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DECISION SUPPORT FOR OPTIMAL REPOSITIONING OF CONTAINERS IN A FEEDER SYSTEM

ABSTRACT

The transport of empty containers represents a serious problem in the fast growing sphere of maritime container transport. The most widespread type of container transport organization in maritime transport is the hub and spoke mode, which enables the transport of a great number of containers via large vessels between hub ports, from where feeder ships transport to smaller ports that thus gravitate to the central hub port. The article contains a detailed analysis of the northern Adriatic ports and the feeder connections with the hub ports of the Mediterranean. A two-level VRPPD (Vehicle Routing Problem with Pickup and Delivery) problem is modelled on a graph, where the transport of full containers is privileged over the transport of empty containers. This enables the simulation of the feeder system in the northern Adriatic, meaning that it shows the ship's operator the movement programme with minimal transport costs for the superfluous empty containers in the complex of the regular transports of full containers in the feeder system.

KEY WORDS

hub and spoke, feeder service, VRPPD model, graphs, two-level logistics, container transport, empty containers

1. INTRODUCTION

In the last decade the yearly growth of maritime container transport amounted to 8-10%. Ports had to urgently adapt to the increasing tempo. Based on the data in the Review of maritime transport 2006[1] the growth of the port container transport in the year 2004 was 12.6% and reached 336.9 million TEU. Such growth in the container transport meant for many ports the introduction of a different, advanced method of container manipulation that aside from acquiring advanced equipment also demanded the adaptation of work organization. Because of the rationalization of work the ports connected into the so called hub and spoke systems that consist of two types of ports – the smaller feeder ports and the bigger hub ports. The function of the smaller container ports is to supply their accessible mainland region with goods that reach the port by smaller container ships, which is why the smaller ports successfully incorporate into the so called feeder system the main purpose of which is the rationalization and filling of the capacities of the bigger container ships that stop in one of the central (collecting-hub) ports on their important maritime routes around the world. The feeder system is especially suitable for enclosed seas like the Mediterranean.

An ancillary consequence of the growth of container transport is the increasing number of empty containers in the transport network. Information and analysis in professional publications show that empty containers represent around 20% of the container transport.

A portion of the empty containers is dependent on the direction of the maritime transport. The most marked disproportion was in the year 2005[2] in the direction east-west when the container transport from Asia towards North America was 13.8 million TEU and in the other direction only 4.3 million TEU.

This disproportion in transportation of full and empty containers has been occurring also in the northern Adriatic. A solution model is presented later on with the use of VRPPD algorithm that helps in the choice of optimal size and feeder ship service, so that fulfilment of the need for transport priority of full over empty containers would be assured.

2. TRANSPORT OF CONTAINERS IN NORTHERN ADRIATIC PORTS

Increased container transport over the last decade forces the northern Adriatic ports, that lie deep in the European mainland and have relatively limited gravitational hinterland, to direct their development tendencies exclusively into feeder service development, because they alone do not fulfil the prerequisites for the acceptance of big container ships.

Big ships with load capacity of 5,000-6,000 TEU need a fast service because such ships are remunerative only whilst navigating and every hour of waiting means loss. Thus, big container ships stop at the central hub ports of the Mediterranean Sea, such as Gioia Tauro, Malta or Algericas.

The discussed northern Adriatic port system comprises ports from Rijeka in Croatia, Koper in Slovenia and Italian ports like Trieste and Venice. The ports have geographically quite limited space but are gravitationally very differently oriented and have been operating separately for decades. When analysing container transport in the northern Adriatic ports the rapid container transport growth (Table 1) and the illustrated growth of empty container transport (Table 2) were considered.

Table 1 - Transport of containers in northern Adriatic ports

(TEU)	2002	2003	2004	2005
Rijeka	15,485	28,300	60,864	76,258
Koper	114,864	126,237	153,347	179,745
Trieste	180,861	118,401	171,570	196,213
Venice	262,337	283,667	290,898	314,461

Source: Containerisation international

Table 2 - Transport of empty containers in northern Adriatic ports

(TEU)	2002	2003	2004	2005
Rijeka	4,981	9,572	20,082	25,477
Koper	18,925	24,863	29,421	35,832
Trieste	37,200	14,804	19,760	22,787
Venice	85,937	77,207	87,234	89,944

Source: Containerisation international

In the analysed period the container transport of the port of Rijeka has increased the most, a consequence of investment in equipment. In spite of this the container transport in this port still lags behind in comparison with other northern Adriatic ports. The Vecon terminal in the Venetian port registers an increase in traffic and it is the biggest in the quantity of transported containers today among all the northern Adriatic ports. But all of the four ports together do not match the container traffic that is registered by Rotterdam.

The problem faced by the northern Adriatic ports is that there are too few container lines. The introduction of new feeder lines is necessary, but their economic justification in the first years of operation is questionable. With regular and more frequent feeder servicing in northern Adriatic ports, they would become interesting for new freight and looking at a long-term plan they would gain new containers and would successfully compete with the western/northern European ports that command with their block-trains most of the middle and eastern Europe traffic that could potentially gravitate to the northern Adriatic.

With the fast growing number of full and empty transported containers and the limited possibilities of warehousing the empty containers in terminals demand an effective planning of the feeder ship navigations in the system. Only by doing so can we lower the transport expenses of the ship's operator and prevent the accumulation (shortage) of empty containers.

3. OPTIMIZATION MODEL OF THE SHIP OPERATOR TRANSPORT EXPENSES

The problem is described as an example of a VRPPD[3] (Vehicle Routing Problem with Pickup and Delivery) problem on a complete graph $G=(V,E)$, with one ship's operator and one main hub port in the system. A set of nodes $V(G), |V(G)|=n'+1$, that represents the actual ports in the system, is distributed into three subsets:

1. The node $\{0\}$ is a point where the main – hub – port of the system is situated. This port represents the connection between the discussed system and the other ports. The superfluous (empty) containers that come from the other ports in the system are going to be gathered in this port.
2. The set $L=\{1,2,\ldots m\}$ includes those ports of the system where full containers are unloaded from ships that come from the hub port.
3. The set $B=\{i,i+1,\ldots,m,m+1,\ldots,n'\}$ where $i\in\{1,2,\ldots,m\}$ includes those ports of the system from which containers need to be taken towards other ports in the system.

Set B is the union of two sets: $B=B^1\cup B^2$. Set B^1 includes those ports from which empty containers need to be taken away. Set B^2 includes those ports where the empty containers are filled and need to be loaded onto a ship and taken to their final destination. Sets B^1 and B^2 are not necessarily disjunctive.

The description of the problems also demands certain additional conditions because ports from set L usually have priority over those from set B^2 and the latter have priority over those from set B^1. This means that on the route that goes through the points of each set the first ports to be serviced will be from the first set.

Such requirements are proper because ship's operators generally tend to load a ship first with full containers and only then if there is some space left with empty containers. But it can happen that needs for empty containers are such that the ship's operator is forced to load a ship with empty containers only and send them where there is a shortage.

To find an optimal solution of the distribution of empty containers in the graph, where the nodes $V(G)$ are actual ports of the system, we form a new graph where the nodes will no longer represent the concrete locations in the system, but the requirements of the problem.

In the new graph G_T the new set of nodes $N = V(G_T)$ will be considered in two parts:

- *Takeover nodes:* $P = \{1,\ldots,n\}$ are nodes where empty or full containers are loaded.
- *Delivery nodes:* $D = \{n+1,\ldots,2n\}$ are nodes where the empty or full containers are unloaded.

Set $P = \{1,\ldots,n\}$ is composed of two parts:

- *Takeover nodes of empty containers:* $P^1 = \{1,\ldots,h\}$ are nodes where empty containers are loaded.
- *Takeover nodes of full containers:* $P^2 = \{h,\ldots,n\}$ are nodes where full containers are loaded.

Parameter n is the number of requirements in graph $G = (V, E)$ (see Table 4). The following connections between nodes from set P and those from set D exist in the theoretical graph G_T: each node $i = 1,2,\ldots,n$ is connected with node $n+i$, because l_i containers are transported from node i into node $n+i$; therefore we define $l_{n+i} = -l_i$. Set κ includes the minimal number of ships that can effectively supply the system ports.

The request that each crossing begins and ends in a hub port determines the generalization of the theoretical graph G_T onto graph G_{ST} that is called generally theoretical graph and is defined as graph $G_{ST} = G_T * \{0\}^4$. It is obtained from $G_T \cup \{0\}$ by joining all the vertices of G_T to $\{0\}$.

In this way we can arrange for each ship $k \in \kappa$ a set $N_k = P_k^1 \cup P_k^2 \cup D_k$ of ports that it services. Sets N_k, P_k and D_k are subsets of sets N, P and D. In this way we can arrange for any ship $k \in \kappa$ a subgraph $G_{STk} = (V_k, E_k)$, where the nodes are defined as: $V_k = N_k \cup \{0\}$ and the connections as: $E_k \subseteq V_k \times V_k$. The capacity of the ship $k \in \kappa$ or the number 20' of containers [TEU] that can be loaded on the ship is marked with C_k.

The expenses of the ship's operator during movement of empty and full containers in the feeder system can be divided into:

- expenses that originate from the navigation and the stops of the ship, and
- expenses that originate from the moving of the containers in the terminal.

The expenses of the ship's operator that originate from the navigation and the stops of the ship are directly dependent on the length of the crossing and the eventual waiting of the ship. That is why the base for the definition of these expenses is Table 3.

Table 3 - The distance of the ports in NM

	Koper	Trieste	Rijeka	Venice	Gioia Tauro
Koper	0	3	137	62	686
Trieste		0	137	62	686
Rijeka			0	120	626
Venice				0	667

Source: ECDIS Navi-sailor 3000

Thus:

$$c_{ijk} = A_1 \cdot d_{ij} + A_2, \quad (1)$$

where c_{ijk} are the expenses of the crossing from node i into node j with the ship k, d_{ij} the distance of port i from port j in the system, A_1 and A_2 are the parameters that define the influence of the size of the ship and the speed of navigation on the crossing expenses. Therefore, the minimization of the crossing expenses is the minimization of the distance.

4. FORMULATION OF THE PROBLEM

The problem is composed of two parts:

1. Basic problem (OP) on the graph G_{ST},
2. Map of the solution in the beginning graph G (PR).

1. Basic problem (OP)

The mathematical record of the basic problem contains two types of variables:

- binary variables x_{ijk} take the value 1 exactly when ship k uses the connection $e_{ij} \in E_k$, and the value 0 when this does not happen,
- variables L_{ik}, that illustrate the number of containers on the ship k after casting of the port (node) $i \in V_k$.

Formulation of the basic problem is the following:

$$\text{(OP)} \quad \min\left\{\sum_{k\in K}\sum_{e_{ij}\in E_k} c_{ijk}\cdot x_{ijk}\right\} \quad (2)$$

$$\sum_{k\in K}\sum_{j\in N_k\cup\{0\}} x_{ijk} = 1 \quad \forall i \in P_k, \quad (3)$$

$$\sum_{j\in N_k} x_{ijk} - \sum_{j\in N_k} x_{j,n+i,k} = 0 \quad \forall k \in \kappa, i \in P_k, \quad (4)$$

$$\sum_{j\in P_k^2} x_{0jk} = 1 \quad \forall k \in \kappa, \quad (5)$$

$$\sum_{i\in N_k\cup\{0\}} x_{ijk} - \sum_{i\in N_k\cup\{0\}} x_{jik} = 0 \quad \forall k \in \kappa, j \in N_k \quad (6)$$

$$\sum_{i \in D_k \cup \{0\}} x_{i0k} = 1 \quad \forall k \in \kappa, \tag{7}$$

$$x_{ijk}(L_{ik} + l_j - L_{jk}) = 0 \quad \forall k \in \kappa, e_{ij} \in E_k \tag{8}$$

$$l_i \le L_{ik} \le C_k \quad \forall k \in \kappa, i \in P_k \tag{9}$$

$$0 \le L_{n+i,k} \le C_k - l_i \quad \forall k \in \kappa, n+i \in D_k \tag{10}$$

$$L_{0,k} = 0 \quad \forall k \in \kappa \tag{11}$$

Conditions (3) and (4) impose that each request is served exactly once. Condition (5) imposes that full containers have priority to empty ones. Conditions (6) and (7) characterize the flow structure. Conditions (8) - (10) assure that the shipped quantities of full and empty containers in graph G_{STk} correspond to the capacity of the ship. Artificial condition (11) allows creation of the hub and spoke structure.

The basic problem allows only direct connections between nodes from set P and those from set D. Connections with additional intermediate conditions must be expressed with the addition of new nodes to the sets P and D.

2. Map of the solution in the beginning graph G (PR)

The solution of the basic problem (OP) gives the optimal way in the subgraph G_{STk}. We map the solution into the beginning subgraph $G_k \prec G_{STk}$.

Because of the overlapping of paths in minor G_k it can happen that the conditions:

$$x^*_{ijk}(L^*_{ik} + l^*_j - L^*_{jk}) = 0, e_{ij} \in E(G_k) \tag{12}$$

$$l^*_i \le L^*_{ik} \le C_k, i \in B_k \tag{13}$$

$$0 \le L^*_{n+i,k} \le C_k - l^*_i, n+i \in D_k \tag{14}$$

are not fulfilled.

Variables x^*_{ijk}, L^*_{ik} and l^*_j are the restriction of the values x_{ijk}, L_{ik} and l_j on the minor G_k. On a defined path let $j^* \in B_k$ be the first node where condition (12) is not satisfied (the node j^* is the ending of the connection $e_{i^*j^*} \in E(G_k)$). That means that the ship has too low capacity to load all the full and empty containers in port j^*.

Therefore $x^*_{i^*j^*k^*} = 1$ and $(L^*_{i^*k} + l^*_{j^*} + w^*_{j^*} - L^*_{j^*k}) \neq 0$. The capacity at disposal of the ship after leaving node i^* is $C_k - L^*_{i^*k}$. In the node j^* the ship wants to load $l^*_{j^*}$ containers and unload $w^*_{j^*}$ containers ($w^*_{j^*} = l_{n+\tilde{i}=j^*}$ for a proper index $\tilde{i}$), but $l^*_{j^*} \ge C_k - L^*_{i^*k} + w^*_{j^*}$.

If $j^* \in B^1_k \cap B^2_k$ it follows that $l^*_{j^*} = \lambda^1_{j^*} + \lambda^2_{j^*}$ where $\lambda^1_{j^*}$ is the number of empty containers that we want to load onto the ship ($\Delta\lambda^1_{j^*}$ is a part of these ones, that can be loaded onto the ship) and $\lambda^2_{j^*}$ is the number of full containers that we want to load onto the ship ($\Delta\lambda^2_{j^*}$ is a part of those that can be loaded onto the ship). Therefore, in accordance with conditions (13) and (14), the following applies:

$$L^*_{j^*k} = \sup_{\Delta\lambda^1_{j^*} \le \lambda^1_{j^*}} \{\Delta\lambda^1_{j^*} + \lambda^2_{j^*}\} + L^*_{i^*k} - w^*_{j^*} \le C_k \tag{15}$$

If $j^* \in B^1_k$ it follows that $l^*_{j^*} = \lambda^1_{j^*}$. Therefore, according to conditions (13) and (14), the following applies:

$$L^*_{j^*k} = \sup_{\Delta\lambda^1_{j^*} \le \lambda^1_{j^*}} \{\Delta\lambda^1_{j^*}\} + L^*_{i^*k} - w^*_{j^*} \le C_k \tag{16}$$

If $j^* \in B^2_k$ it follows that $l^*_{j^*} = \lambda^2_{j^*}$. Therefore, in accordance with conditions (13) and (14), the following applies:

$$L^*_{j^*k} = \sup_{\Delta\lambda^2_{j^*} \le \lambda^2_{j^*}} \{\Delta\lambda^2_{j^*}\} + L^*_{i^*k} - w^*_{j^*} \le C_k \tag{17}$$

The priority for the ship's operator is to load the ship with as many full containers as possible. If all the containers cannot be loaded, the empty ones are left at the terminal. When the capacity of the ship does not satisfy the needs of the ship's operator for transportation of the full containers, it is reasonable to decide on a bigger ship. The described procedure is repeated until all the nodes are analysed on a definite cycle in graph G_k.

The algorithm of the map (PR) problem has the following shape:

PR Algorithm

INPUT:

$C = 0 j_1 j_2 \ldots j_h 0 \subseteq G_k$ (solution cycle in the basic graph);

$\{l^*_1, l^*_2, \ldots, l^*_h\}$ (load quantity at the nodes of the cycle);

$\{L^*_{0k}, L^*_{1k}, \ldots, L^*_{hk}\}$ (respectively the number of containers on the ship k after casting of nodes on the cycle);

WHILE $l^*_{j_l} \ge C_k - L^*_{j_{(l-1)}k}$; (index l, $1 \le l \le h$)

DO

$$L^*_{j_l k} = \sup_{\Delta\lambda^1_{jl} \le \lambda^1_{jl}} \{\Delta\lambda^1_{j_l} + \lambda^2_{j_l}\} + L^*_{j_{(l-1)}k} - w^*_j \le C_k$$

OUTPUT: $L^*_{j_l k}$.

5. SIMULATION: DEFINITION OF THE FEEDER SYSTEM IN THE NORTHERN ADRIATIC

On the basis of previous feeder system studies in the northern Adriatic[5], which did not consider the priority of full containers to the empty ones, a simulation of the movement planning of full and empty containers in the feeder system is given: V_1-Koper, V_2-Trieste, V_3-Rijeka, V_4-Venice and the main hub port V_0-Gioia Tauro. These are the nodes of the basic graph $G = K^5$. K^5 is a complete graph on five nodes. In Table 4 demands for the movement of full and empty containers in the feeder system are given. In the basic simulation a single ship of $C_1 = 2{,}500$ TEU capacity is used, therefore $k = 1$.

Table 4 - Definition of graph

i	l_i (TEU)	Movements in the real graph	P^1	P^2	D	$n+i$ $[n=10]$
1	600	$V_0 \to V_4$ full		V_1	V_{11}	11
2	600	$V_0 \to V_2$ full		V_2	V_{12}	12
3	600	$V_0 \to V_1$ full		V_3	V_{13}	13
4	600	$V_0 \to V_3$ full		V_4	V_{14}	14
5	200	$V_4 \to V_0$ full		V_5	V_{15}	15
6	200	$V_2 \to V_0$ full		V_6	V_{16}	16
7	100	$V_1 \to V_0$ full		V_7	V_{17}	17
8	50	$V_1 \to V_2$ empty	V_8		V_{18}	18
9	600	$V_3 \to V_0$ full		V_9	V_{19}	19
10	500	$V_3 \to V_0$ empty	V_{10}		V_{20}	20

Source: authors

From Table 4 it follows that: node $V_0 \in V(G)$ is multiplied into nodes $\{V_1, V_2, V_3, V_4, V_{15}, V_{16}, V_{17}, V_{19}, V_{20}\} \in V(G_T)$, node $V_1 \in V(G)$ is multiplied into nodes $\{V_7, V_8, V_{13}\} \in V(G_T)$, node $V_2 \in V(G)$ is multiplied into nodes $\{V_6, V_{12}, V_{18}\} \in V(G_T)$, node $V_3 \in V(G)$ is multiplied into nodes $\{V_9, V_{10}, V_{14}\} \in \in V(G_T)$ and node $V_4 \in V(G)$ is multiplied into nodes $\{V_5, V_{11}\} \in V(G_T)$. So the theoretical graph G_T is a complete graph on 20 vertices.

The solution is obtained with the optimization program ILOG OPL Development Studio IDE Version 5.0 by the elimination of 425 rows and 295 columns. The reduced Mixed Integer Program has 34 rows and 163 columns. The solution in the general theoretical graph G_{ST} is presented in Table 5.

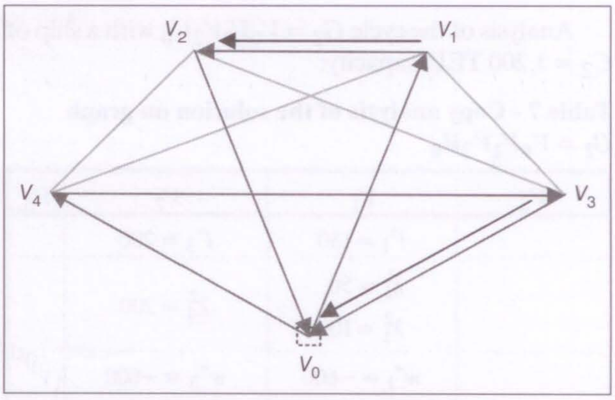

Figure 1 - Solution on the real graph K^5

Source: authors

The value of the goal function in the graph G_{ST} is 11,834 (in this graph the distance of the connection between the vertices that represent the same port in the basic graph is 1,000), its value drops to 2,788 in the basic graph G. In the solution analysis of the basic graph, we find that in the system we can effectively replace the feeder ship with the capacity $C_1 = 2{,}500$ TEU by two smaller ships with capacities $C_1 = 1{,}200$ TEU and $C_2 = 1{,}200$ TEU (see Figure 1 and Figure 2), which is why the usage of the algorithm (PR) for the map of the optimal path will be presented only in this case.

Analysis of the cycle $G_1 = V_0V_4V_3V_0$ with the ship of $C_1 = 1{,}200$ TEU capacity:

Table 6 - Copy analysis of the solution on graph $G_1 = V_0V_4V_3V_0$

V_0	V_4	V_3	V_0
	$l^*_4 = 200$	$l^*_3 = 1{,}100$	
	$\lambda^2_4 = 200$	$\lambda^1_4 = 500$ $\lambda^2_4 = 600$	
	$w^*_4 = -600$	$w^*_3 = -600$	
$L^*_{0k} = 1{,}200$	$L^*_{4k} = 800$	$L^*_{3k} = 1{,}300$	
$C_1 - L^*_{0k} = 0$	$C_1 - L^*_{4k} = 400$	$C_1 - L^*_{3k} = -100$	
		$\Delta\lambda^1_3 = 400$	
		$L^*_{3k} = 1{,}200$ (corrected)	
		100 empty TEU remain at the terminal in V_3	

Source: authors

Table 5 - Values of solution

$$x = \begin{bmatrix} x_{0,1} = 1, x_{1,11} = 1, x_{2,12} = 1, x_{3,13} = 1, x_{4,14} = 1, x_{5,15} = 1, x_{6,16} = 1, x_{7,17} = 1, x_{8,18} = 1, x_{9,19} = 1, \\ x_{10,20} = 1, x_{11,10} = 1, x_{12,7} = 1, x_{13,6} = 1, x_{14,5} = 1, x_{15,9} = 1, x_{16,4} = 1, x_{17,2} = 1, x_{18,8} = 1, x_{19,3} = 1, x_{20,1} = 1 \end{bmatrix}$$

Source: ILOG OPL Development Studio IDE Version 5.0

Analysis of the cycle $G_2 = V_0V_1V_2V_0$ with a ship of $C_2 = 1{,}200$ TEU capacity:

Table 7 - Copy analysis of the solution on graph $G_2 = V_0V_1V_2V_0$

V_0	V_1	V_2	V_0
	$l^*_1 = 150$	$l^*_3 = 200$	
	$\lambda_1^1 = 50$ $\lambda_1^2 = 100$	$\lambda_4^2 = 200$	
	$w^*_1 = -600$	$w^*_3 = -600$	
$L^*_{0k} = 1{,}200$	$L^*_{1k} = 750$	$L^*_{3k} = 350$	
$C_1 - L^*_{0k} = 0$	$C_1 - L^*_{1k} = 450$	$C_1 - L^*_{3k} = 850$	

Source: authors

The first ship with the capacity $C_1 = 1{,}200$ TEU performs the service GIOIA TAURO–VENICE–RIJEKA–GIOIA TAURO. The second ship with the capacity $C_2 = 1{,}200$ TEU performs the service GIOIA TAURO–TRIESTE–KOPER–GIOIA TAURO. The ships perform a weekly or 10-day service depending on the time that they spend in ports. Such a feeder service exploits the ships quite effectively but 100 TEU of empty containers are left in the container terminal in the port of Rijeka. The result is the consequence of the priority of full containers over empty ones, that is comprised in the described model and it takes into consideration the general means for decision-making on the part of the ship's operators that privilege full containers over empty ones. The ship with $C_1 = 1{,}300$ TEU capacity on relation GIOIA TAURO–VENICE–RIJEKA–GIOIA TAURO enables the movement of all full and empty containers but the exploitation of the ship is less than optimal and this decision incurs extra expenses for the ship's operator.

6. CONCLUSION

This study can be an effective support to the ship's operator when planning new connections in feeder services by explicitly taking into account empty container distribution. Whilst there is huge literature on ship routing and scheduling problems, few studies treat the design of container hub and spoke shipping network and none of them incorporate the problem of repositioning of empty containers. In this paper, this problem was dealt with by forming a shipping hub and spoke network with the assumption that necessary empty container repositioning is performed using spare space on ships.

Based on the computational experiments that we conducted, the following conclusions can be reached: The rationalization of space in container terminals and preventing of accumulation (shortage) of empty

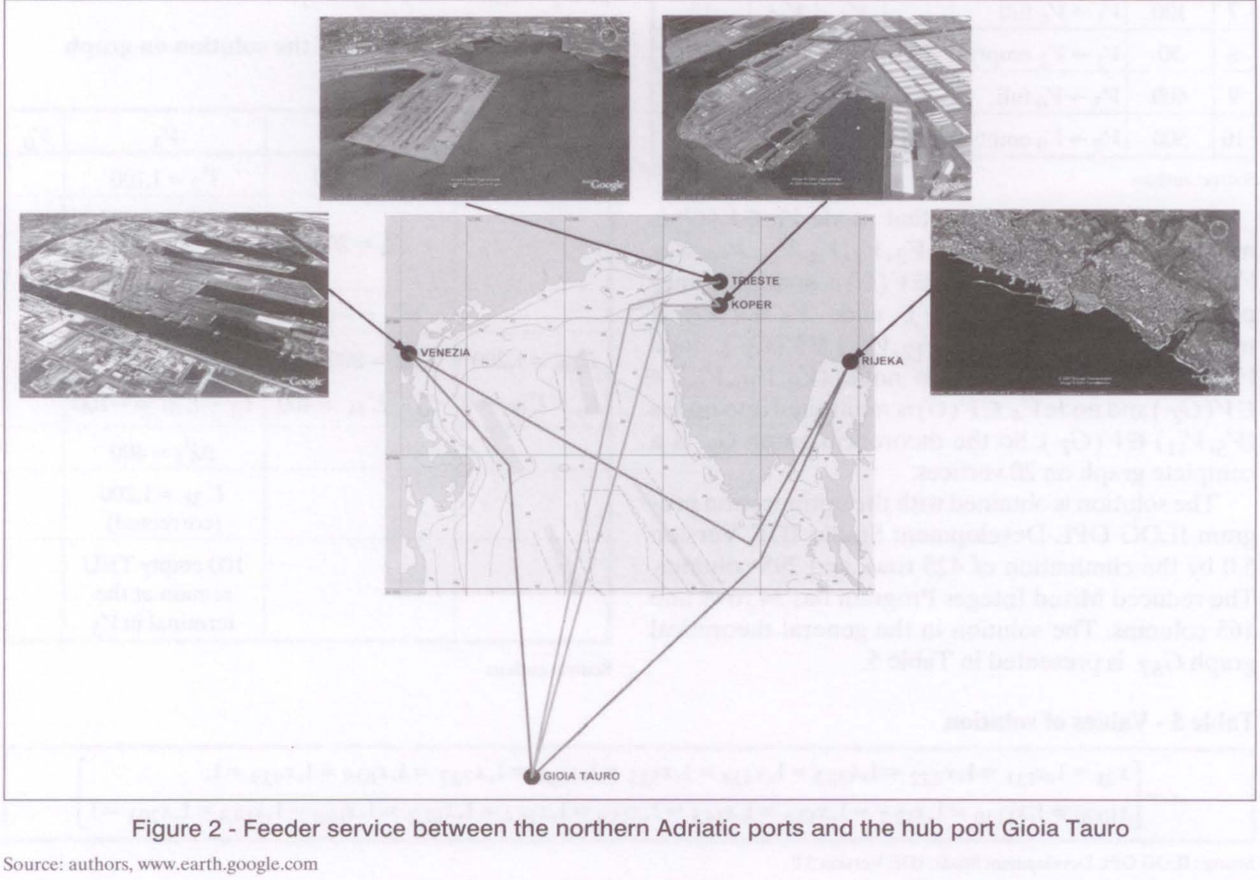

Figure 2 - Feeder service between the northern Adriatic ports and the hub port Gioia Tauro

Source: authors, www.earth.google.com

containers. The design of container shipping hub and spoke network without consideration of the empty container traffic becomes very costly due to less efficient empty container distribution associated with the resulting network.

In practice, there is a fierce competition among shipping companies; therefore, optimization of the crossing cost and load rejection in the basic level of the system (feeder connections of smaller ports) helps also with the rationalization of expenses in the second level of the system (the connection to main hub ports) because it enables a better exploitation of big container ships that connect the hub ports.

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POVZETEK

OPTIMALNO ODLOČANJE PRI PREMIKANJU KONTEJNERJEV V FEEDER SISTEMU

Prevozi praznih kontejnerjev predstavljajo resen logističen problem v hitrorastočem pomorskem kontejnerskem prometu. Najbolj razširjen način organizacije prevozov kontejnerjev v svetovnem pomorskem prometu je model hub and spoke. Le-ta omogoča prevoz velikega števila kontejnerjev z velikimi ladjami med hub pristanišči, od koder jih manjše feeder ladje razvažajo do manjših pristanišč, ki gravitirajo na centralno hub pristanišče. V članku so podrobno analizirana pristanišča severnega Jadrana in feeder povezave s hub pristanišči v Sredozemlju. Modeliran je dvonivojski problem VRPPD (Vehicle Routing Problem with Pickup and Delivery) na grafu, kjer je prevoz polnih kontejnerjev privilegiran nad prevozom praznih,. Ta omogoča simulacijo sistema feeder v severnem Jadranu, in sicer tako, da prikaže ladjarju razpored premika z minimalnimi prevoznimi stroški odvečnih praznih kontejnerjev v sklopu rednih prevozov polnih kontejnerjev v sistemu feeder.

KLJUČNE BESEDE

hub and spoke, feeder servis, VRPPD model, grafi, dvonivojska logistika, kontejnerski promet, prazni kontejnerji

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