters;
- sequential increase of parameters by one unit;
- continuation of the search until the most rational values of parameters corresponding to the maximum processing capacity of the container terminal are found.

IV. DEFINITIONS OF CONTAINER TERMINAL CAPACITY SERVED BY REACH STACKERS

With the development of small and medium-sized businesses in Uzbekistan, the light industry is actively developing. In this regard, there is a need for transportation of goods in containers. To date, the processing of containers with the help of reach-stacker (stacker with retractable load-carrying) is one of the most flexible ways to reload containers.

The maneuverability provided by the retractable boom and spreader allows using the reach-stacker efficiently and due to this, the productivity of this loading and unloading machine is relatively higher than that of other types of machines used at container terminals (see Pic. 9).

Picture 9: Basic parameters of *Kalmar'sDRF420-60S5L* reach stacker

Depending on the length and height of the reachstacker boom, it is possible to load containers with gross weight from 11 to 42 tons. Picture 10 shows the characteristics of *Kalmar's DRF420-60S5L* reachstacker.

Picture 10. Kalmar's reachstacker load capacity is DRF420-60S5L

It is necessary to note the possibility of operation of the reachstacker at the railway loading and unloading section (see Pic. 11). Among all types of loading and unloading machines, reach-stacker is very popular in the loading and unloading areas of the container terminal.

Pic. 11. Possibility of loading and unloading on the second railway track

However, it is necessary to note the disadvantages of using reachstacker in the main storage areas. First of all, it is the capacity, because of wide passages for maneuvering the car. High fuel consumption, as well as the high cost of asphalt pavement (depending on the model of reachstacker).

As mentioned above, the main disadvantage of this machine is its capacity. A more limited task in this paper was to find an increase in container capacity in the main storage area.

The capacity of the main storage area of the container terminal can be determined by the following formula:

$$R = x \cdot y \cdot z, \qquad (4)$$

where x is the number of containers placed in width;

y - the number of containers placed along the length;

z - number of container tiers by height.

The number of containers placed in the width of the main storage area equipped with a reach stacker is determined by the formula 5:

$$x = \varepsilon \left\{ \frac{B - n \cdot B_{arr} - C}{\left(b_{cont} + \lambda\right)} \right\}, \qquad (5)$$

where B is the width of the main storage area, m;

n - number of longitudinal passages between stacks of containers (see formula 3);

B_{arr} - width of passage for reach stacker, m (see Pic. 9);

($b_{cont}+\lambda$) - width of one container, taking into account the gap between the containers, m;

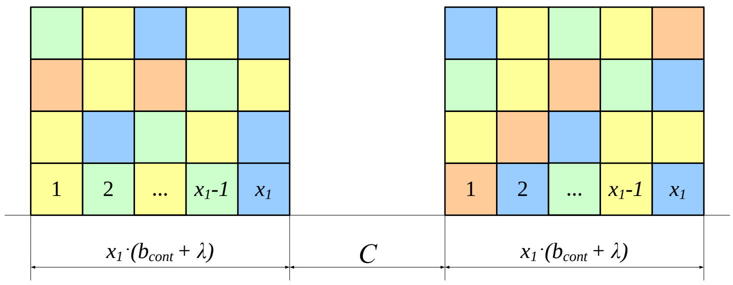
C - longitudinal passage width, m (taking into account the passage for the reach stacker, the width of road transport and half the size of the approximation of the structure) (see Pic. 12);

ε{...} - designation of the whole part of the number, resulting from the actions in curly brackets.

Pic. 12: Longitudinal width for reach stacker, motor transport along the railway line

To determine the total number of containers x by width in the main storage area, first calculate the number of longitudinal passages n, which depends on the number of containers placed at the depth of stack x_1:

$$n = \varepsilon \left\{ \frac{B - (b_{cont} + \lambda) \cdot x_1 - C}{\frac{x_1}{2} \cdot (b_{cont} + \lambda) + B_{arr}} \right\} \qquad (6)$$



Picture 13. Number of containers placed at stack depth x1

The number of containers placed along the length is determined by the formula (7).

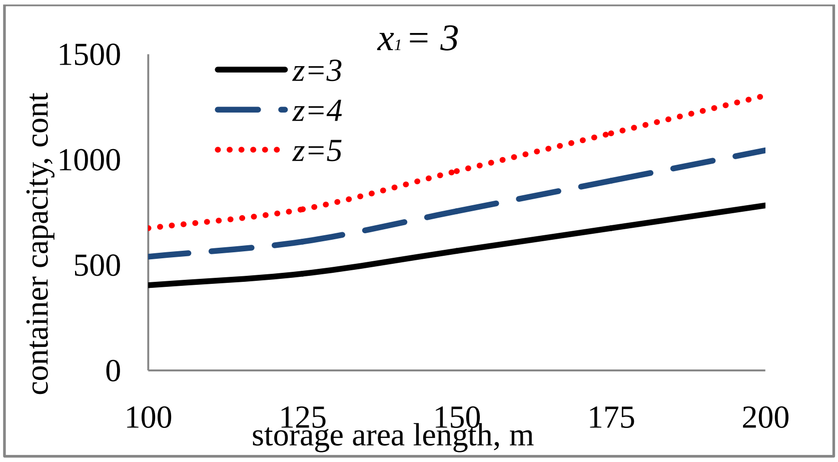
$$y = \varepsilon \left\{ \frac{L - m \cdot B_{arr}}{\left(l_{cont} + \omega\right)} \right\}, \qquad (7)$$

where L is the length of the main storage area, m; m is the number of transverse passages along the length of the main storage area (for reach stacker are accepted after 80-100 m); ($l_{cont}+\omega$)- the length of one container, taking into account the gap between containers, m.

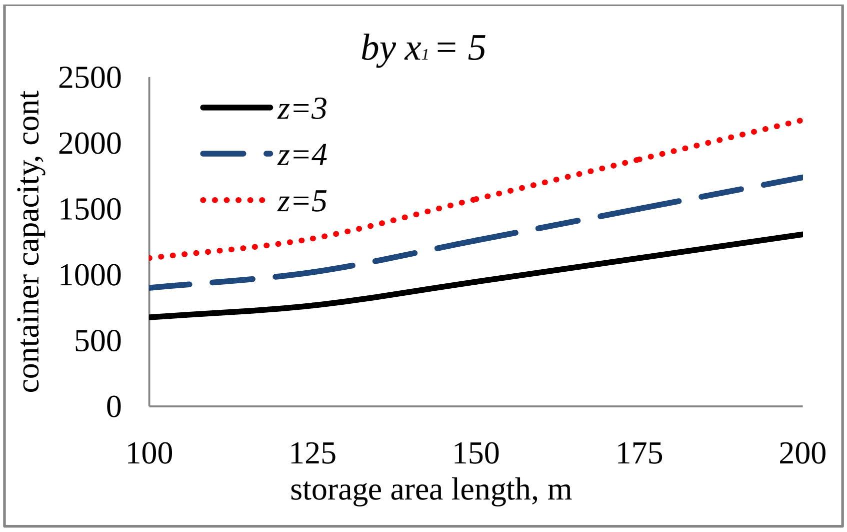
The number of container tiers in terms of height z at the reach stacker service is accepted according to the technical characteristics of the loading and unloading machine (see Pic. 10).

V. DISCUSSION OF THE RESULTS

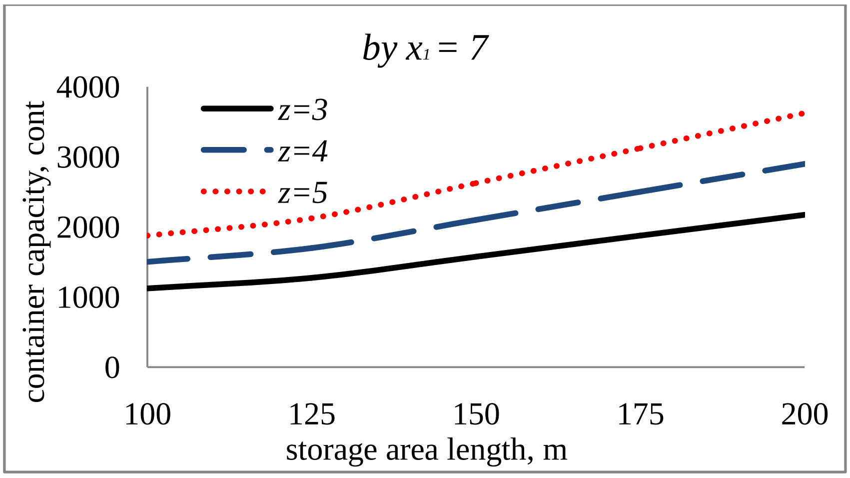
Pctures 11-13 show graphs of the results of the dependence of container capacity on the length of the storage area of the container terminal. It can be seen from the graphs that the total capacity of the terminal is primarily influenced by the number of containers placed at a depth of stack x_1. It should be noted that the more x_1, the higher is the probability of the number of in-terminal processing of containers. That in the final account influences additional expenses.



Picture 11. Container capacity depending on the length of the platform at x_1= 3

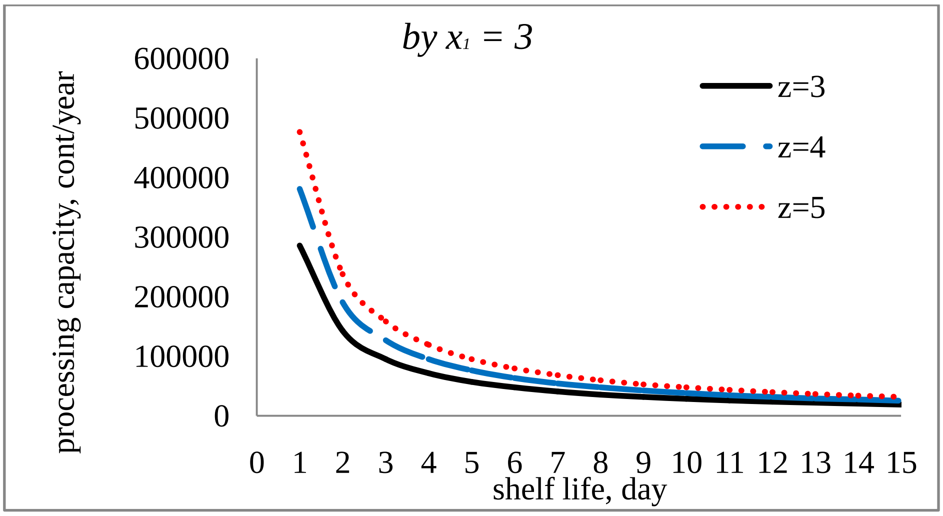


Picture 12. Container capacity depending on the length of the platform at x_1= 5

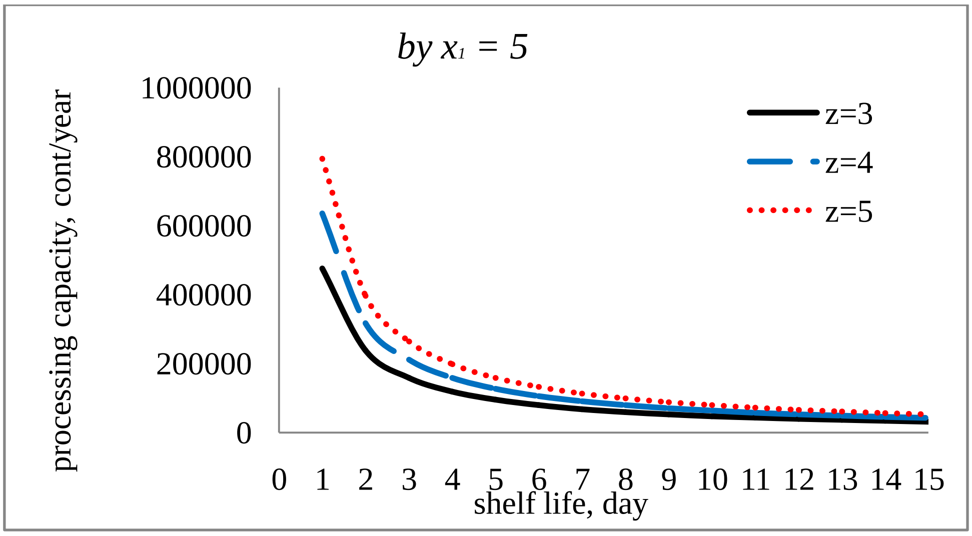


Picture 13. Container capacity depending on the length of the platform at x1 = 7

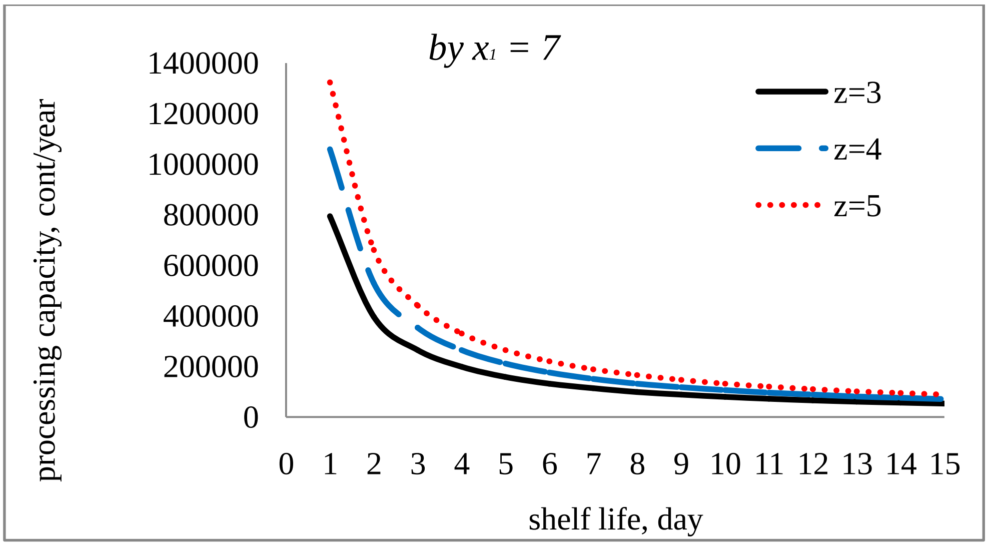
Pictures 14-16 show that the terminal's processing capacity increases with short shelf life, i.e. up to 5 days. It is also necessary to note the effects of the number of containers placed at a depth of stack x_1.



Picture 14. Container term processing capacity at x_1= 3



Picture 15. Container term processing capacity at x_1= 5



Picture 16. Container term processing capacity at x_1= 7

VI. CONCLUSION

The analysis shows that the rational parameters of the container terminal depend primarily on the technical characteristics of material handling machines, type of containers and container turnover. It is also recommended to apply the method of directed search to determine the most rational values of parameters.

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