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AN APPROACH TO DETERMINE OPTIMAL NUMBER OF CONTAINERS FOR CARGO STACKING IN FUNCTION OF TRANSPORTATION COST

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Abstract. *Contrary to conventional transportation systems in which different modes of transportation operate in an independent manner, container transport aims at integrating various modes and services of transportation to improve the efficiency of the whole distribution process with clear task to define the final price of the product.This paper develops mathematical model to minimize transport cost in container transport through proper "stuffing", using optimal number of containers,depending on different dimensions and weight of cargo.The analysis of this modelwould be helpful for the study of intermodal transport systemsand enables consignee to achieve market competitiveness.*

Key words: *Container transport, Transportation cost, Mathematical model.*

1.INTRODUCTION

In one of its most widely accepted meanings, intermodal freight transportations refer to amultimodal chain of container-transportation services. This chain usually links the initial shipper to the final consignee of the container (socalled door-to-door service) and takes place over long distances. Transportation is often provided byseveral carriers. Aclassical example of an intercontinental intermodal chain is given in,[1].

Containerized intermodal transportation supports a significant part of the international movement of goods and container-related transportation activities have grown remarkably over the last 10 years and the trend does not show any sign of slowing down, [8].

Determination of cargo weight and volume is one of the crucial information when selecting the type of container and whose information the buyer of the goods must always specify to the appropriate forwarding agency how they organize transport making booking for appropriate type of container.

The developed mathematical model in this paper, programmed in C and MATLAB, offers a possibility of determining optimal solutions, choosing the optimal routes in terms of concurrent minimization of the observed transport costs. The model provides a possibility of selection of cargo volume and weight, based on which a number of required containers, transported from the port of consignor to the consignee, are determined.

The remaining part of the paper is organized as follows: Section 2 presents the literature review; Section 3 describes the methodology which is suggested in this work; Section 4 reports and analyzes the results of the mathematical model and illustrates how the model could be used. Finally, Section 5 is focused on conclusions and future developments.

2. BACKGROUND

One of the most important tasks in the transportation of containers is the integration of container networks into a single network using different modes of transport. Studying literature data it was concluded that a small number of researchers investigated at the same time see and land legs together.

The main goal of Newman,A. M. and Yano, C. A. [6], was to minimize operating costs, including a fixed charge for each train, variable transportation and handling costs for each container and yard storage costs, while meeting on-time delivery requirements.

Francesetti D. C. [2], presented andanalyzedthe costs of shipping containers, clearly showing that Genoa and Trieste are favourable solutions.

A multimodal transportation problem considered by Kim et al. [5], was the problem of determining the transportation flow, i.e. volume of container cargoes,

and the transportation mode in each trade route, for the objective of minimizing the sum of shipping and inland transportation costs.

Similar investigations a next year was made by Infante et al. [4]. It focused on an intermodal freight transport service in which containers represent the moved loading units. In particular, it deals with the advantages of combining sea and road transportation – sea for transferring large quantities over long distances, road for collecting and distributing over short or medium distances.

Han et al. [3], considered the problem of determining transportation quantity and mode in transporting international cargoes between Myanmar and her trading countries, especially focusing on the countries in South East Asia to check the extent of using short sea shipping, and inland transportation. The objective of theirs paper is to minimize transportation costs by mode between cargo origin and destination, subject to the maximum cargo volumes being handled at each seaport.

Payman, J. and Robert, C. L., [7] introduced an analytical models for predicting the allocation to ports and transportation channels of containerized goods imported from Asia to the USA. The first model, termed the Long-Run Model, is a large mixed integer non-linear programming model, and a set of heuristics to solve that. The objective is to minimize the total costs for transportation and handling, pipeline inventory, and safety-stock inventories.

3. METHODOLOGY

This paper examines transportation of goods from one part of the world to another. All cargo of different volume and weight is transported in containers by ship, assumed to originate from a major loading point far away. Depending on different dimensions and weight of shipments, the type of container in which goods are loaded is selected. This paper considers three different types of container: 20′ container, 40′ container, 40′ high-cube container (Table 1).

Table 1. Weights and dimensions of some common types of containers

	20′ container	**40′ container**	**40′ high-cube container**
internal volume	33,1 cbm	67,5 cbm	75,3 cbm
maximum gross weight	30.400 kg	30.400 kg	30.848 kg
empty weight	2.200 kg	3.800 kg	3.900 kg
net load	28.200 kg	26.600 kg	26.580 kg

The considered network includes three categories of nodes: origin port (port of loading), gateway ports (ports of discharge) and destination (place of delivery), and two categories of links, maritime and inland. The first one represents maritime transfers from origin port to gateway ports and the second the inland component of the distribution, in which containers are routed from gateways to final destination by road, rail and barge.

The main goal of this mathematical model is to minimize the sum of shipping and inland transportation costs for three different types of containers. The transport cost was considered for each of the most commonly used types of containers in the container transport, and is based on the Free On Board - FOB term. Total cost includes local costs in the port of discharge, customs clearance and handling costs. During inland transport it was used different modes of transport, and because of more appropriate comparisons of the costs of rail and barge with truck, it was included also handling costs at the terminals and final delivery to users by truck (local delivery).

This section presents the model formulation and corresponding explanations are given as follows:

N - set of nodes, let N = S ∪ E ∪ B, while S stands for origin port, E stands for gateway ports stands for place of delivery

A - set of arcs connecting an origin to a gateway (first-leg arcs)

C - set of arcs connecting gateways to place of delivery (second-leg arcs)

t_{ij} - binary cost variable representing containers flow on first-leg arc, operator i to gateway j, $t_{ij} \in \{0,1\}$

l_{jk} - binary cost variable representing containers flow on second-leg arc, gateway j, mode of transport k, $l_{jk} \in \{0,1\}$

i - number of operator, $i \in \{1, \dots, 6\}$

j - number of port, $j \in \{1, \dots, 5\}$

t - type of container, $t \in \{1, \dots, 3\}$

k - mode of transport, $k \in \{1, \dots, 3\}$

CSE_{ijt} - transportation cost on first-leg arcs (expressed in $)

EX - exchange rate (€ / $)

CPC_{ijt} - port cost (expressed in €)

CEB_{jkt} - transportation cost on second-leg arcs (expressed in €)

Objective functions:

Min cost =

$$\left(\sum_{(i,j)\in A}\left(CSE_{ij}\frac{1}{EX}+CPC_{ij}\right)*t_{ij}+\sum_{(j,k)\in C}CEB_{jk}*l_{kj}\right) \quad (1)$$

Constraints:

$$\sum_{(i,j)\in A} t_{ij} = 1 \quad (2)$$

$$\sum_{(j,k)\in C} l_{jk} = 1 \quad (3)$$

$$\sum_{(i,j)\in A} t_{ij} = \sum_{(j,k)\in C} l_{jk}, \ \forall j \quad (4)$$

Corresponding Explanations:
The objective function (1) minimizes total cost of container import flow through the transport network. They include transport cost on the first leg-arc (ocean costs), port cost and transport cost on the second leg-arc (cost of using inland vehicles - truck, rail and barge. Constraints (2) and (3) define a single best solution for cost from a group of ordered pairs on the maritime and inland part. Constraint (4) selects the same port for the first and second leg-arc and defines one route from origin to place of delivery regarding transportation cost.

4. RESULTS

As a case study it was developed mathematical model which minimize transportation costs of container import from Shanghai to Belgrade. Optimization model was programmed in C and MATLAB and simulations were performed on an Intel Core i7-3612 QM 2.1 GHz computer. We use original input data regarding first half of 2014. Table 2 represents simulation results of different type of cargo (different volume and weight) while figure 1 represents optimal transport routes for each type of container:

Table 2. Simulation results

Simulation	Volume (cbm)	Weight (t)	20 dv	40 dv	40 hq	Total cost (EUR)
1	200	200	8	0	0	12752
2	500	100	1	2	5	18949
3	1000	500	4	18	0	50836
4	5000	1000	1	0	71	177887
5	10000	5000	2	203	0	504598

Optimal transportation cost between Shanghai and Belgrade per each container (20 DV, 40 DV, 40 HQ) are respectively 1594 €, 2470 €, 2483 € using see and land legs together.

5. CONCLUSIONS

This paper analyzes the supply chain network with primary focus on import of containers from Shanghai to Belgrade through selected Mediterranean ports, observing the six world's largest container operators (Maersk Line, Mediterranean Shipping Company, CMA CGM, Evergreen Line, China Ocean Shipping Company and Hapag-Lioyd) with theirs different type of services.
The main goal of this research is to provide an optimal route with lowest transportation cost of different type and number of container from Shanghai to Belgrade depending on different weight and volume of cargo.

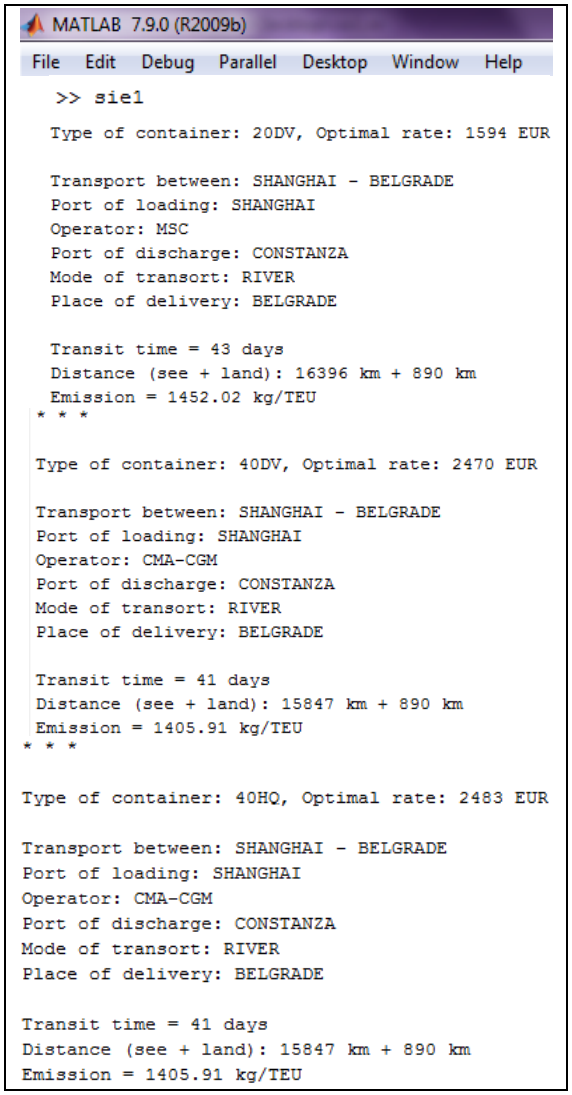

Figure 1. *Optimal transport routes for each type of container*

Mathematical model give us possibility to get reliable data of the minimal cost on the observed route per each type of container. Computational results shows that the lowest transportation costs between Shanghai and Belgrade, per each type of containers are reached using barge (river transport) on hinterland.
A mathematical model has also a practical use in determining the optimal route. Using this model it can be generate competitive bids in transport organization. Appropriate forwarding agency can provide these bids to its customers and constantly it can inspect the most optimal routes depending on the selected criteria.
Further research is needed, because this research is recited only part of the problem. It can be extended in the future and can be imported with a lot of new nodes and new objectives such as transit time and emissions.

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