HEURISTIC SUPPORT IN CONTAINER TRANS-SHIPMENT DECISION

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Abstract

Intermodal transport based on exchanging containers needs effective and efficient functioning of land terminals. The article presents a heuristic method, which combines the issues of scheduling loading machine operation and its route in the fulfilment of carriage-yard transport orders. This method is implemented at four stages: a comparison of dates of container release to the end recipient, valuation of task implementation and valuation of the accumulated value of the performance of entrusted tasks.

Keywords: Intermodal transport, container yard, container handling, handling schedule

1. INTRODUCTION

Intermodal freight transport is the transportation of a load from its origin to its destination by a sequence of at least two transportation modes, the transfer from one mode to the next being performed at an intermodal terminal [1]. Intermodal transport cannot fulfil its tasks without handling terminals, where the means of transport is changed. Container ports are of paramount importance in intercontinental transport and land terminals play an important role in the further route of the load (there are several hundred of these in Europe). They are situated near important transport nodes, economic centres, very often as an element of a larger logistics centre.

Inland terminals fulfil transport and warehousing functions. Loaded containers are usually stored for several days; however, there are empty ones even for several weeks. In this case, not only loading machine operation is important, but also appropriate management of storage places at the yard.

In the practice of land terminals, which are not equipped with a computer-assisted storage place management system, there are cases of another container being stored on a container to be released: this requires another operation connected with moving the upper container to another place (where it can block other loading units). In cost accounting, land terminal operators include 4 operations during container flow at the terminal; however, our research has shown that there are on average nearly 8 such operations, even up to 14 [2].

The idea of quick handling of loads between the carriage and the yard involves taking containers directly to their ultimate storage place after they are taken off the carriage. This will make it possible to reduce the number of performed operations, reduce the service time of loading units and, as a result, will increase work efficiency. The solution should allow:

- indicating a storage place with the shortest time of the unloading operation, taking into account the filling of the storage space (reducing the time needed to perform the operation),
- indicating the order of task performance (reducing the time between operations),
- establishing the order of storage, so that the container intended for longer storage is not placed on one that will leave the terminal earlier (reduction of non-productive operations).

For the operational plan for the general formulation of the problem, it can be said that a solution is searched for an order fulfilment system where:

- all orders must be fulfilled,
- each order can be fulfilled in a different way (various places for placing the container),
- the order will be fulfilled with a minimum use of resources measured by the task performance time (taking into account the cubic capacity of the storage yard),

- the total time to perform all tasks will be minimal,
- not all tasks can be performed right away (some containers will be stored on those which were taken off carriages earlier); some tasks can be performed only after performing other tasks.
- the place of the task commencement is different each time.

The aim of the article is to present a practical solution to the carriage-yard container service at a land container terminal according to a method comparing values of parameters characterising the container intended for handling, the yard and transport routes.

2. OVERVIEW OF THE LITERATURE

The aim of the overview of the literature is the presentation of a scientific solution to the scientific problem formulated in the introduction to the article.

Literature on land terminals discusses the problems of routing containers (loaded or empty), business elements of the container handling process, issues of the transport process risk and resistance of systems.

Solutions to operation scheduling at land terminals are usually optimization solutions. In [3] the authors focused on scheduling gantry crane operation during load-handling work between container trains. In [4] Authors dealt with the same topic (train-to-train loading); however, they proposed a heuristic solution. Scheduling of gantry crane operation in car-to-yard loading was the subject of the study by [5], where a solution was proposed for container terminals, which involves dividing space into sections. The organization of handling activities was also proposed there [6,7]. The operation of land container terminals and the methods of their management were also presented in [2].

In the relevant literature, there are publications which focus on solving decision-making problems by improving reliability or increasing the resistance of systems. The use of stochastic values in considerations on resistance are included in [8], and physical forms of interference during handling tasks in [9].

In a vast majority, however, the available literature pertains to sea terminals. Two areas of such studies can be distinguished: scheduling and internal transport at terminals [10,11]. They focus on issues, such as berthing time minimization, routing, scheduling of crane operation at the wharf and at storage blocks.

In study [12] the Authors made an attempt at solving the reshuffling problem on the basis of genetic algorithms. The topic of reshuffling in the operation of container terminals is still valid from the practical point of view. The only way of avoiding this problem is only full and reliable information about the predicted container storage time, which, as we know from practice, is available only for some loading units. However, this issue is well worth dealing with because appropriate planning makes it possible to reduce such operations.

In such publications [13], it was assumed that containers, after being unloaded from the means of transport, are stored in a buffer area. For ports, this seems a completely obvious way of operation. However, the idea of the author of this article involves the elimination of temporary storage, which means the elimination of reshuffling. The study, on the basis of the Chinese postman problem, solves the issue of straddle carrier movement at a sea terminal. The use of such machines makes the shortest path solution impractical - land terminals are usually served by cranes or reach stackers.

The problem of task performance task minimization was also undertaken on numerous other occasions [12, 14, 15].

A solution to the problem specified in the introduction makes it necessary to look for solutions in other logistics areas, the use of practical methods in other areas. Scientific solutions related to work scheduling in the storage space considering energy consumption are presented in the studies by [16] and [17] The algorithm for a task-scheduling procedure was proposed in [6,18,19,20] while a railway traffic procedure was described in [22,23] The issue of performing experiments during operation was analysed in [24]. Analysis reliability of real system is shown in papers [25,26]. Maintaining resources is an important element of the use of machines and devices [7,27,28,29] as well as the development of operation models presented by [19,25].

In summary, the state of knowledge on models used for solving the problem of planning the task performance order at an intermodal trans-shipment node during carriage-yard handling activities, it can be concluded that there is no solution which would:

1. reduce the problem of buffer storage,
2. reduce the amount of reshuffling needed,
3. assume probabilistic values of duration of individual parameters of the process.

Such a solution is proposed in the next part of the article. Heuristics will be used for the issue of scheduling and routing of a reach stacker at a land container terminal while unloading containers on the carriage-yard route.

3. SOLUTION OF THE PROBLEM

General solution:

The solution to the problem is based on three steps, which can be recorded as an ordered three of [*S*, *V*, *D*], where:

S - task performance status,
V - task performance value,
D - task performance order.

Task performance status:

In the discussed approach, after reports are entered in the order fulfilment system, it is first checked whether a task from the list can be performed or whether another task with another status value must be performed first. For the purposes of the model, it has been adopted that tasks with a lower status value have a lower rank. It has been assumed that the value of the parameter can fall within the following range: S = {0, 1, 2, …, n}.

As regards the list of containers which must be unloaded from the carriage to the container yard, the performance of this part of the method is the verification of the expected storage time of arriving containers and containers which are already stored. The point is that containers unloaded from the carriage may not block those which will be used for subsequent transport sooner. Therefore, the statuses of containers on the carriages and on the yard are compared as well as statuses of containers for unloading. If the *i*-th container is intended for earlier release than the *j*-th container, then $S_i>S_j$.

If containers are to be released at the same time, their status values can be the same.

Task performance value:

Another parameter of the presented approach is the task performance value *V*. In its general meaning, the "value" can pertain to the observed value selected by the decision-maker. In practice, with the operation time schedule, attention is usually paid to the time of a single task performance, its cost, distance, usually in search of the minimum value of the quantities listed.

In the discussed case of unloading operations at an intermodal container terminal, the order fulfilment time was adopted as the time of order fulfilment, i.e. moving container from the carriage to the yard, considering that this is a cycle consisting of:

- lifting the container from the carriage,
- taking the container to the yard,
- taking a position for unloading at the storage place,
- the activity of placing the container at the storage place.

Attention is paid here to the fact that, basically, values of performing the same task are different for a classical gate crane, different for a reach stacker; they also differ if the container is placed on the first layer as compared to being placed higher.

Task performance order:

Establishing the value of task performance does not answer the question which order they should be performed in. As a result, the discussed approach to the performance of a cycle of orders is complemented by the value of the sequence of task performance marked as *D* where *D*={0, 1, 2, …, *n*}.

It must be determined how much time (or another “value”) is needed for conversion (or preparation) required to perform the next task. An analysis of the required “preparation” times will make it possible to define an order of task performance when the adopted value will be the lowest (or the highest in the case of looking for solutions with the maximum value); it must be defined how much time will be needed for getting from the container placement location to the next containers to be unloaded. In this way, a tree of task performance variants can be prepared, where the node is the trip of the container from the carriage to the storage place, the branches, on the other hand, defines values of the trip time to the places, from which subsequent loading units are taken. The choice of the path with the lowest sum of values will allow for obtaining the sequence of nodes travelled, i.e. the sequence of task performance.

In summary, a list of orders consists of single orders and their fulfilment can be described using the status, the values and the performance sequence.

The status defines collisions between tasks; this value makes it possible to assess and choose the best method for solving the elementary task; the sequence makes it possible to minimize (or maximize) the values of all tasks undertaken.

4. CALCULATIONS

In the next part of the article, results of calculations are presented and the usefulness of their use is discussed. The task performance time was adopted as the value to be assessed for the calculation of the V parameter. It is a very important parameter in the practice of container terminal.

The task performance time was calculated on the basis of deterministic values obtained on the basis of observations made in 2014 at land container terminals in Poland (at the Cargosped company, Gliwice and Warsaw terminals). Operations performed using Kalmar reachstackers were observed. 28 container trains unloaded on the carriage-yard basis were observed.

The observed order-handling cycle consisted of the following elements:

1. setting the reach stacker in a position to take a container from the carriage,
2. lifting the container,
3. turning and preparing for driving,
4. carrying the container in the yard,
5. placing the load at the storage place,
6. preparing for the drive (bringing the mast down and turning),
7. driving to the carriage to get another container.

The use of this method makes it possible to combine several listed elements of the process. Therefore, it was assumed that activities 1-5 reflect the actual performance of a transport task.

The process implementation value depends on the following factors:

- the distance over which the container is to be transported,
- the storage height.

For calculation purposes, it was adopted that containers could be stacked in layers 1-4. Differences in container placement times occur, depending on the storage height. Table 1 presents results of observations.

Table 1 Time of container placement in a layer.

Storage layer	Placement time [s]
1	15.3
2	18.4
3	21.9
4	45.5

The comparison of the proposed method with the currently performed container replacement was performed in the following way:

1. characteristics of the storage yard were collected,
2. characteristics of containers at the storage yard were collected (including the expected date of handing the container over to the client),
3. after the arrival of the container train at the terminal, the place of the commencement of their handling was defined,
4. the places of their actual placement were recorded (for buffer storage),
5. alternative places for their placement were calculated according to the proposed method.

The results presented in Tables 2, 3, 4 pertain to the shortest trains, carrying 24, 27 and 30 containers, respectively. The shortest trains were selected for the presentation of the method, due to the lowest number of operations, it was the most difficult to obtain a satisfactory, i.e. reduced, accumulated time of the performance of all operations. Those tables include:

- The number of the container served (according to the actual sequence),
- the actual container-handling time, including the full cycle described in the previous chapter (consisting of 7 elements, i.e. together with the return to get the next container) (in seconds),
- container-handling time (according to the model) containing the full cycle described in the previous chapter (consisting of 7 elements) (in seconds),
- time saving for the service of one container (expressed as a percentage value),
- time saving for the service of one container expressed in seconds,
- accumulated value of the recorded time savings in the fulfilment of orders - expressed in seconds.

Table 2 includes the order fulfilment results for a train with 24 containers. The actual average handling time for one container was 96.5 s. For operations performed according to the proposed method, this time was 92.8 s on average. The longest handling time was recorded for container 1 which was handled for nearly 2 minutes. In accordance with the method, no better handling time was recorded for many unloading operations. The accumulated total saving time was nearly 2 minutes. Therefore, it can be said that the effectiveness of the method is quite low in this case.

Table 3 includes the order fulfilment results for a train with 27 containers. The average time of the actual handling of one container was 122.5 s. For operations performed according to the proposed method, this time was 90.4 s on average. In the discussed case, only one operation performed in accordance with this method brought a loss. The greatest time saving was recorded for the last container: over 50% of time saving. Also in physical values, we deal with 1.5 minutes.

Table 4 presents the order fulfilment results for a train with 30 containers. The actual average handling time for one container for a train was 88.2 s, while for operations performed according to the proposed method, this time was on average 83.3 s. In the case under analysis, 8 operations performed according to the proposed method brought a small loss while savings were observed 16 times. For this train, the actual times of container handling fall within the range from 89 s to 130 s.

Table 2 Table of results for a train with 24 containers

Container number	Service time, actual, [s]	Service time according to the method [s]	Time saving for container service [%]	Time saving for the service of one container [%]	Accumulated time savings [s]
1	114.8	90.5	21.1	24.2	24.2
2	89.8	92	-2.5	-2.2	22
3	89.4	90.5	-1.3	-1.1	20.9
4	114.4	92	19.5	22.3	43.2
5	94	93.6	0.4	0.4	43.6
6	114	98.6	13.5	15.4	59
7	114	98.6	13.5	15.4	74.4
8	114	97	14.8	16.9	91.3
9	94	98.5	-4.8	-4.5	86.8
10	94	94	0.0	0.0	86.8
11	94	94	0.0	0.0	86.8
12	94	94	0.0	0.0	86.8
13	94	94	0.0	0.0	86.8
14	94.4	93.5	0.9	0.9	87.7
15	94.4	92	2.5	2.3	90
16	89.8	92	-2.5	-2.3	87.7
17	89	89	0.0	0.0	87.7
18	89	89	0.0	0.0	87.7
19	89	89	0.0	0.0	87.7
20	94	92	2.1	1.9	89.6
21	89.4	90.5	-1.3	-1.1	88.5
22	94	90.5	3.7	3.5	92
23	90.2	92	-2.1	-1.9	90.1
24	89.4	90.5	-1.3	-1.1	89

Table 3 Table of results for a train with 27 containers

Container number	Service time, actual, [s]	Service time according to the method [s]	Time saving for the service of 1 container	Time saving for the service of one container [%]	Accumulated time savings [s]
1	94.4	90.5	4.1%	3.8	3.8
2	114.8	89	22.5%	25.8	29.6
3	89.8	89	0.9%	0.8	30.4
4	94.4	89	5.7%	5.4	35.8
5	114.8	89	22.5%	25.8	61.6
6	98.2	92.1	6.2%	6.1	67.7
7	118.6	93.6	21.1%	25	92.7
8	90.6	92.1	-1.6%	-1.5	91.2
9	150	89	40.7%	61	152.2
10	155	89	42.6%	66	218.2
11	95.6	92.1	3.7%	3.4	221.6
12	110	92.1	16.3%	17.2	238.8
13	110	95.2	13.5%	14.6	253.4

Container number	Service time, actual, [s]	Service time according to the method [s]	Time saving for the service of 1 container	Time saving for the service of one container [%]	Accumulated time savings [s]
14	150	90.5	39.6%	59.5	312.9
15	140	94	32.9%	46	355.9
16	93.2	89	4.5%	4.1	360
17	97.4	89	8.6%	8.4	368.4
18	117	89	23.9%	28	396.4
19	132.4	89	32.8%	43.4	439.8
20	92.8	89	4.1%	3.8	443.6
21	118.2	89	24.7%	29.2	472.8
22	132.6	89	32.9%	43.6	516.4
23	165	92.1	44.2%	72.9	589.3
24	140	90.5	35.3%	49.5	638.8
25	150	90.5	39.6%	59.5	698.3
26	165	89	46.1%	76	774.3
27	180	89	50.6%	91	865.3

Table 4 Table of results for a train with 30 containers

Container number	Service time, actual, [s]	Service time according to the method [s]	Time saving for the service of 1 container	Time saving for the service of one container [%]	Accumulated time savings [s]
1	89	89	0.0%	0.0	0
2	114.4	90.5	20.9%	23.9	23.9
3	114	94	17.5%	20.0	43.9
4	89.8	90.5	-0.8%	-0.7	43.2
5	89.8	92.1	-2.5%	-2.3	40.9
6	94	94	0.0%	0.0	40.9
7	89	89	0.0%	0.0	40.9
8	94.4	90.5	4.1%	3.9	44.8
9	89.4	90.5	-1.3%	-1.1	43.7
10	89.4	94	-5.2%	-4.6	39.1
11	94.8	92.1	2.9%	2.7	41.8
12	115.2	93.6	18.7%	21.6	63.4
13	97.4	95.2	2.3%	2.3	65.7
14	114.4	94	17.8%	20.4	86.1
15	94.8	97.1	-2.4%	-2.3	83.8
16	114.4	95.5	16.5%	18.9	102.7
17	94	93.6	0.4%	0.4	103.1
18	94	94	0.0%	0.0	103.1
19	94.4	92.1	2.5%	2.3	105.4
20	94.4	89	5.7%	5.4	110.8
21	89.4	90.5	-1.3%	-1.1	109.7
22	114.8	92.1	19.8%	22.7	132.4
23	89.4	93.6	-4.7%	-4.2	128.2

Container number	Service time, actual, [s]	Service time according to the method [s]	Time saving for the service of 1 container	Time saving for the service of one container [%]	Accumulated time savings [s]
24	94	94	0.0%	0.0	128.2
25	94	93.6	0.4%	0.4	128.6
26	89	92	-3.4%	-3.0	125.6
27	114.4	92	19.6%	22.4	148
28	94	92	2.1%	2.0	150
29	94	93.6	0.4%	0.4	150.4
30	129.4	92.1	28.8%	37.3	187.7

Fig. 1 presents histograms of task duration times (actual and achieved by means of this method. It can be noticed that the actual task performance tasks mostly fall within the 89-99 s range. However, there are also cases of task implementation above 150 s. The use of the method makes it possible to even out task performance times. Nearly all are performed in a time below 99 s (with the minimum value of 88.5 s).

5. CONCLUSION

Practical solutions of carriage-yard container service were presented in the article. The solutions are prepared for land container terminal, and allowed:

- indicating a storage place with the shortest time of the unloading operation, taking into account the filling of the storage space (reducing the time needed to perform the operation),
- indicating the order of task performance (reducing the time between operations),
- establishing the order of storage, so that the container intended for longer storage is not placed on one that will leave the terminal earlier (reduction of non-productive operations),
- it minimized the return routes to the next containers.

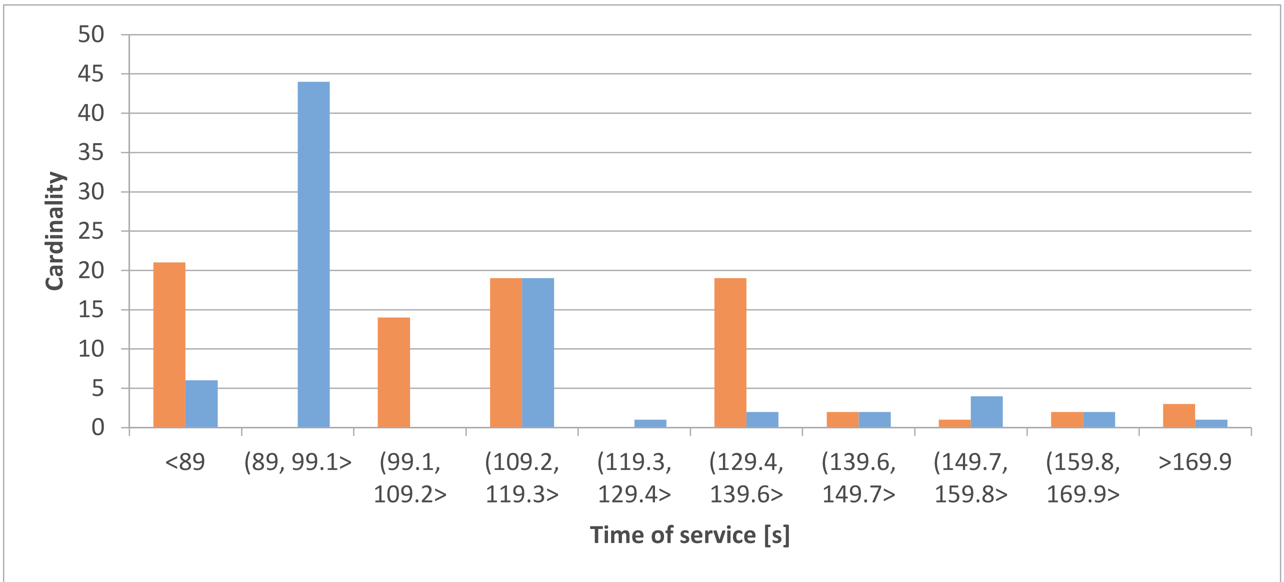

Fig.1 Histograms of task duration times

The method for the problem is based on three steps which can be recorded as an ordered three of [*S*, *V*, *D*], where

S - means the task performance status,

V - task performance value,
D - task performance order.

In the method, after reports has entered in the order fulfilment system, it is checked whether a task can be performed or whether another task with another status value must be performed first.

The second parameter taken into account in the approach was the task performance value V. In this way, the "value" has been pertained to the observed value selected by the decision maker. Practically the aim is to minimize the task performance time, costs, energy consumption, etc.

The discussed approach to the performance of a cycle of orders was complemented by the value of the sequence of task performance marked as *D*.

In this step, it was determined how much time (or another "value") had been needed for conversion (or preparation) required to perform the next task. The analysis of the required "preparation" times allowed for establishing the sequence of time implementation when the adopted value is the lowest (or the highest if maximum value solutions are searched).

The verification of the method was based on real data collected in an intermodal loading node. The values obtained using this method made it possible to save time while unloading containers as compared to actual values.

Further work involving an increase in calculation possibilities for the determination of the task sequence and introduction of random interference in the operation of the system.

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