LOGISTICS OPERATIONS WHEN TRANSHIPPING FROM CONTAINER VESSELS

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Abstract

Containerisation of goods is a trend, which is constantly increasing in a meaning of volume of transported goods. The most of bulk goods are transhipped through container terminals in seaports. Concerning this fact, it is necessary to define logistics operations for loading, transhipping and unloading in every port. A base is an analysis of a current state of a container transhipment in seaports and a definition of bottlenecks in logistics chains. Thanks to this a functional logistic terminal model can be established.

Keywords: Container, container transport, container terminal, logistics, logistics operations

1. INTRODUCTION

Seaports are one of the most important points in a freight transport system. They participate in total freight transport performance from 60 % to 70 %. They play very important role from a global point of view, as goods are loaded, unloaded and transhipped there between different modes of transport. Maritime transport has been a basic element of international transport and it has never been operated only at a national level. Because shipping routes are characterized by a long route between the first and a final port, it is necessary to organize loading and unloading so, that costs and time of transport in a logistics chain is minimized. Sea ships transporting containers along seaports and their terminals are described in this contribution.

It is important to deal with a modal split of each terminal, because mode of transport, that continues after maritime transport, is an important factor.

The most of goods and materials are transported in containers. Ports have different sizes, equipment and varying quality of inland connection through different modes of transport. A fact, that there are more terminals in the most of ports available, where each terminal is equipped with different technologies with regard to a type of goods transported, should be mentioned.

2. ANALYSIS OF PRESENT STATUS

Container transport is the most widespread type of intermodal transport. Container transport is defined as a transport using just one transport unit and several different modes of transport. Only the transport unit is handled during transportation, but not a content of the transport unit. Several types of transport can be considered. [1, 2]

- LCL/LCL - Shipments are taken over from shippers, consolidated into containers, transported and then deconsolidated and delivered to recipients;
- LCL/FCL - Shipments are taken over from shippers, consolidated, transported and delivered to one recipient;
- FCL/LCL - Shipments are handed over by one shipper in a whole container, transported, deconsolidated and delivered to recipients;
- FCL/FCL - Shipments or a container is taken over from one shipper and delivered to one receiver. Content of the container isn't manipulated during the transport.

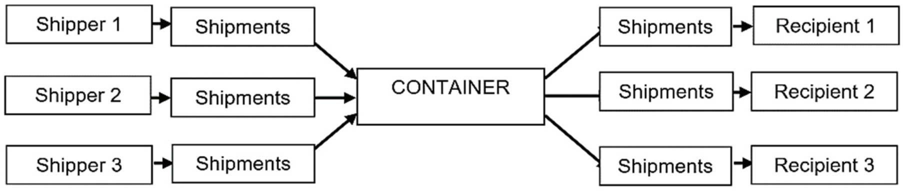


Figure 1 LCL/LCL diagram [Source: Authors]

Consequence of use of containers in transports is a simplification of transhipment and thus a cost reduction. An advantage is a possibility of transhipping difficult-to-handle goods. A container transport has a growing presence in transport process of goods. A containerisation process can be defined as process of gradual introduce of containers and use of related equipment and technology. The main reason for use of containers is a need of efficiency and speed increase of a ship loading and unloading, thus shortening of waiting time of a ship in a port. Containerisation allows use of similar or compatible technologies for loading, unloading and transhipping in different ports, and thus speeding up of these processes is reached. [1, 2, 4, 5]

A volume of transported goods has an increasing tendency. Therefore new container ships are bigger and bigger. As the container ships are getting larger, goods can be transported for lower prices. [7, 8]

Seaports have been always major business centres and they are world trade centres still today. There are duty-free zones. An important factor is creating conditions for business and production activities. Freight ports allow anchoring, handling with ships, unloading or loading of goods and material, or passengers getting off or passengers boarding. A following **Figure 2** shows development of transhipped TEU units (TEUs million) in years 2010, 2013 and 2014. [5, 6, 9]

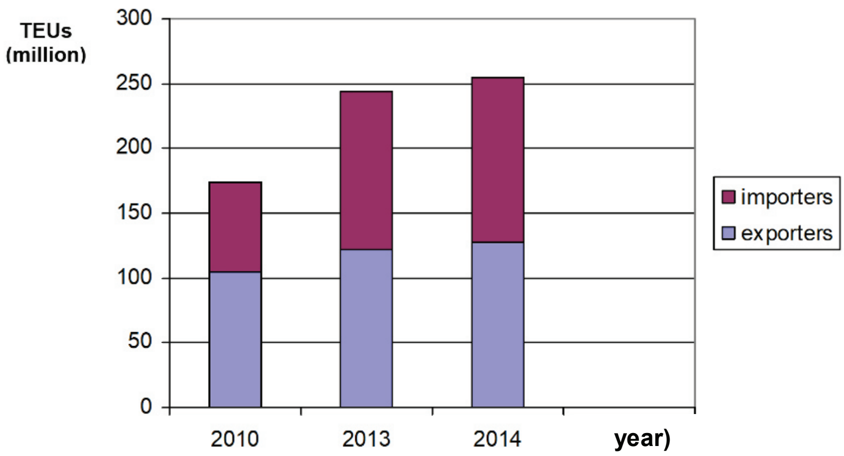


Figure 2 TOP 20 Exporters and Importers of Containerized Cargo - 2010, 2013 & 2014.
Note: TEUs are fully loaded.
[Source: Authors with use of data from IHS Global Insight, World Trade Service].

3. LOGISTICS OPERATIONS IN TERMINALS IN SEAPORTS

A logistics terminal is a nodal point, where different modes of transport, including related transport infrastructure, tie together. Different combinations of transport chains can be used, for example: maritime - rail - road; maritime - road - rail; maritime - air - road; marine - inland waterway - road and other combinations. [3]

Use of a logistics terminal system brings an ensuring of effective management of all logistics operations. This leads to reduction of transport infrastructure burden and it leads to efficient use of its capacity. Thanks to this transport externalities are reduced. This means, that negative environmental impacts are reduced. Overall benefits and benefits of logistics terminals need to be evaluated in a complex way and it can't be evaluated separately only in a particular region. These benefits have to be understood from a wider perspective. This is done on a basis of cooperation and transport connection along logistics terminals. [2, 7, 11]

The following points should be ensured for designing a logistics terminal:

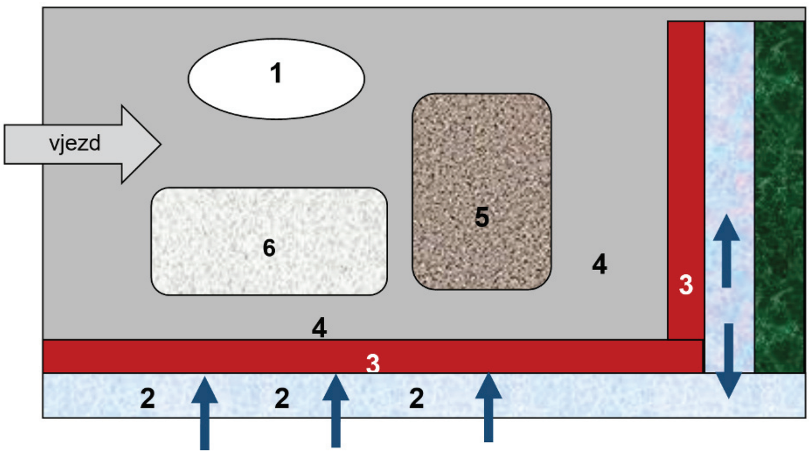
- Lands and local plan compliance. A study of a future intent can be used for verification.
- Goods flows in a selected region. Existing and predicted goods flows in relation to an economic status of population of the region and a demographic development.
- Network goods flows. Based on partnership relationships with business entities in seaports and connected inland LCs.
- Prognosis of new goods flows. Large increase in shipments of containerized goods can be expected.
- Follow-up of a transport network. Connection to an external transport network.
- Financial and operational financing. Both of them have to be considered. [10]

4. LOGISTICS OPERATIONS MODEL

A model of logistics operations in a maritime container terminal is applied to a fictional terminal. Basic input parameters and a location are defined in the model. Input parameters, used technologies and terminal orientation might be different. This means, that different variants of a layout of internal elements exist, as well as different technologies used there, as well as transport and handling devices. In this model, a container terminal with precisely given parameters and distribution of elements is taken into an account. The terminal is located in a port area in Hamburg.

A fictional terminal scheme is shown in **Figure 3**.

Only the main areas, where processes and operations run, are there and described. The whole process is described then in a following text. All component operations are included in a follow-up scheme (**Figure 4**). Different procedures and means of transport can be used during operations. Distinction is based, in particular, on size of a ship and a number of containers in TEU units placed on a ship. An important factor is a mode of transport used on a way further inland. These possibilities and differences will be demonstrated in a following diagram. The main operations are numbered.



1) administration of container terminal
2) arriving ships
3) coastal edge and cranes
4) unloading, transhipment, loading
5) storage area - connection to road or water transport
6) storage area - connection to rail transport
7) watercourse inland

Figure 3 Scheme of a fictional terminal [Source: Authors]

Description of operations in a terminal from arrival of a marine ship to a transport of a container inland:

- Order of terminal services, sending cargo size information and number of containers, etc. Terminal administration sends timetables and assigns a time window.
- Arrival of a ship at scheduled time and to a designated pier. Anchorage of a ship at a coastal edge.

- Ship unloading using coastal cranes.
- Containers are taken into a storage area in a terminal.
- Storage of containers in a warehouse by means of handling.
- At selected time, containers are prepared and then loaded onto selected means of transport by means of handling.
- Transport of containers to an inland destination by road/rail or using inland waterways.

4.1. Scheme of follow-up operations

Following **Figure 4** shows a scheme of follow-up operations in a terminal based on the previous text. It can be stated, that the first phase of the scheme applies to most terminals. In the next stage, when unloading containers from ship, there is possible choice among different technologies for moving containers from a coastal edge into a storage area. The scheme shows the most common variants like different automatic units, tractors, etc.

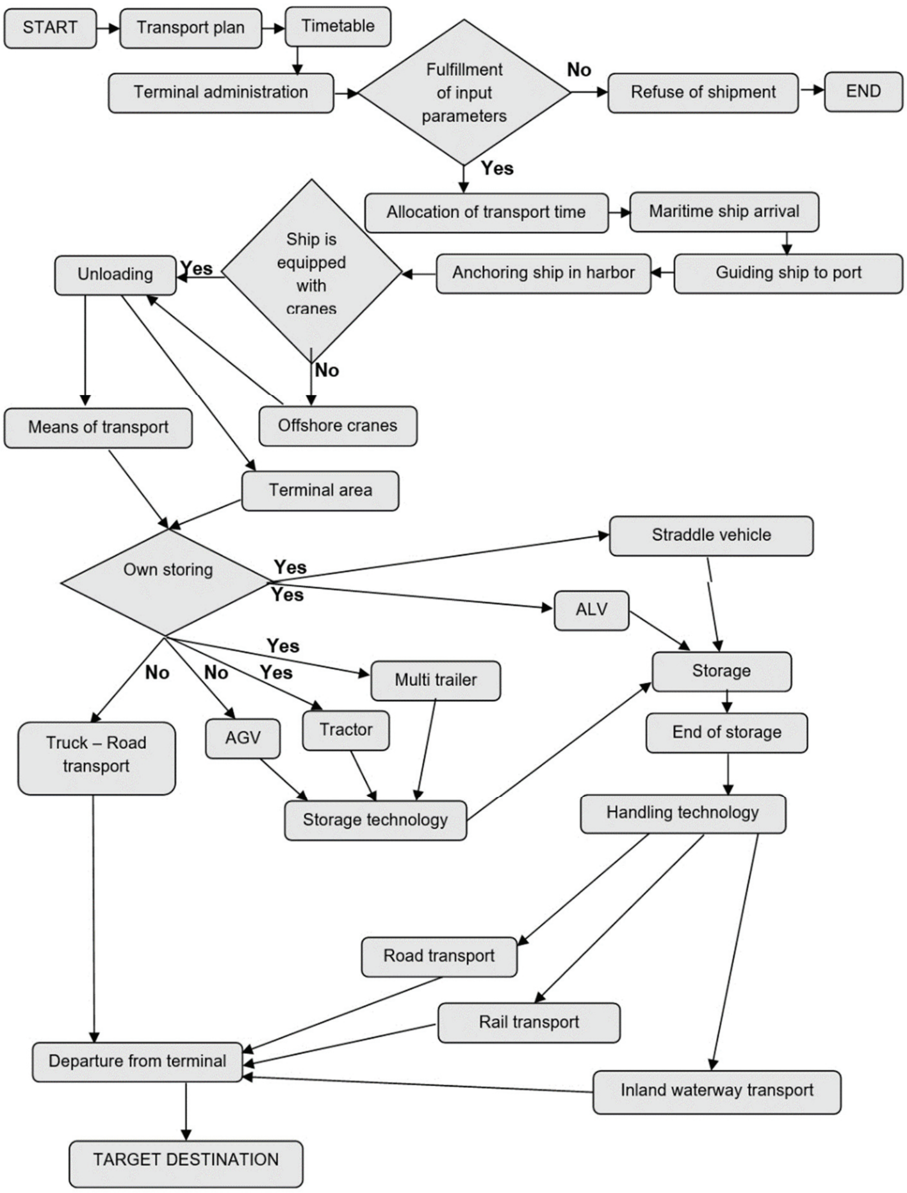


Figure 4 Scheme of follow-up operations in a terminal [Source: Authors]

The scheme is based on container journey inland through a terminal after being unloaded from a maritime ship. The opposite direction would be similar in reverse order. [11]

4.2. Model for determining an optimal number of cranes for unloading a ship

Coastal cranes are an entry point for a ship arriving at a terminal. Only few ships have with their own cranes compared to a number of container ships without their own crane, which are referred to terminal equipment. This is an important and critical place in all terminals, because it's a bottleneck for unloading, transhipping and loading, and use of cranes at terminals have to be therefore well organized and well utilized. Therefore, it's necessary to solve a question, what is the smallest number of offshore cranes in a terminal for unloading or loading a ship at the shortest period of time.

4.2.1. Mathematical model

Mathematical model of operation is represented by QCAP model, in which constant crane speed can be assumed, as well as impossibility of working all of the cranes at the same time, if their shoulders cross. There is a maritime ship served by five side-by-side cranes as an input. [11, 12]
Model parameters:

m …………….number of cranes
n ……………..number of tasks
t_i ……………..task processing time i ($1 \leq i \leq n$)

Definition of model variables

q_i ……………time to complete a task i ($1 \leq i \leq n$)
Q_{max} …………time to finish all tasks

$$x_{ik} = \begin{cases} 1, \text{ if task } i \text{ is assigned to crane } k \\ \text{Otherwise } 0 \ (1 \leq i \leq n,\ 1 \leq k \leq m) \end{cases}$$

$$y_{ij} = \begin{cases} 1,\ q_i \leq q_j - t_j,\ (1 \leq i, j \leq n), \text{ task } j \text{ begins after the end of task } i \\ \text{Otherwise } 0 \end{cases}$$

$$z_{ijkl} = \begin{cases} 1, \text{ if task } i \text{ is assigned to crane } k \text{ and task } j \text{ is assigned to crane } l \\ \text{Otherwise, } 0 \end{cases}$$

A model
To minimize Q_{max} under a given condition, which is minimization of time, during which tasks will be completed according to minimax principle:

$$Q_{max} \geq q_i,\ \forall\ i,\ i = 1,\dots n \tag{1}$$

$$q_i - t_i \geq 0,\ \forall\ i,\ i = 1,\dots n \tag{2}$$

$$\sum_{k=1}^{m} x_{ik} = 1,\ \forall\ i,\ i = 1,\dots n \tag{3}$$

$$z_{ijkl} \leq x_{ik},\ \forall\ i, j;\ i, j = 1,\dots n,\ \forall\ k, l;\ k, l = 1,\dots m \tag{4}$$

$$z_{ijkl} \leq x_{jl},\ \forall\ i, j;\ i, j = 1,\dots n,\ \forall\ k, l;\ k, l = 1,\dots m \tag{5}$$

$$x_{ik} + x_{jl} - 1 \leq z_{ijkl},\ \forall\ i, j;\ i, j = 1,\dots n,\ \forall\ k, l;\ k, l = 1,\dots m \tag{6}$$

$$q_i - (q_j - t_j) + y_{ij}S > 0,\ \forall\ i, j;\ i, j = 1,\dots n \tag{7}$$

$$q_i - (q_j - t_j) - (1 - y_{ij})S \leq 0,\ \forall\ i, j;\ i, j = 1,\dots n \tag{8}$$

$y_{ij} + y_{ji} \geq z_{ijkk}$, $\forall$ i, j; $i, j = 1,\dots n$, $i \neq j$, $\forall$ k, $k, = 1,\dots m$ (9)

$y_{ij} + y_{ji} \geq z_{ijkl}$, $\forall$ i, j, $1 \leq i < j \leq n$, $\forall$ k, l, $1 \leq l < k \leq m$ (10)

[12, 13]

Model explanation:

(1, 2) Definition Q_{max} and q_i properties. According to a condition $q_i \geq t_i$ is stated, that a task completion time follows only when the task is completed.

(3) Tasks are always assigned to one crane.

(4, 5) Properties definition of z_{ijkl}. If $x_{ik} = 0$ (task ***i*** isn't performed by crane ***k***), then $z_{ijkl} = 0$ (task ***j*** is done by crane ***l***). Otherwise, when $z_{ijkl} = 1$ (task ***i*** is done by crane ***k*** and task ***j*** is done by crane ***l***), then $x_{ik} = 1$ and $x_{jl} = 1$ at the same time.

(6) If $z_{ijkl} = 0$, then only one from variables x_{ik} and x_{jl} is 1. It isn't applicable at the same time, that task ***i*** is done by crane ***k*** and task ***j*** is done by crane ***l***. If variables x_{ik} and x_{jl} have value equal 1, then $z_{ijkl} = 1$ (both of the tasks are done at the same time)

(7, 8) Properties definition of y_{ij}. If $q_i \leq (q_j - t_j)$, then $y_{ij} = 1$ (task ***i*** is finished before task **j** starts). In a case of $y_{ij} = 0$, then $q_i > (c_j - t_j)$, which means that ***i*** is finished after start of task ***j***.

(9) Tasks assigned to one crane mustn't overlap. If $y_{ij} = 1$ ($y_{ji} = 1$), then we can assign them to crane ***k***.

(10) Cranes can't work at the same time, if their shoulders cross. If $z_{ijkl} = 1$ (task ***i*** is done by crane ***k*** and task ***j*** is done by crane ***l***), is $y_{ij} = 1$ or $y_{ji} = 1$ to avoid cross of crane's shoulders. If $y_{ij} = 0$ or $y_{ji} = 0$, then $z_{ijkl} = 0$ to avoid crossing of crane's shoulders. [11, 12]

A calculation of ship's unloading time depending on a number and a type of cranes

One-sided transhipment is the most frequently used. Another assumption is derived from terminal parameters, when handling capacity is 4 million TEUs yearly.

This means, that 11,000 TEUs on average is transhipped daily. These assumptions serve as an example of average transhipment and they don't include transhipment fluctuation.

There are 6 types of coastal cranes in the calculation compared.

A type of ship Post Panamax, which arrives at a port with 4,000 TEU containers, is used for the calculation. Another assumption is, that one operation is equal to one unloaded container.

Transhipment times, when different types of cranes are used for unloading of 4,000 TEUs, are compared.

Table 1 Crane Types [Source:11]

Crane Type		Number of Operations/Hour
1	Crane type A with single lifting	30
2	Crane type A with double lifting	40
3	Crane type A with double lifting and movable platform	54
4	Crane with height adjustable boom	55
5	Crane with height-adjustable boom (lowered)	66
6	PACECO Supertrainer (future concept)	67

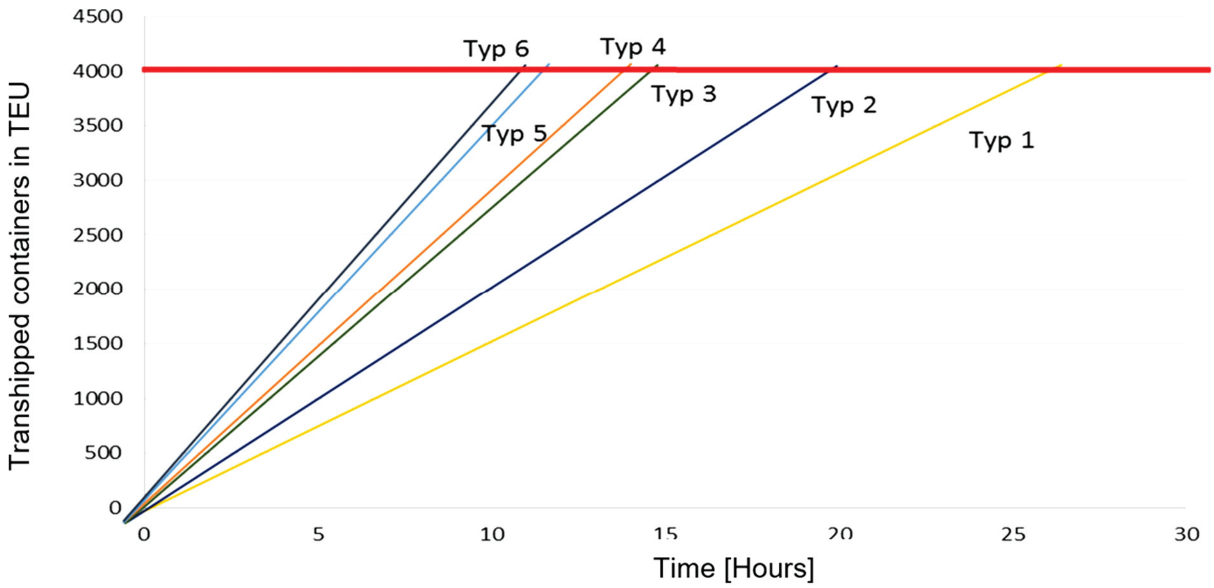


Figure 5 Performance comparison of different types of cranes [Source: Authors]

Figure 5 shows time required to unload a ship with a capacity of 4,000 TEUs. Unloading time of cranes of type 1 and type 2 is unbearably high, the ship would have to spend many hours in a harbour, even there is a continuous operation of the cranes without interruption in the figure supposed and no time losses caused by extraordinary events are supposed. Therefore, there have to be cranes of type 3 or even more powerful used in a fictional terminal. Time savings can be achieved by using more cranes, but it isn't very advantageous from economic and organizational point of view. It is important to point out, that other ships have to be unloaded in the terminal as well. **Table 2** shows how to calculate data needed for creating a figure.

Table 2 Time required for containers unloading [Source: Authors]

Crane Type	Number of Operations/Hour	Number of Operations of 5 Cranes/Hour	Unloading Time/Hour
1	30	150	30
2	40	200	40
3	54	270	54
4	55	275	55
5	66	330	66
6	67	335	67

5. CONCLUSION

The aim was to create a model of logistic operations during unloading, respectively loading a ship. These operations are demonstrated on a fictional terminal example using chosen input parameters. A scheme of follow-up operations, which should and could take place there, was created. The scheme is general and it describes a possible tour of a container through the terminal. The scheme includes critical points, where various successive variants of procedure can be used. However, it always depends on technologies used. Subsequently, a solution of a model of determining an optimal number of cranes for unloading a ship using a mathematical model is presented.

The result is a calculation of unloading time of a ship depending on a number and a type of offshore cranes in a seaport.

The solved theme is very extensive and it offers a number of another variants when solving an optimization of operations in terminals.

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