ENHANCING COMPETITIVE ADVANTAGE THROUGH THE OPTIMISATION OF THE SUPPLY CHAIN OF THE CONTAINERIZED FLOW OF GOODS

Povećanje kompetitivne prednosti kroz optimizaciju opskrbljujućih lanaca kontejneriziranih tokova robe

Ass. Prof. Ratimir Dovečar
Faculty of Maritime Studies and Transport
University of Ljubljana
ratimir.dovecar@fpp.edu

Prof. Igor Trupac
Faculty of Maritime Studies and Transport
University of Ljubljana
igor.trupac@fpp.edu

Ass. Prof. Peter Vidmar
Faculty of Maritime Studies and Transport
University of Ljubljana
peter.vidmar@fpp.edu

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Summary

The basic aim of this treatise is to research into relevant features of the multimodal transportation chains, their advantages and disadvantages as well as the problems of the sinchronization of work of all participants in multimodal transport. With the development of information technology the method of optimisation of the multimodal transportation chains is more and more based on the computer programs being representative tools in solving of the comprehensive tasks.

It is believed that the present research, the methodology applied and its findings, should promote and improve the multimodal transportation chains in order to cope with the complex contemporary logistic demands of global economy.

Key words: optimisation, multimodal transportation chains, information technology

Sažetak

Osnovni cilj članku je istraživati relevantne faktore multimodalnih transportnih lanaca, njihovih prednosti i slabosti, ali i probleme sinkronizacije rada svih sudionika u multimodalnom transportu. Razvoj informacijskih tehnologija i metoda optimalizacije multimodalnih transportnih lanaca sve se više temelji na kompjutorskim programima koji su reprezentativna sredstva u procesu rješavanja složenih transportnih problema.

Vjeruje se da će sadašnje istraživanje, aplicirana metodologija i rješenja unaprijediti multimodalne transportne lance poradi zadovoljavanja kompleksnih sadašnjih i budućih logističkih zahtjeva globalne ekonomije.

Ključne riječi: Optimizacija, multimodalni transportni lanac, informacijska tehnologija.

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INTRODUCTION / *Uvod*

The logistic approach determines today the choice of strategies and the performance of transport activities, both helping consolidate and expand trade currents and providing new opportunities to improve the quality of service and in consequence to develop new income sources. Operational efficiency of the transport-logistics cycle is affecting, by all actors involved: linear companies port authorities, stevedores, forwarders, agents, as well as hinterland transportation modes.

A transportation chain is integrity of technical, technological and organisational operations, synchronised in space and time (e.g. packaging, loading, discharging, transhipment, warehousing and delivery of goods), providing fast, secure and optimal flow of goods from their raw basis to the consumer. This research focuses on the container transportation chain aiming to optimise it and identifies its advantages. Even though the system of optimal functioning of international transportation chains depends on several factors (traffic infrastructure, modern transportation technologies, development of foreign trade exchange etc.), its seems that the integral information system based on modern information technology represents its fundamental precondition.

Constant development and the quality improvement of computer hardware and software for the optimisation and algorithm technology paves the way for faster and more sophisticated software solutions of the problems occurring in traffic systems. The new software generation based on the integration of object technology and econometric engineering provides a substantial change, thus reducing the complexity and time of carrying out applications. The software components, which bridge the gap between the linear and limitation programming, based on the generation of automatic codes. With the development of information technology the methods of optimisation of transport are increasingly based on the application of data tables. Accordingly, a hypothesis is proposed: The electronic Excel data table, being a representative packet for mathematical programming in the function of solving the transportation problems, enables an effective optimisation of the multimodal transportation chains [1].

In order to prove the proposed hypothesis the following methods are used: analysis, synthesis, system, mathematical modelling and mathematical programming.

DATA TABLE AND THE QUANTITATIVE ANALYSIS / *Tablica podataka i kvantitativna analiza*

The data table includes the computer programs that may be used for computation and publication of the quantitative analysis. A data table may compute the majority of mathematical problems totally or partially. Even though there is a definite number of table programs on the market, the most popular is the Excel data table. The standard data tables, which solve the problems of the quantitative analysis, are further supported with specialised programs in order to widen their capacity. They are called “add-in” programs and once they are added, they may be used as an integral part of the data table. An example of an “add-in” program is the Solver.

Usage of Solver application in mathematical programming and limitation programming technology requires ability to create a transport problem-solving model. It is necessary to integrate highly specialised knowledge about computer-supported optimisatisation methods such as matrix generation, data preparation for solver, mathematical programming, and programming in computer program languages that support mathematical programming. Solver, as a computer-supported method of optimisation supports the creation of transport problems solving model which describes relations between problem area, decisions and limitations, contains a set of logical procedures that are incorporated in computer application for finding an optimal transport problem solution. It is used to solve problems with many variables and assists in finding a combination of variables, which raise the target value to the maximum or reduce it to the minimum.

The quantitative analysis is a scientific approach for the managerial decision making. Concepts, emotions and guessing are not considered to be a part of such analysis. This approach begins with data. These are, like raw materials in factories, handled, i.e. transformed in information used by managers on all levels of decision making. Such handling of raw data, shaping them into important information, is the essence of the quantitative analysis. The approach of the quantitative analysis consists of defining the problem, developing a model, acquiring inputs, developing solutions, testing them, analysing results and applying them. The transportation problems take an important place in the operation research as well as in the application of quantitative methods for the solution to complex problems. The transport problem of linear programming occurs when the transport of definite goods from several points of departure and several points of destination has to be programmed (e.g. transport of containers with cargo from production points to seaports and from there to consumer points) with minimum costs. It should be pointed out here that addressing the transportation problems has a wider application and greater importance than usually believed. Namely, apart from the transport problems also different other problems may be methodologically solved in a similar way, as they are formally manifested in the same way.

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The problem of transport is shown in the table 1 - quantity of transport, followed by the matrix of costs - table 2.

Table 1. Quantity of transport
Tablica 1. Transportna količina

Starting point	Destination point B_1 B_2 ....B_n	Quantity despatched
A_1	x_{11} x_{12} ....x_{1n}	$= a_1$
A_2	x_{21} x_{21} ....x_{2n}	$= a_2$
.	. . ..	.
.	. . ..	.
A_m	x_{m1} x_{m1} ....x_{mn}	$= a_m$
Quantity received	$= b_1$ $= b_2$ .....$= b_n$	

Table 2. Matrix of costs
Tablica 2. Matrica troškova

Starting point	Destination point B_1 B_2 .... B_n
A_1	c_{11} c_{12} .... c_{1n}
A_2	c_{21} c_{21} .... c_{2n}
.	. . ..
.	. . ..
A_m	c_{m1} c_{m1} .... c_{mn}

The quantities of dispatch at starting points are distributed to the quantities at destinations, so that the obtained optimal program gives us the minimum transportation costs [2].

RELEVANT FEATURES OF THE MULTIMODAL TRANSPORTATION CHAINS / *Relevantni podaci o multimodalnim transportnim lancima*

A programmed multimodal transport, being a subsystem of the international system, should provide undisturbed functioning of the door to door transportation chain. The latter represents in fact an integrated chronological transportation process from the manufacturer to the consumer. Since the process includes several traffic branches, technological integration of all rings in the chain should be guaranteed in time and space. Should one link in the whole door to door process fail the costs would rise and the multimodal or combined transport would prove to be ineffective [3].

The timing of multiomodal transport as well as the synchronisation of all participants in the transportation chain represents an important factor in providing regular, safe and fast functioning of modern transport. Therefore without considering the established criteria - the synchronisation and co-ordination of work, the accomplishment of individual functions and relations – the transportation chain cannot work. Important conditions for the formation of a transportation chain are as follows:

- exact establishment and synchronisation of possible transport combinations on the basis of qualitative advantages as well as acquiring procedures of criteria evaluation;
- the choice of the most favourable variant, i.e. an optimal solution of forming the transportation chain considering the interests of all participants in it and avoiding risks at the same time;
- co-ordination of functions of the industrial and public or general transport, particularly during warehousing of goods and loading/discharging operations of containers, swap bodies, vehicles, trailers or pallets;
- regular provision (without standstills or waiting) of necessary transportation capacities in the chain of different traffic branches;
- provision of uninterrupted, regular and fast flows of goods in the process of reproduction, so that no phase is affected in "its production";
- use of modern unified technical and technological means in transport, production, despatch, packaging, warehousing etc.

DEFINING THE PROBLEM IN THE CONTAINER TRANSPORTATION CHAIN / *Definiranje problema u kontejnerskomu transportnom lancu*

The international multimodal transport operator is often faced with the problem of continuous distribution of containers with heterogeneous or homogeneous cargoes from numerous starting and destination points using several different traffic branches, meeting all supply and demand with minimal manipulation and transportation costs. In such case the operator may first identify partial transportation problems for the individual traffic branch and then for the whole transportation chain.

Further are formulated partial theoretical problems of container transport in TEU. It is presumed that the multimodal transport operator should arrange dispatch of a greater number of containers with cargo from several shore terminals in the US by road vehicles through several US ports (i.e. port container terminals - New York, Norfolk); from there to the European ports (i.e. port container terminals - Koper, Rijeka, Trieste, Antwerpen); further to distribute containers with

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cargo by rail to several shore terminals (i.e. rail-road terminals); and finally from these terminals distribution would continue by road vehicles to consumers in the countries of Eastern Europe.

In order to simplify a complicated multiindex problem of container transport (all in TEU) in the multimodal transport chain comprising four traffic branches with their technical, technological, organisational, economic and legal specificity, first, four individual, partial problems are formulated. Then, after these problems have been solved and optimal solutions found, the problem is formulated for the whole multimodal transport chain. Each partial problem of the multimodal transportation chain has generally been formulated in the tables 1 and 2.

In the table 3 is formulated the first partial problem of container transport (TRANS-1) by road vehicles from four American continental container terminals (i.e. $ACCT_1$, $ACCT_2$, $ACCT_3$, $ACCT_4$) to five American port container terminals (i.e. $APCT_1$, $APCT_2$, $APCT_3$, $APCT_4$, $APCT_5$). The price is given in hundred € per 20-foot container unit [4].

Table 3. The model of a the transport problem of containers with cargo – TRANS-1

Tablica 3. Model transportnog problema kontejniziranoga tereta TRANS 1

j / i	$APCT_1$	$APCT_2$	$APCT_3$	$APCT_4$	$APCT_5$	a_i
$ACCT_1$	2,2	3,1	3,4	2,7	2,5	8 200
$ACCT_2$	1,9	2,3	2,7	3,2	3,3	8 500
$ACCT_3$	2,9	3,4	2,5	3,3	4,2	8 000
$ACCT_4$	3,2	2,7	2,9	3,4	3,8	8 300
b_j	6 500	6 600	5 400	6 200	8 300	33 000

The second problem (cf. Table 4) shows transportation and distribution of containers with cargo (TRANS-2) by container ships of the fourth and fifth generation from five American port container terminals (i.e. $APCT_1$, $APCT_2$, $APCT_3$, $APCT_4$, $APCT_5$) across the Atlantic Ocean to four European port container terminals (i.e. $EPCT_1$, $EPCT_2$, $EPCT_3$, $EPCT_4$).

Table 4. The model of a the transport problem of containers with cargo – TRANS-2

Tablica 4. Model transportnog problema kontejniziranoga tereta TRANS 2

j / i	$EPCT_1$	$EPCT_2$	$EPCT_3$	$EPCT_4$	a_i
$APCT_1$	15	17	19	20	6 500
$APCT_2$	19	17	15	21	6 600
$APCT_3$	14	18	17	19	5 400
$APCT_4$	21	20	19	18	6 200
$APCT_5$	19	15	14	16	8 300
b_j	6 500	6 600	5 400	6 200	33 000

The third partial problem (cf. Table 5) of transportation and distribution of containers with cargo (TRANS-3) shows transportation of containers by rail from four European port container terminals (i.e. $EPCT_1$, $EPCT_2$, $EPCT_3$, $EPCT_4$, $EPCT_5$ to five European continental container terminals (i.e. $ECCT_1$, $ECCT_2$, $ECCT_3$, $ECCT_4$, $ECCT_5$).

Table 5. The model of a the transport problem of containers with cargo – TRANS-3

Tablica 5. Model transportnog problema kontejniziranoga tereta TRANS 3

j / i	$ECCT_1$	$ECCT_2$	$ECCT_3$	$ECCT_4$	$ECCT_5$	a_i
$EPCT_1$	1,0	1,2	1,4	1,5	1,7	8 200
$EPCT_2$	1,2	1,5	1,6	1,7	1,9	8 500
$EPCT_3$	1,4	1,6	1,9	2,1	2,2	8 000
$EPCT_4$	2,0	2,1	2,3	1,9	2,2	8 300
b_j	6 500	6 600	5 400	6 200	8 300	33 000

The fourth partial problem (cf. Table 6) of transportation and distribution of containers with cargo (TRANS-4) shows transportation of containers by road vehicles from five European continental container terminals (i.e. $ECCT_1$, $ECCT_2$, $ECCT_3$, $ECCT_4$, $ECCT_5$) to nine European continental container terminals (i.e. $ECCT_1$, $ECCT_2$, $ECCT_3$, $ECCT_4$, $ECCT_5$, $ECCT_6$, $ECCT_7$, $ECCT_8$, $ECCT_9$).

Table 6. The model of a the transport problem of containers with cargo – TRANS-4

Tablica 6. Model transportnog problema kontejniziranoga tereta TRANS 4

j / i	$ECCT_1$	$ECCT_2$	$ECCT_3$	$ECCT_4$	$ECCT_5$	$ECCT_6$	$ECCT_7$	$ECCT_8$	$ECCT_9$	a_i
$ECCT_1$	0,8	0,7	0,6	0,7	0,8	0,9	0,8	0,7	0,6	6 500
$ECCT_2$	1,0	1,1	1,2	1,3	1,2	1,0	1,1	1,3	1,4	6 600
$ECCT_3$	0,9	1,0	1,2	1,3	1,4	1,5	1,6	1,3	1,2	5 400
$ECCT_4$	1,0	0,9	0,8	1,2	1,1	1,3	1,5	1,4	1,3	6 200
$ECCT_5$	1,2	1,3	1,4	1,5	1,6	1,7	1,3	1,1	1,4	8 300
b_j	3 800	3 600	3 500	3 700	3 750	3 850	3 600	3 600	3 600	33 000

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OPTIMISATION OF MULTIMODAL TRANSPORTATION CHAINS WITH THE APPLICATION OF DATA TABLE / *Optimizacija multimodalnih transportnih lanaca s pomoću tablice podataka*

The multiindex problems of transport generally as well as the problems of container transport in the multimodal transportation chain are solved with different methods (simplex method, method of jumping of stone to stone, Vogel method, MODI method or the modified method of distribution, Hungarian method as well as other linear or non linear methods. Table 7 shows the solution to a transportation problem by means of the Excel hardware Solver. The model is set up for the first partial problem of container transport from four starting to five destination points. The data and formulae are arranged in the addresses of a working list prepared for the computation of minimum costs.

Table 7. The model of a the transport problem of containers (TRANS-1)

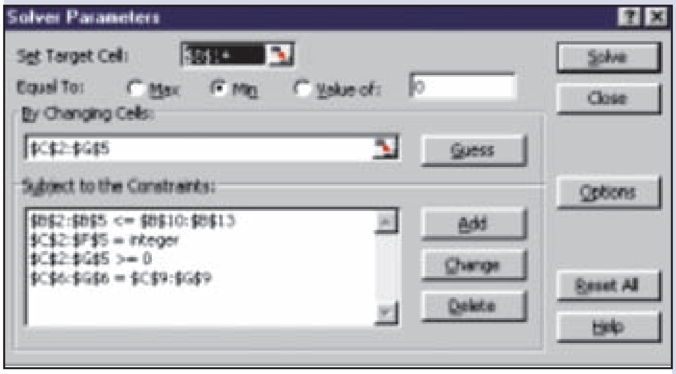
Tablica 7. Model transportnog problema kontejnera TRANS 1

	A	B	C	D	E	F	G	H	I
1				Odredišta					
2		●	0	0	0	0	0		
3	Izvori	●	0	0	0	0	0		
4		●	0	0	0	0	0		
5		●	0	0	0	0	0		
6			●	●	●	●	●		
7				Odredišta					
8			1	2	3	4	5		
9			6500	6600	5400	6200	8300		
10		8200	2,2	3,1	3,4	2,7	2,5		
11	Izvori	8500	1,9	2,3	2,7	3,2	3,3		
12		8000	2,9	3,4	2,5	3,3	4,2		
13		8300	3,2	2,7	2,9	3,4	3,8		
14		0	0	0	0	0	0		
15									
16									
17									
18	Upisane formule i naredbe u MSExcelu								
19									
20	B2 --> = SUM (C2:G2)				C14 --> = SUM(C2*C10+C3*C11+C4+C12+C5*C13				
21	B2 --> EDIT/COPY								
22	B3:B5 --> EDIT/PASTE				C14 --> EDIT/COPY				
23					D14:G14 --> EDIT/PASTE				
24	C5 --> =SUM(C2:C4)								
25	C5 --> EDIT/COPY				B14 --> SUM(C14:G14)				
26	C5:G5 -->EDIT/PASTE								

In order to solve the problem posed it is necessary to set up the chart Solver Parameters, so that the set target is entered in the window Set Target Cell or the address containing the target function is selected; in the window Equal the option Min is selected considering the tendency to have minimal costs; in the window By Changing Cells the address series is entered containing all variables; and necessary constraints are entered in the window Subject to the Constraints [5].

Figure 1 – Solver solving the problem of container transport TRANS-1

Slika 1. Solversko rješenje problema transportiranja kontejnera TRANS 1



When all parameters are entered, the key Solve on the chart Solver Parameters is clicked, thus activating the Solver program, which calculates the decisive variable values in the address series. The most important result is calculated in the address representing the result of the transport problem TRANS-1. The decisive variables calculated in the address series C2: F4 define the cheapest transport route. Table 7 has shown the optimal solution to the problem with the application of MS Excel.

Table 8. – Optimal solution to the problem of container transport TRANS-1

Tablica 8. Optimalno rješenje problema transportiranja kontejnera TRANS 1

	A	B	C	D	E	F	G	H	I
1				Odredišta					
2		0	0	0	0	0	8200		
3	Izvori	0	6600	1900	0	0	100		
4		0	0	0	5400	2600	0		
5		0	0	4700	0	3600	0		
6			6500	6600	5400	6200	8300		
7				Odredišta					
8			1	2	3	4	5		
9			6500	6600	5400	6200	8300		
10		8200	2,2	3,1	3,4	2,7	2,5		
11	Izvori	8500	1,9	2,3	2,7	3,2	3,3		
12		8000	2,9	3,4	2,5	3,3	4,2		
13		8300	3,2	2,7	2,9	3,4	3,8		
14		8456	1235	1706	1350	2082	2083		
15									
16		min T = 84560,00							
17									
18	Upisane formule i naredbe u MSExcelu								
19									
20	B2 --> = SUM (C2:G2)				C14 --> = SUM(C2*C10+C3*C11+C4+C12+C5*C13				
21	B2 --> EDIT/COPY								
22	B3:B5 --> EDIT/PASTE				C14 --> EDIT/COPY				
23					D14:G14 --> EDIT/PASTE				
24	C5 --> =SUM(C2:C4)								
25	C5 --> EDIT/COPY				B14 --> SUM(C14:G14)				
26	C5:G5 -->EDIT/PASTE								

Table 8 shows that the total costs of container distribution is 84 560,00 **€.** Analysing the optimal solution to the problem of container transport and distribution (TRANS-1) from the operator's viewpoint, it can be

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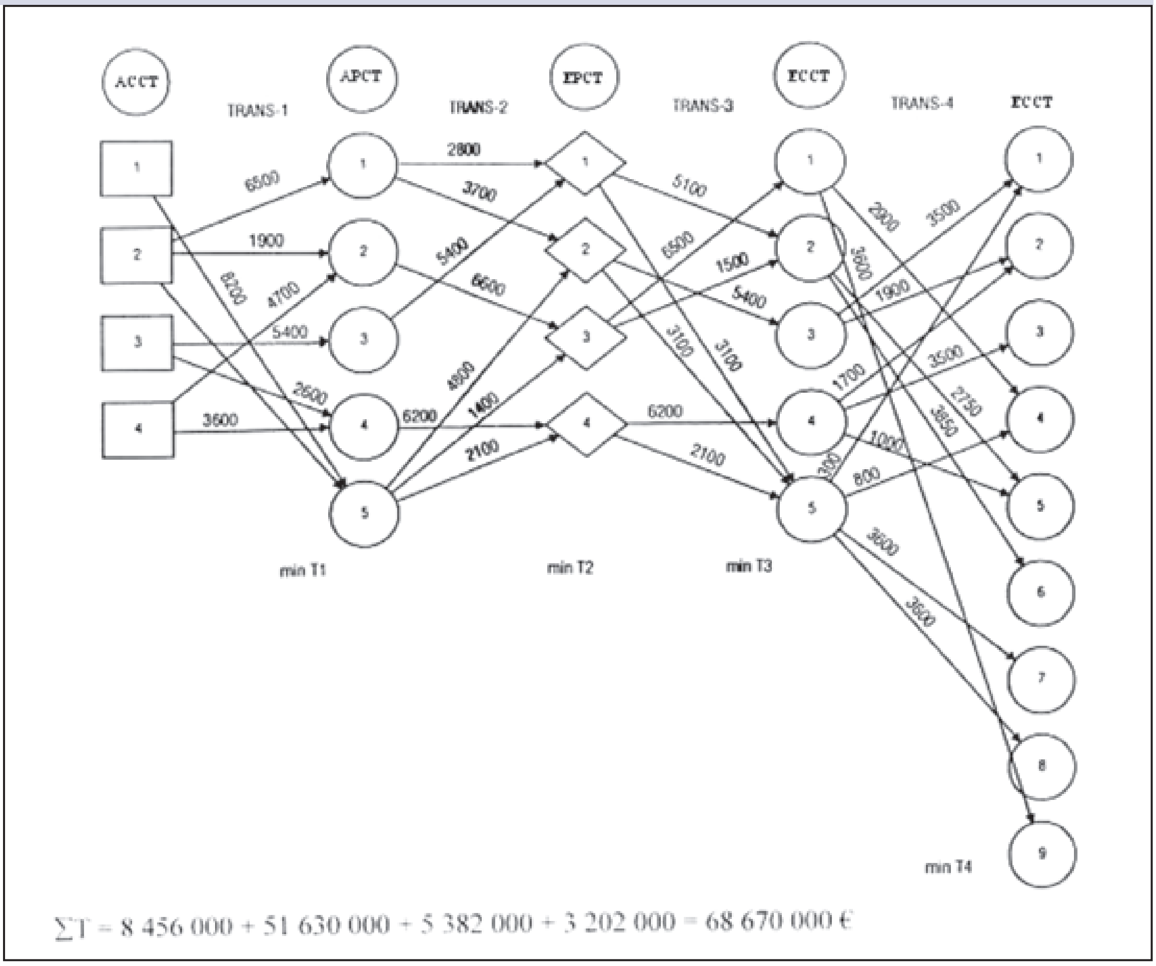
concluded that it is necessary: 1) from the starting point $ACCT_2$ to transport 6500 TEU per unit price of 190 € to the destination point $APCT_1$; 2) from the starting point $ACCT_2$ to transport 1900 TEU per unit price of 230 € to the destination point $APCT_2$; 3) from the starting point $ACCT_4$ to transport 4700 TEU per unit price of 270 € to the destination point $APCT_2$; 4) from the starting point $ACCT_3$ to transport 5400 TEU per unit price of 250 € to the destination point $APCT_3$; 5) from the starting point $ACCT_3$ to transport 2600 TEU per unit price of 330 € to the destination point $APCT_4$; 6) from the starting point $ACCT_4$ to transport 3600 TEU per unit price of 340 € to the destination point $APCT_4$; 7) from the starting point $ACCT_1$ to transport 8200 TEU per unit price of 250 € to the destination point $APCT_5$; 8) from the starting point $ACCT_2$ to transport 100 TEU per unit price of 330 €. In such distribution costs are minimal and they are lower than those obtained by the (most unfavourable) empirical program by 27%. Such substantial saving in transport costs is extremely important in setting competitive sale price of exported goods [6].

The second, third and fourth partial transport problems are solved according to the same pattern with the same procedures as elaborated in the previous program TRANS-1. These procedures therefore do not need to be repeated. The costs of optimal partial distribution programs and their comparison with the (most unfavourable) empirical program will be discussed in more detail in the conclusion of this treatise. Following is illustrated the distribution of containers (TEU) in all four optimal programs: TRANS-1, TRANS-2, TRANS-3 and TRANS-4 together with the number of containers and the total manipulation and transportation costs [7].

Figure 2. Distribution of containers (TEU) presented by all four optimal programs: TRANS-1, TRANS-2, TRANS-3, TRANS-4 with the number of containers and the sum of the manipulating transport costs

Slika 2. Prezentacija četiri optimalnih programa distribucije kontejnera TRANS 1,TRANS 2,TRANS 3,TRANS 4 s količinama kontejnera i sumom manipulacijskih troškova transportiranja



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CONCLUSION / *Zaključak*

The development of utilitarian oriental programs for the quantitative analyses to be applied in the optimisation of transport shows the extension of possibilities of the program and the solving of complex strategic transport problems. The example is the multiindex transport problem presented in this treatise. The total manipulation costs amount to 68 670 000 € or 2080,9 € per container unit (TEU) of the multimodal transportation chains for the 33 000 full containers (TEU), carried from the shipper somewhere in the central USA to numerous consignees at the ports of destination in Eastern Europe by road, sea, rail and road again,

If the optimal program for the distribution of the whole quantity of containers (33 000 TEU) is compared with the most unfavourable empirical programs of distribution of the same quantity, the multimodal transport operator shipping containers under FIATA Bill of Lading may save even up to 25 426 773 €. The said saving derives from the following calculation of four most favourable and four most unfavourable programs of distribution of 33 000 containers (TEU):

TRANS-1 empirical (most unfavourable) program	$\sum T =$ 11 583 561,6 €
Most unfavourable program	$\sum T =$ 8 456 000 €
Saving (27%)	$\sum T =$ 3 127 562,6 €
TRANS-2 empirical (most unfavourable) program	$\sum T =$ 71 708 333,3 €
Most unfavourable program	$\sum T =$ 51 630 000 €
Saving (28%)	$\sum T =$ 20 078 333,3 €
TRANS-3 empirical (most unfavourable) program	$\sum T =$ 6 900 000 €
Most unfavourable program	$\sum T =$ 5 382 000 €
Saving (22%)	$\sum T =$ 1 518 000 €
TRANS-4 empirical (most unfavourable) program	$\sum T =$ 3 904 878 €
Most unfavourable program	$\sum T =$ 3 202 000 €
Saving (18%)	$\sum T =$ 702 878 €

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