Logistics Container Warehouse in a Tandem Sea Port

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THE LOGISTICS CONTAINER WAREHOUSE IN A TANDEM SEA PORT

ABSTRACT

Background: The paper solves the problem of the logistics of container warehouses in a tandem seaport - LMK . The subject of transport is a ship that transports goods in containers.
LMK is dispersed - it is located on N wharfs (n=1,…, N) of the port.
It stores containers with goods delivered from ships and factories by trains or cars.
The warehouses contain stacks of containers with only the top of the stack available. Due to the unloading time, the containers from ships, trains/TIRs are placed on the nearest free positions in the warehouse. Due to the loading time, the containers should be collected from the warehouse. For this purpose, the containers should be reloaded in the logistics warehouse. The unit price of the container storage (in the warehouse) is minimized. The presented problem belongs to the NP class - its optimal solution requires a review of all variants. The container reloading algorithm includes: designating quays at which ships can be unloaded, designating quays where ships can be loaded, calculating the costs of storing containers in warehouses, designating tugs for a ship, setting vessel traffic schedules and a port optimization criterion. These variables can be determined by the multi-stage programming method - a problem of the NP class with small N.
Methods: The presented problem was solved with the artificial intelligence method with the help of the dedicated software. The optimization criterion was minimization of the service time of this warehouse, taking into account limitations.
Results: A logistics system for handling a sea port container warehouse was developed.
Conclusions: Global IT allows you to designate containers with exported / imported goods. The large port database allows you to designate the quays for the ship. The high speed of the computer allows you to determine the optimal solution.

Keywords: reloading algorithm, logistics, container warehouse, optimization, port.

INTRODUCTION

Management systems are optimized according to economic criteria (e.g. income, cost, income, profit) [Bucki et al. 2012, Bucki et al. 2013, Bucki et al. 2014]. Usually, income and expense are dependent on time (e.g. exchange rate). In the case of ship handling, the handling time (transport and container handling) is important [Bucki et al. 2010, Frąckiewicz and Marecki 2018]. In tandem ports (e.g. Szczecin-Świnoujście), the ship requires partial unloading - due to the depth of the water channel connecting the tandem ports. The storage time of containers with exported or imported goods is equally important in the port. For this reason, reloading in container warehouses is used. The warehouse management in the port is optimized with the help of IT systems.

A container ship is a logistic system used by the shipowner as a means of transport. Its service schedule covers ports $P_i,\ i = 0, 1, \dots, I$ with each section $P_{i-1} \rightarrow P_i$, using its buoyancy. The depth of the ship's draft and stability, determined by the location of its center of gravity, are of significant importance. At each port of P_i, the ship unloads and loads containers. The ship's route is an NP problem [Papadimitriou 2002]. The ship "earns" when it transports goods. Therefore, her schedule is "ahead". Sometimes the transport is longer (e.g. due to bad weather). The vessel's location is determined by GPS (Global Positioning System).

The IT system of container port management mainly includes:

- vessel traffic scheduling;
- steering of tug boats transporting ships;
- container warehouse management.

Vessel traffic between the roadstead and the quays is scheduled. The standard scheduling cycle is one week but it may be shorter due to random reasons (e.g. weather). The scheduling problem is NP class [Papadimitriou 2002, Marecki and Marecki 2007, Bucki, et al. 2010, Frąckiewicz and Mrecki 2018].

STATEMENT OF THE PROBLEM

The container warehouse is located on the wharf. The ship is placed in the centre of this quay (not on the side as usual) which allows the containers to be unloaded from the ship to both sides. Similarly, the loading of containers onto a ship takes place from two sides. This reduces the time of unloading and loading the ship.

It is assumed that the containers intended for export are delivered to the warehouses by freight trains or lorries (TIRs). Therefore, there is a bypass enabling the access of trucks to the ramps of the container warehouse. In addition, internet boards inform the TIRs which ramp they are to travel to in order to unload or load the container.

Aggregates (e.g. specialized wheeled vehicles, overhead cranes) that transport containers along the warehouse lines are of significant importance. They store the containers in the nearest free position on the line. When there is no ship and truck, the aggregates reload the containers in the tracks so as to minimize the time of loading the containers onto the ship or trucks.

The problem presented in the paper is to determine the tandem port in which the containers from the ship fit and in which warehouse the containers intended for the ship are located. If such a warehouse is located at one quay, the ship is transported to only one quay. Otherwise, it must be transported by a tug boat to the next quay which extends the ship's service time, so the basic problem is to minimize the time of handling ships and trucks (transport and unloading / loading containers).

CONTAINER STORAGE MODEL

Let us consider a container port that contains one warehouse. This warehouse consists of many sections containing two identical fragments / parts: right A and left B. Each warehouse has a basin for the ship (unloaded or loaded). The innovative quay consists of aggregates enabling unloading or loading of containers on both sides of the ship. These operations can be performed with $N, n = 1,\dots,N$ aggregates on each side of the ship. Therefore, the unloading or loading of the ship is carried out quickly (almost twice as fast as in the case of traditional). The ship does not have to be "shifted" between the loading and unloading berths if the following condition is met:

$$(V > L) \wedge (W > K)$$

where: L - the number of containers on board;

K - the number of containers that the ship can take;

V - the number of warehouse items in which containers can be located;

W – the number of warehouse items with containers that can be shipped.

Calculations are performed with the help of the specialized software.

Parts A and B are on both sides of the container warehouse and are the same. They consist of:

ii) $N,\ n = 1,\dots,N$, tracks - between the ramps for trucks and the ship;

iii) aggregates (e.g. cranes, wheeled vehicles) move in tracks to carry containers;

iiii) there are M , $m = 1,\dots,M$ piles of containers in the duct (on the left B and right A);

ivi) each stack may contain K, $k = 0,1,\dots,K$ containers.

Moreover, the containers are stacked "on top of each other". Thus, the collection of the k-th container requires prior "removal" of the containers: $i = k + 1, \dots, K$. Assuming that only the container is "picked" from above, a three-dimensional warehouse can be considered as two-dimensional which simplifies the problem.

Adoption of separate container warehouses for the quay for imported and exported goods allows for two-way unloading and loading of ships. Aggregates in the *n*-th, $n = 1, \dots, N$ duct unload containers in time t^n depending on the position of free places on the stacks. In this case, the ship is unloaded at time *t* which is determined by unloading of the last container. However, only after the unloading phase can the loading phase begin which is carried out in a similar way as it results from the organization of containers on the ship.

Thus, a container warehouse consists of *N* consoles (with parts A and B) containing containers with imported goods (the right part A from the ship) or exported (the right part A from the ramp). It is assumed that each container is delivered or picked up from the ramp by the TIR. Thus, containers with exported goods are first delivered by TIRs, and then containers with imported goods are collected (perhaps from another ramp). Containers with imported goods are unloaded from the ships to part A of the duct while containers with exported goods are loaded onto the ship also from part A of the duct. Thus, imported goods use a different share of the output than exported goods.

TRANSHIPMENT OPERATIONS IN THE CONTAINER WAREHOUSE

Let us assume that an innovative container warehouse consists of two parts: import and export. In the middle between these parts there is a quay for the ship from which:

a) containers with imported goods are unloaded;
b) containers with exported goods are loaded.

If there is no ship at the quay, the containers are "reloaded" in lines so as to reduce the time of unloading and loading the ship. The unloading and loading of containers onto the ship takes place to the right part and from the left part by means of aggregates located at the quays on both sides of the ship.

Parts A and B contain N, $\mathrm{n} = 1, \dots, N$ tracks between the warehouse ramps and the quay / ship. On both sides of the line there are M, $m = 1, \dots, M$ stacks of containers. There can be K containers in each stack, $k = 0, 1, \dots, K$. Containers with exported goods are reloaded from the TIR at the *n*-th ramp to the next empty stack position on the right-hand side of A in the *n*-th line. On the other hand, containers with imported goods are reloaded from the ship to the next empty position in the stack on the right side of A in the *n*-th line. Thus, containers from

TIRs and from the ship are placed to the nearest empty position in relation to the ramp or the ship which allows to reduce the reloading time on the *n*-th line.

The location of the containers to the nearest free position of the stack is preferred by the operators of aggregates (i.e. overhead cranes, wheeled vehicles) that move in the tracks and carry the containers. This is how the containers:

a) are located near the ramp when they are exported;
b) are located in the vicinity of the ship when they are imported.

Therefore, we need to reload containers:

a) to be in the vicinity of the ship when they are exported;
b) to be near the ramp when they are imported.

In this way, the times of loading the containers on trucks and on the ship will be shorter.

Container handling can be performed successively by aggregates from the *n*-th line (two or three depending on the design / intensity of operations). Suppose there can be only one aggregate in the *n*-th duct. This requires the phases for the aggregate to be distinguished:

a) unloading of containers from the ship (e.g. in the morning);
b) unloading of containers from TIRs (e.g. by noon);
c) handling of stacks of containers in the dedicated lines (e.g. in the afternoon);
d) loading trucks (e.g. in the evening);
e) ship loading (e.g. at night).

In the phases, we need the regulations for the location of containers respected by aggregate operators distinguishing the A and B sides of the duct and the elementary times of horizontal movement τ_H and vertical τ_V.

Let us consider the implementation of phases assuming that on both sides of the n-th, $n = 1, \dots, N$ duct there is room for M, $m = 1, \dots, M$ stacks of containers. Stacks 0 and $M + 1$ are used for reloading:

1) **Unloading containers from the vessel.**

   If the piles: M, $M-1, M-2, \dots., M-m$, are empty, the containers unloaded from the ship may be placed in these piles. The container place on the ship remains empty when it is taken.

2) **Unloading of containers from TIRs.**

   If the stacks: $1, 2, 3, \dots, m$ are empty, the containers unloaded from TIRs may be stored in them. The place on the TIR platform after the container is empty.

3) **Reloading of stacks of exported containers in haulage.**

If there are exported containers in the stacks: $1, 2, 3, \dots, m$ and places for the stacks $M, M-1, M-2, \dots, M-m$ are empty, the reloading consists in moving the next, k-th container from stack 1 to stack M, (the space on stack 1 after the container is empty) and on moving the next k-th container from stack M to stack 1. Place k on stack M after the container is empty.

4) **Loading trucks.**

If the initial stacks: $1, 2, \dots, m$ contain containers, then the k-th container closest to the ramp should be selected in terms of time. The space on the stack after the k-th container is empty.

5) **Ship loading**

If the initial stacks: $M, M-1, \dots, M-m$ contain containers, then the k-th container which is closest to the ship (in terms of time) that the ship can take should be chosen. The place for the stack after the k-th container is empty. The containers placed on top of the stacks are preferred.

In general, instead of time phases, the following operation priorities can be introduced:

a) unloading containers from the ship;
b) loading the ship;
c) unloading containers from TIRs;
d) loading TIRs.

However, this requires a computer simulation to prove the effectiveness of such an operation.

THE LOCAL WAREHOUSE COMPUTER NETWORK

The local computer network of the container warehouse covers all container warehouses of the port. It has a database of B (t) containers in individual warehouses:

a) the number of vacancies for imported containers;
b) the number of containers exported (by the country).

This base includes ships "on their way" to the quays and containers selected by the ships being loaded.

The local base B (t) allows us to check whether:

a) containers from a given vessel fit in the warehouse;
b) how many containers a given vessel can take.

Based on these data, the quay for a given ship is selected.

Artificial intelligence is associated with large computer memory, high speed data processing and transaction archiving (in the port).

Let us assume that an innovative container warehouse occupies the following acreage:

1) Aquatorium (for ships).
2) Territory (for a warehouse): symmetrical unloading / loading lines and net port roads to warehouse paths.

Ships are located in the centre of the warehouse which allows to shorten the times of unloading and loading containers (this is human natural intelligence).

Let us assume that a given warehouse can accommodate imported containers from a ship and there are also containers exported in it which are to be placed on a ship. The ship can then be unloaded and loaded at the same quay. Therefore, it does not waste time "switching" to other quays. The innovation of such a warehouse is due to the IT infrastructure.

The information network is wireless: WiFi (802.11). It includes the aquatorium and the port territory. Let us assume that the container warehouse is located in the quadrilateral: N (north), E (east), S (south), W (west), with the side: N - E separating the aquatorium from the territory. Let us assume that there are gates to the warehouse in points: N, E, S and W in which the "container shipping list" is checked. Such a letter includes:

a) container type: E (export) or I (import);
b) the consignor and the consignee (container);
c) the contents (goods) of the container;
d) date of registration;
e) container parameters (e.g. weight);
f) parameters of the goods (e.g. expiry date).

In addition, such a "letter" is placed in the port's IT system where the TIR registration number is also automatically saved.

After the registration process, the TIR should:

a) drive up to the *n*-th ramp, $n = 1, \dots, N$;
b) leave the warehouse.

The TIR can go to the warehouse by means of the external or internal bypass. The outer bypass has 4 gates / roundabouts (*N*, *E*, *S*, *W*) while the inner bypass has *N* roundabouts (for ducts). There are wireless access points (APs) at the roundabouts of the outer ring road. Thus, TIRs can be routed to the warehouse ramps via the Intranet. Whereas in ducts, the Intranet is available in aggregates. Thus, the picked up or positioned container can be controlled by a aggregate.

The import and export part of the warehouse consists of:

a) $N, n = 1, \ldots, N$ tracks between the warehouse ramps and the ship;

b) M stacks of containers on both sides of the tracks;

c) K places for containers in each stack.

There are aggregates in the tracks that transport the container to / from the correct position. For this purpose, the IT system photographs the "transport lists" of the containers.

METHOD

The method used in this study is artificial intelligence. But domain knowledge is of major importance. Information technology appeared only in the 20th century and today it is "considered" to be the information society [Kaku 2014, Kasperski 2003, Wolfram 2002].

The issues presented in the publication concern the container port [Marecki and Marecki 2007, Bucki et al. 2010, Frąckiewicz and Marecki 2018,]. In general, the port information system comprises:

1) Scheduling ships in port (movement, unloading and loading).
2) Managing tugs that transport ships.
3) Management of container warehouses at the quays.

In each of the above-mentioned points, the method of artificial intelligence was used. Innovation is related to the use of artificial intelligence in AI as a supplement to natural intelligence associated with the human brain. For example, the standard scheduling horizon is one week and the tugs are routed in a shift cycle while the container warehouses work continuously (asynchronously). Moreover, the ship performs transport services between the ports $P_i, i = 0, 1, \ldots, I$, which is a difficult problem.

The port's container warehouses located at the quays balance the streams of containers with imported or exported goods. These goods are:

a) unloaded from ships and loaded onto lorries (TIRs) or freight train wagons;

b) loaded onto ships and unloaded from heavy goods vehicles (TIRs) and freight trains.

Ships transport about 2,000 containers and trucks or wagons - only 1 or 2.

Due to organizational simplifications, so far container warehouses have been divided into unloading (import) and loading (export) warehouses. The quays are classified in a similar way. Nevertheless, there should be one container warehouse (loading and unloading). It is an innovative logistics solution which, however, requires a road bypass and an appropriate IT system.

The IT systems of the container warehouse allow for:

a) the location of a free space in the warehouse for the container containing imported goods unloaded from the ship;
b) the location in the warehouse of the container containing imported goods (unloaded from the warehouse onto the ramp with the appropriate TIR).

Similar IT procedures are used for exported containers where the logistics chain includes: TIR → container warehouse → ship. The innovation consists in the division of natural (human) and IT intelligence.

An innovative container warehouse should have a road bypass with roundabouts and ramps for unloading and loading containers. At the roundabouts, the TIR number is recorded and the number of the container unloading ramp is provided. At the unloading ramp, the number of the unloading ramp is provided for a given TIR. Artificial intelligence of the IT system of a container warehouse consists in determining the smallest times:
a) free places in the warehouse where unloaded containers are located from the ship or TIR;
b) the warehouse locations where containers are loaded onto a vessel or a TIR.

An innovative IT system for container warehouse management reduces the time of unloading and loading containers (more than twice). In addition, it shares the natural intelligence (human) - distinguishing computer intelligence.

CONCLUSIVE REMARKS

This publication presents the innovative container warehouse. The ship has the ability to enter "inside" such a warehouse to eliminate "shifting" the ship to other quays which reduces the times of its unloading and loading. It consists of a territory and an aquatorium. There are container cranes in the warehouse. Parts A and B contain N ducts where there are aggregates (e.g. overhead cranes, wheeled vehicles) for transporting containers. These ducts run from the crane on the wharf to the warehouse ramp. On the left and right side of the duct, there are M, $m = 1, \ldots, M$ places for stacks of containers. There can be K, $k = 0, 1, \ldots, K$ containers in each stack, stacked "on top of each other".

The container warehouse (parts A and B) consists of a road network with roundabouts. The n-th, $n = 1, .., N$ ramp can be reached by two roads in the opposite direction as in Token Ring communication. The TIR license plate is read and the number of the unloading / loading ramp is displayed at the roundabout. After the container is delivered and / or collected from the warehouse, the TIR leaves the warehouse. The exported containers are placed on one side of the line and the imported containers on the other. So up to $2 * M * K$ containers can be unloaded / loaded. Unloading and loading of ships takes place from / to parts A and B of the warehouse.

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