The Application of Simple Simulations of Loading Operations for the Chosen Container Terminal

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Intermodal transport and especially container shipments have been characterized by a dynamic growth, both in Poland and globally. One cannot ignore the importance of technical preparation and organization of terminals which perform integrated loading units reloading. Various elements of IT infrastructure have been introduced to seaports for the last years and they aim at improving the working conditions. Ground terminals, usually small reloading centres, most often give up any modern solutions and blame it on the lack of appropriate funds. The paper presents the rules of carrying out a simple simulation the results of which can become useful for improving activities at container terminal.
Keywords: simulations of loading operations, container terminal, intermodal transport.

Nowadays the majority of cargo on European routes is carried by roads (approx. 80%), which badly influences the environment. The White Paper promotes however the limitation of road transport to be replaced by other modes of transport by promoting intermodality [3]. The main characteristic of such a solution is carrying cargo from the consignor to the consignee in the same loading unit e.g. a container, but with the usage of various modes of transport. In western Europe approx. 16% of cargo is carried in this way [1] while Poland unfavourably differs in this respect from other member states. Nevertheless for the last years a steady increase in number of transported containers has been observed which is due to convenient location on a route connecting the western and eastern parts of Europe and Asia. The already existing terminals in Poland are being extended and the new ones are being built. Unfortunately container terminals have limited capacity and very often it is impossible to enlarge them. As a result more layers are added in order to increase the capacity. Although such a solution allows a bigger number of containers but at the same time it hampers tracing individual containers and therefore it hampers any operations on this particular container. As the number of reloaded unit grows new problems arise. For smaller terminals finding a containers does not cause much trouble for the staff, but nowadays terminals serve a great number of consignees and consequently finding a particular container becomes extremely difficult. Therefore any further development of intermodal transport in Poland is impossible without introducing proper IT solutions and without automated yard management systems. The next step should be a complete automation of terminals.

Another important issue is the time of handling drafts of cars on rail terminals. A big number of handled drafts determines the need of fast reloading. This paper presents a simulation which aimed at comparing the operations of handling drafts of cars depending on way of storing on the yard and on the order of loading units for unloading.

1. DETERMINING BASIC PARAMETERS FOR THE TERMINAL

The terminal being described is located in central Poland and its annual turnover is approximately 150 00 TEU.

The loads are carried in various loading units. Table 1 shows the structure of types of loading units.

Table 1. The share of various container types in Total turnover of the terminal.

Container type	Share	Amount [TEU/year]
20`	40%	6000
30`	5%	750
40`	40%	6000
45`	15%	2250
total:	100%	15000

Table 2 shows the required area of storage for each type of a container.

Table 2. Storage area for each container type.

Contain-er type	total	measure-ments of the container's base	The area of the base [m^2]	The area for each type of a container [m^2]
20'	270	6,1x2,4	14,64	1317,6
30'	32,4	9,2x2,4	22,08	238,464
40'	140,4	12,2x2,4	29,28	1370,304
45'	54	13,5x2,4	32,4	583,2

If we add up the areas necessary for All types of containers we will get the area of the whole storage area. The indispensable size of the area is 3510 m^2.

No matter of what kind of storage we choose, the above given storage area must be provided.

2. THE CHOICE OF STORING METHOD FOR CONTAINERS IN THE TERMINAL

Delivering containers to the terminal should be finished by an appropriate arrangement of loading units. It seems that in the process of container arrangement the most important issue is to minimise the number of operations for each container as it results in shortening handling time.

The algorithm according to which containers will be arranged must take into consideration many technical and organizational factors. The proper container management, also called yard planning, directly contributes to shortening cycle times, and consequently to increasing the capacity of the loading centre and to lowering costs connected with performing needless loading operations.

While choosing an adequate algorithm which manages receipts, releases and storage area of each container, one should typically take into consideration the following criteria:

- **Time of receipt** – depending on the date of the receipt of a container, it should be located accordingly. The sooner the receipt date the higher level of storage. It will ensure minimum number of operations when a container is released.
- **Container type** – one of the key criteria, containers of each type are stored at the same location. 20`, 30`, 40` and 45` containers are stored separately. It improves the stability of any given container block when more levels are used for storage. Such an arrangement of containers also facilitates significantly identification of units.
- **Creating a draft of cars** – in case containers are transported on a train, the arrangement of containers on cars is planned well ahead. Therefore it is possible to pick the containers which will be transported by rail and store them separately which will significantly speed up loading operations. It must be remembered however, that containers going to different destination points should not be loaded together. Also the draft of cars has limited length so if a container is not loaded on one of drafts it has a priority on the next day.
- **Loading capacity** – this criterion takes into consideration the weight of containers. They are stacked according to their weight: heavier containers should be stored on lighter ones, and the heaviest containers should be stored on the lowest level. Empty containers should be stored separately, on a so called depot.
- **Vessel operators** – on terminals where containers belong to a few vessel operators, they can be stored on separate yards, each dedicated for one operator only. It will minimize problems with container identification.

It is not possible to fulfil all the criteria at the same time and therefore the appropriate way of storage should be chosen in order to perform specific functions. In each terminal the differences lie in different geometrical structure, in number of handled containers, in technical conditions of reloading devices etc. In the case under discussion two ways of storing containers and a few ways of positioning loads on container cars have been dealt with, according to a fixed rule.

3. EXAMPLES

It has been analyzed whether the method of storing containers according to the size of loading units or according to appurtenance to a vessel operator appeared relevant. Storing limitations have been plotted against the way of loading containers onto rail cars. In order to obtain the minimum value the times of serving different configurations of various storing and container arrangements inside cars have been compared. They were used to calculate the most effective option, from the point of view of time needed to serve the draft of cars.

The simulation calculations have been carried with the usage of a standard calculation sheet. The idea behind this action was not to complicate the situation but to obtain trustworthy information.

3.1. STORING CONTAINERS ACCORDING TO THEIR SIZE

In that case containers will be stored on a yard according to their size, starting with 20-foot containers and finishing with 40-foot ones. They will be stacked on 3 levels and in 4 rows, so the total width will be approx. 10 m. The length of areas for each container type can be calculated on the basis of tables 1 and 2, where the number of containers is given. Knowing the length of each container type and their number in one row, it is possible to calculate the length of the storing area for each container size. The way of arranging containers has been presented in figure 1.

In the upcoming parts of the paper the times of serving a train with various container arrangements on cars will be compared. A simplified way of arranging containers on trains must be assumed. Containers are freely located on cars and it happens occasionally that cars with 30 and 40-foot containers are completed with 20-foot ones. It happens quite seldom however, that the whole space on a car is used up, which may result from the fact that containers originate from various vessel operators or that cars may be attached at different side-tracks. On a terminal a train can be composed of maximum 17 cars which have the loading length of 60’, and the maximum number of containers is 28.

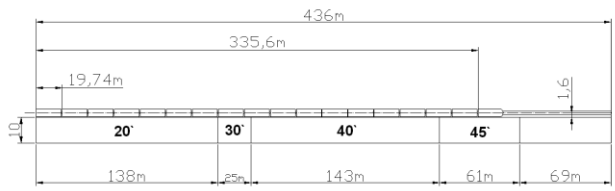
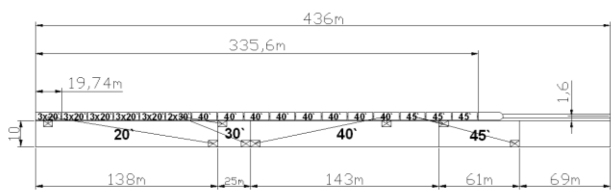


Figure 1 The way of arranging containers on the terminal.

3.1.1. Containers leave according to their size

First case focuses on the most advantageous arrangement of containers on the train, which means they are in the ascending order starting at the end of the train. The servicing time of each container is an arithmetical average of the shortest and the longest possible cycle. The distance which the gantry will have to cover depends on the placement of the container and the actual spot it is to be transferred to. In the drawing no 2 one can observe the way the containers are put on the train and the examples of routes the containers will have to cover. The figures determine both the longest and the shortest distance.



Drawing 2. The arrangement of containers on the train and their possible routes.

Due to a great number of calculations while determining the length of the train servicing it was used a calculation sheet, and below there are presented the assumptions applied for the calculation.

It was assumed that if the container is next to the spot it was to be put the shortest possible distance is the distance the gantry has to cover from the carriage to the spot. It was stated that the distance is 3 meters according to the guidelines[2]. I also established that due to the collision-free nature of the undertaking, the height to which the container can be lifted is about 1 meter. However, if the container is beyond the space it is to be put on (as the 30` container in the drawing no 2), then the shortest possible cycle will be calculated on the basis of the route to the closest free room in the storage area determined for the given container type. In this case the container has to be lifted over 3 levels. Due to the possible collisions, the manoeuvrable height is 10 meters. The longest possible cycle will be calculated as the time of transport to the furthest point of the storage spot, as it is shown for the 20` and 40` container in the drawing no 2. In this case the container will also have to be lifted over 3 levels, which is 10 meters. It was established that the movements of the cart and gantry were associated. However, the lifting and lowering movements of the spreader will not be associated due to the possible collisions. The simplification regarding the container`s placement on the carriage was considered as well. The gantry`s route is calculated starting in the middle of the carriage on which the container is, regardless the number and type of the containers. This simplification reduces the amount of calculation without significant changes in the result. The manipulation time is t_m=2 min. It is enough to put the container spreader in the right position.

A full interpretation of the work cycles of shipment machines can be attained at work. [2]. Cycle time after a consideration of the above guidelines is determined by the following equation:

$$t_c = \frac{(2 \cdot t_{ok} + 2 \cdot t_{jk} + 2 \cdot t_{pk} + t_m)}{2} + \frac{(2 \cdot t_{od} + 2 \cdot t_{jd} + 2 \cdot t_{pd} + t_m)}{2} \qquad (1)$$

where:

t_{jk} – the time of gantry`s movement (the shortest), $t_{pk}$ – the time of lifting/lowering of the container spreader (the shortest) $t_{ok}$ – the time of lifting/lowering of the spreader together with the container (the shortest) $t_m$ – the manipulation, $t_{jd}$ – the time of gantry`s movement (the longest), t_{pd} – the time of lifting/lowering of the container spreader (the longest), t_{od} – the time of lifting/lowering of the spreader together with the container (the longest),

The speed of the gantry`s particular:

$V_p = 20 \left[\frac{m}{\min}\right]$ – the speed of lifting/lowering of the spreader,

$V_o = 10 \left[\frac{m}{\min}\right]$ – the speed of lifting/lowering of the spreader together with the container,

$V_j = 100 \left[\frac{m}{\min}\right]$ – the speed of the cart and gantry.

In order to determine the length of the movements it is necessary to determine the route they will cover. According to the above guidelines, the routes of the 20` container equal:

- d_{jk}= 3 [m] – the route of the cart (the shortest)
- d_{pk}=1 [m] – the height of lowering/lifting of the spreader (the shortest)
- d_{ok}= 1 [m] – the height of lowering/lifting of the spreader together with the container (the shortest)
- d_{jd} = 138-9,87=128,13 [m] – the longest route of the gantry
- d_{pd} = 10 [m] – the height of lowering/lifting of the spreader (the longest)
- d_{od} = 10 [m] – the time of lifting/lowering of the spreader together with the container (the longest)

After replacing the equation figures with the above data, we have:

$$t_{c20`} = \frac{(2 \cdot \frac{1}{10} + 2 \cdot \frac{3}{100} + 2 \cdot \frac{1}{20} + 2) + (2 \cdot \frac{10}{10} + 2 \cdot \frac{128,13}{100} + 2 \cdot \frac{10}{20} + 2)}{2} \approx [illegible] [\min]$$

The servicing time of other freight units was determined In the similar way.

For the 30’ containers the cycle equal:

$$t_{c30`} = \frac{(2 \cdot \frac{10}{10} + 2 \cdot \frac{29,43}{100} + 2 \cdot \frac{10}{20} + 2) + (2 \cdot \frac{10}{10} + 2 \cdot \frac{54,43}{100} + 2 \cdot \frac{10}{20} + 2)}{2} \approx [illegible],8 [\min]$$

For the 40’ containers:

$$t_{c40`} = \frac{(2 \cdot \frac{1}{10} + 2 \cdot \frac{3}{100} + 2 \cdot \frac{1}{20} + 2) + (2 \cdot \frac{10}{10} + 2 \cdot \frac{103,49}{100} + 2 \cdot \frac{10}{20} + 2)}{2} \approx [illegible],7 [\min]$$

And for the 45’ containers:

$$t_{c45`} = \frac{(2 \cdot \frac{10}{10} + 2 \cdot \frac{19,77}{100} + 2 \cdot \frac{10}{20} + 2) + (2 \cdot \frac{10}{10} + 2 \cdot \frac{80,77}{100} + 2 \cdot \frac{10}{20} + 2)}{2} \approx [illegible],0 [\min]$$

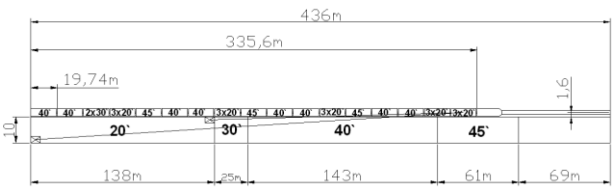
The above examples show the calculation way of the cycles of the particular cases. After calculating of the cycles for every container on the train, it is possible to calculate the train`s servicing time as their sum. Due to the printing size, the results will not be presented here in the tables.

3.1.2. Containers leave according to the ship owner and their size

In this case, the train consists of carriages which belong to four ship owners, each of which owns 4 or 5 carriages. Each ship owner put on the carriages containers from 20` to 45`. The calculations will be based on the same guidelines as when I discussed the ascending order of the containers.

3.1.3. Containers go in according to the ship owner and the order is conversed

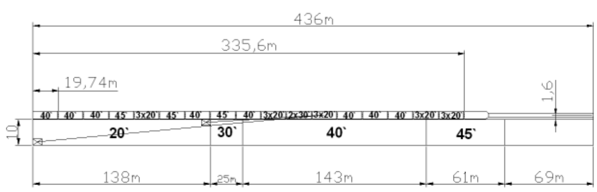
This case is different than the previous one when the containers were arranged from 45` to 20`, as it was presented in the drawing no 3.



Drawing 3. The conversed order of the containers (4 ship owners)

3.1.4.Containers go in according to the random order

In this case the arrangement of the containers is random. It was calculated in order to check the influence of the whole fortuity in the arrangement of the containers going onto the terminal on the whole train servicing time. The arrangement was made by means of the calculation sweet. It is illustrated in the drawing no 4 along with the example sample of the container`s route.



Drawing 4. Containers are randomly arranged on the train.

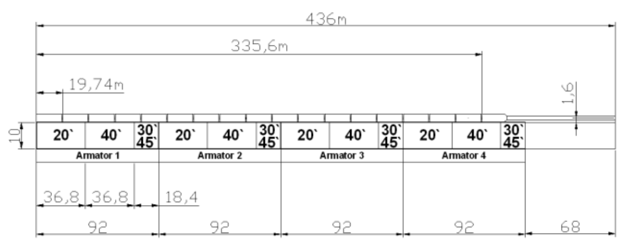
3.2. STORAGE OF THE CONTAINERS ACCORDING TO THE SHIP OWNERS

The containers will be serviced according to the ship owners. There will be services the containers of four ship owners. Each of them will get a 92meters storage spot (it is due to the organizational guidelines of the terminal). Each spot will also be divided into units for the storage of particular types according to the tables 1 and 2. For the particular types of containers, the spots` length will be as follows:

$$D_{20`} = 92 \cdot 40\% = 36,8\ [m]$$
$$D_{30`} = 92 \cdot 5\% = 4,6\ [m]$$
$$D_{40`} = 92 \cdot 40\% = 36,8\ [m]$$
$$D_{45`} = 92 \cdot 15\% = 13,8\ [m]$$

where: $D_{20`}$ – the storage length of 20` containers, $D_{30`}$ – the storage length of 30` containers, $D_{40`}$ – the storage length of 40` containers, $D_{45`}$ – the storage length of 45` containers

The above data show that the length of 30` and 45` containers is very short due to the small number of these containers in the loading. Therefore, their spots will be joint. The number of the serviced carriages is odd so it is not possible to equally split them between the 4 ship owners. Thus, I established that the last ship owner will have 5 carriages. In the drawing no 5 such a storage way is illustrated.



Drawing 5. Containers stored according to the ship owner

3.2.1. Containers go in according to the ship owner and size

Similarly to the case where the containers were stored according to the size, first we focus on the most beneficial case, which means that the containers will be placed on the train according to the ship owners and size. The cycle time will be the arithmetical average of the shortest and longest possible cycle. The distance which the gantry has to cover depends on the distance between the container and the ship owner`s storage spot and the spot`s part determined for particular container type. It applies both to the shortest and longest cycle.

Similarly to the previous cases, I used the calculation sheet. The way of determining the servicing time remains unchanged. However, the routes which will be covered by the gantry will be different. The guidelines considering the servicing time calculations will be the same as well.

Underneath I will present the calculations for the guideline where the containers are stored according to the ship owner, and there are placed on the train according to the ship owner and size. These calculations will concern the containers marked in the drawing 4.7.

3.2.2. Containers go in according to the ship owner and their order is converted

In this case the train consists of carriages which belong to four ship owners, each of which owns 4 or 5 carriages. The carriages go in from 1 to 4, and the containers are put in the descending order.

3.2.3. Container go in according to their size and ship owners

In this case the containers are put in the ascending order, from 20` to 45`, and the consecutive four carriages have their ship owner.

4. RESULTS

In the table no 3 there are illustrated servicing cycles for all the cases and both storage ways.

Table 3. Train servicing time

Storage way	The way of the arrangement on the train	Servicing time[min]
Storage according to the containers` size	According to the size	139,2
	According to the ship owner and size	188,1
	According to the ship owner and the con-versed size	208,5
	According to the random order	214,5
Storage according to the size and ship owner	According to the size	150,1
	According to the size and ship owner	150,8
	According to the ship owner and conversed size	161,8

When the containers are stored according to the size, it is obvious that the introduction of seclusions to the optimal arrangement makes the servicing cycle much longer and thus comparable to the servicing cycle of to that of randomly arranged. In the case of storage according to the ship owner, the shortest time is a bit longer than the shortest of the storage according to the size. Despite this the train servicing time for varied arrangements does not differ a lot from this value. Therefore, it can be stated that storage according to the ship owners is more beneficial in this case due to the insignificant influence of the containers` arrangement changes on the servicing cycle.

5. SUMMARY

Sixth chapter focused on the arrangement of stored containers on the terminal. The results indicate that the storage according to the ship owners is more beneficial due to the fact that the changes in the containers arrangement on the train and the servicing time are less probable. It is presented that the choice of this kind of simulation can be right only when servicing a small number of the ship owners. Loading of the containers onto terminal has to be verified with the delivery note which notifies the actual delivery. It is a subject matter of present studies of the author. The solution of this problem may be helpful in the determination of a right algorism which will allow to establish the storage spot of the container at the moment of the notification. This will significantly stimulate the works on the terminal.

LITERATURE

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