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SOLUTION FOR INTER-CONNECTING AND SUPPLYING ADRIATIC ISLANDS

Abstract

The main objective of this work was to develop and define a transportation solution for inter-connecting and supplying Adriatic islands with Adriatic ports. Foundations of the method are: (a) Determination of cargo: Determination of factors for the goods conversion - "values to mass factors", (b) Selection of supply policy: selection of the route, schedule and duration of the voyage for the determination of the required speed and required vessel capacity, (c) Cost estimation of ship transport, which provides justification for the project and its comparison with the conventional truck transport. This approach has opened variety of solutions for the problem of supplying Croatian islands and at end the preliminary design of supply ship is given.

Key words: Inter-connecting of islands, Island supply, Supply policy, Adriatic islands, Supply ship

RJEŠENJE ZA MEĐUSOBNO POVEZIVANJE I OPSKRBU JADRANSKIH OTOKA

Sažetak

Glavni cilj ovog rada bio je razviti i definirati transportno rješenje za povezivanje i opskrbu jadranskih otoka s lukama na Jadranu. Temelji metode su: (a) Određivanje količine tereta. Izračunavanje faktora pomoću kojih se preračunavaju vrijednosti grupe proizvoda u njegovu masu proizvoda, (b) Odabir strategije opskrbe. Izbor rute, raspored plovidbe te trajanje plovidbe što nam omogućuje uvid u procjenu potrebne brzine i potrebnog kapaciteta broda, (c) Procjena troškova prijevoza brodom koja omogućuje opravdanost projekta i njegovu usporedbu s dosadašnjem uobičajenim transportom tereta kamionima. Ovakav pristup je otvorio i pogled na niz rješenja problematike opskrbe hrvatskih otoka, a na kraju dan idejni projekt broda za opskrbu.

Ključne riječi: povezivanje otoka, opskrba otoka, strategija opskrbe, jadranski otoci, brod za opskrbu

1. Introduction

Croatian Bureau of Statistics reported in year 2010 12.5 million passengers and 31.9 million tons of goods in maritime and coastal transport [1]. Unfortunately, there are no accurate data on the quantity of cargo and number of passengers annually transferred to the islands. Also, the flow of goods is one big uncertainty which depends on the market. The solutions are very specific with local features where supermarket chains have a major impact. Generally there is no apparent problem analysis of supply ships for Croatian islands so this work represents a step forward and contribution to the solution of this problem.

2. Analyses of population and the required cargo quantity

2.1. Analysis of population

In this paper the islands with a population of more than 1,000 inhabitants are taken into consideration to ensure the cost-effective transport network throughout the year. (Figure 1, Table 5).

Fig. 1 Croatian islands

Slika 1. Hrvatski otoci

2.2. The required quantity of cargo for the islands

Today, the islands are usually supplied by regular ferry lines. There is no existing organized transportation network and no data on the required annual or daily supply per person for the particular islands. We need to determine the daily quantity of goods and building materials per person. The sum of these quantities gives us an average of the required daily quantity of goods per person in Croatia.

2.3. Daily volume of goods per person

Since these data do not exist starting point was consumption expenditure per household in Croatia for the year 2009 [2], data collected by a survey of Croatian citizens. After considering the results of the survey it is necessary to link the amount of money with the mass of individual items. At the end, we got the quantity of mass that one person in Croatia spends a day. It is assumed that all the island inhabitants have the same needs of supplies as the residents who live on the mainland. However, it is realistic to expect that the need for supplies for the islands is smaller because they are generally more autonomous. Consumption expenditure per household for the year 2009 is 76,188 kuna [kn] (30.10.2013 1 EUR=7.62 kuna) [2] Since the certain items are not related to the mass they are not included in the consideration of the problem so we get the following table (Table 1).

Table 1 Expenditure per household in 2009

Tablica 1. Izdaci po kućanstvu u 2009. godini

Expenditure per household in 2009	Yearly, [kn]
Food and non-alcoholic beverages	24,427
Alcoholic beverages and tobacco	2,736
Clothing and footwear	5,553
Furnishings, household equipment	3,976
Health care	2,112
Other goods and services	6,435
TOTAL	45,239

Table 2 Conversion factors

Tablica 2. Faktori za proračun

Net mass of items	Mass of packaging	Price of one group	Factor=total mass/total price
[kg]	[kg]	kn	[kg/kn]
Food and beverages			
26.5	0.9	656.0	0.0417
Alcoholic beverages and tobacco			
1.2	0.0	96.6	0.0128
Clothing and footwear			
1.9	0.1	800.0	0.0024
Furnishings, household equipment			
6.7	0.2	195.6	0.0350
Health care			
0.04	0.03	76.14	0.0009
Other goods and services			
16.3	1.0	537.9	0.032

According to the [2] average household consists of 3 members. Daily consumption is obtained by dividing the annual consumption with 365, where all holidays are included, so the holidays should be taken into account afterwards when selecting the supply routes. For further analysis it is necessary to know the average prices of goods. By using the website [3], or similar, one gets an overview of prices in various supermarkets. As prices for the same product may be different in different stores it is necessary to determine the average prices. Mass is related only to the net mass of the product where packaging is not included. Using the table from the report [4] the mass of plastic packaging can be estimated for particular products. Mass of glass and tins is estimated using data [4][5] of randomly selected manufacturers. On this basis, we get the data that shows the different products with their net masses and the average prices per item groups. Also, we get a certain "values to mass factors" [kg/kn] for the each group by which one can convert household expenditures into mass that is being purchased.

Using the obtained factors [kg/kn] with abbreviated table of expenditure per household (Table 2), average number of members of a single household and the 365 days in the year, we get the total daily required quantity of supplies required by a person in the Republic of Croatia (Table 4)

Table 3 The quantity of supplies per person in Croatia

Tablica 3. Količina potrepština po stanovniku u RH

Expenditure per person in 2009	Factor	daily	daily
	[kg/kn]	kn	[kg]
Food and beverages	0.0417	22.31	0.9298
Alcoholic bev. and tobacco	0.0128	2.50	0.0321
Clothing and footwear	0.0024	5.07	0.0124
Furnishings, household eq.	0.0350	3.63	0.1272
Health care	0.0010	1.93	0.0019
Other goods and services	0.0321	5.88	0.1886
TOTAL		41.31	1.2920

Table 4 The composition of waste in Croatia

Tablica 4. Sastav otpada u RH

Waste	**Quantity (Million t / year)**
Municipal	1.2
Construction and demolition waste	2.6
Industrial and mining	1.6
Agricultural and forestry waste	7.1
Hazardous	0.1
Separately collected	0.2
Other	0.4
Total	13.2

Daily required supply of island inhabitant per person is 1.292 kg plus mass of construction materials.

2.4. Daily quantity of construction materials

As it is said before this information cannot be obtained from statistics. Mass of construction materials is obtained assuming that the building is with the same rate as demolishing since there is no unlimited room for expansion on islands. The starting point was waste management policy of the Republic of Croatia [6]. Table 4 shows the composition of the entire annual quantity of waste in Croatia. Population in Croatia in the year 2001 amounted to 4,437,460 [2]. If we take a look at the composition of the waste it can be seen that it is sufficient to take into account the item "Construction and demolition waste" which is 2.6 million tons / year. This results in 586 kg of annual construction and demolition waste per person. Considered on the daily basis we get 1.605 kg of waste per person which together with 1.292 kg supplies and 10% of reserve on the total sum amounts to 3.2 kg for daily mass that is needed to be supplied to the islands.

2.5. The required number of cargo containers for the transport to the islands

The resulting quantity of cargo per person is multiplied by the number of inhabitants of the observed islands (Table 5), by which we come to the daily quantity of required supply for these islands. The resulting mass can be converted into a daily number of the required 20 TEU containers with a maximum permissible payload of 21.74 tons. The maximum container payload is rarely achieved due to the volume and type of cargo to be stored. In addition, it should be taken into account the additional packaging that serves against damage when loading and unloading the container such as cardboard, wooden boxes or any other proper materials, so when calculating the required number of containers the utilization factor is considered. Report [7] states value of 48% for the container (TEU) utilization factor which corresponds to 10.5 t of cargo. This value is obtained from research of containers utilization in large container ports. For the problem of supply of Croatian islands it is assumed that the utilization of containers will be even smaller since they will be loaded with a lot of different supplies with different sizes, shapes and weights, which will make efficient stowing difficult. In this paper the arbitrary value of 35% of container utilization is used which corresponds to the mass of 7.61 t for one container. The number of containers for the daily transport of supplies to the islands is calculated then by dividing the daily quantity of cargo for each island with 7.61 (Table 5.). The resulting number shall be rounded to the next integer one in order to obtain the number of containers that have to be delivered each day 365 days a year.

Table 5 Number of containers for each island

Tablica 5. Broj kontejnera po svakom otoku

		Inhabitants	Daily qty.	Daily no. of TEU	Final TEU
	Island	**Num.**	**load [t]**	**35% util.**	**35% util.**
1	Krk	17860	57.2	7.5	8.0
2.	Korcula	16182	51.8	6.8	7.0
3	Brac	14031	44.9	5.9	6.0
4	Hvar	11103	35.5	4.7	5.0
5	Rab	9480	30.3	4.0	4.0
6	Pag	8398	26.9	3.5	4.0
7	Losinj	7771	24.9	3.3	4.0
8	Ugljan	6182	19.8	2.6	3.0
9.	Murter	5060	16.2	2.1	3.0
10	Ciovo	4455	14.3	1.9	2.0
11	Vis	3617	11.6	1.5	2.0
12	Cres	3184	10.2	1.3	2.0
13	Pasman	2711	8.7	1.1	2.0
14	Dugi otok	1772	5.7	0.7	1.0
15	Vir	1608	5.1	0.7	1.0
16	Solta	1479	4.7	0.6	1.0
17	Mljet	1111	3.6	0.5	1.0
	Total	116 004	371		56

Table 6 Distances of particular islands

Tablica 6. Udaljenosti pojedinih otoka

Dist.	Location	Supply	Dist.
		[TEU / day]	
[nm]		1TEU35%	[nm]
	Rijeka		22
3	Krk	8.0	
	Cres	2.0	16
24	Rab	4.0	
	Losinj	4.0	19
22	Pag	4.0	
	Vir	1.0	16
4	Dugi	1.0	
	Ugljan	3.0	16
22	Pasman	2.0	
	Murter	3.0	46
8	Ciovo	2.0	
	Solta	1.0	25
24	Brac	6.0	
	Hvar	5.0	24
27	Vis	2.0	
	Korcula	7.0	57
243	Mljet	1	
	Rijeka		

From the Table 5 it can be seen that the 56 containers (TEU) are required for the daily cargo supplies to all islands with a population of more than 1,000 inhabitants.

3. Supply policies

Supply policy of cargo must be on the daily basis, regardless of holidays. The policy is achieved by adequate transport networks that are based on defined fleet routes. Table 6 shows the distances between of particular mutually closest islands and indicates that the fleet of ships is required to ensure daily supplies.

The resulting policy alternatives for the chosen path:

A. Coastal policy with one home port:
   - A.1) Coastal transportation network, Rijeka – Rijeka
   - A.2) Coastal transportation network, Rijeka - Ploce - Rijeka

B. Coastal policy with two home ports:
   - B.1) Coastal transportation network, Rijeka - Ploce (home port Rijeka)
   - B.2) Coastal transportation network, Ploce - Rijeka (home port Ploce)

C. Southern and Northern policy with two home ports:
   - C.1) North transportation network, Rijeka – Rijeka,
   - C.2) South transportation network, Ploce - Ploce

To be able to compare policies and their transportation networks it is necessary to create a routes and time schedules of navigation for each policy where from this results we can get an overview of the possibilities of supplying the islands in one day. Only after a certain number of stages it can be seen how many vessels have to be included in each transportation network and then carry out preliminary costing of particular policy. Selecting the policy has impact on the initial price, crew costs and total costs of maintaining the entire network. The larger the fleet the higher are maintenance costs. After selecting the policy we have to adjust routes in terms of working hours of particular terminals on the islands and port positions

3.1. Routes and navigation schedules

Table 7 The input data for the calculation of the navigation schedules

Tablica 7. Ulazni podaci za proračun raspored plovidbe

Capacity of TEU container	21.74	[t / TEU]
Capacity of utilized TEU container	7.61	[t / TEU]
TEU container utilization	35	[%]
Vessel speed	10.5	[kn]
Time for unloading - loading of an empty and loaded container to the islands (15 min)	0.25	[h]
Time for unloading - loading of an empty and loaded container in port Ploce (5 min)	0.083	[h]
Days a year	365	[days]

Key data that impact the navigation schedule are vessels speed and time of unloading and loading of an empty or loaded container (Table 7.). Times for these operations in the port of Ploce are much lower because of available port equipment. Vessel speed is arbitrary in this paper but it is the result from the previous authors' calculations that satisfies constraints of distances between islands and allowable working hours.

A.1) Coastal policy with one home port – Rijeka - Rijeka

For this transportation network along the route Rijeka – Rijeka (Table 8) the fleet of four ships with capacity of 56 TEU is required. Since last stage finishes at 4 a.m. ship has to depart for the first stage at 5 a.m. This requires increasing the speed of vessel. When considering the daily supply order times for the islands they are as follows, for the: 1st stage - one day, 2nd stage - two days, 3rd stage - three days and 4th stage - four days.

Table 8 Example of calculation for the coastal route Rijeka – Rijeka

Tablica 8. Primjer proračuna za dužobalnu rutu Rijeka - Rijeka

Coastal route Rijeka - Rijeka, speed 10.5 knots								
STAGE	**Place and departure time**		**Voyage time**	**Place and arrival time**		**Loading time**	**Distance [nm]**	**TEU / day**
1	Rijeka	5:00	2:03	Krk	7:03	2:00	22	8
S	Krk	9:03	0:18	Cres	9:21	0:30	3	2
T	Cres	9:51	1:32	Rab	11:23	1:00	16	4
A	Rab	24:23	2:18	Losinj	14:41	1:00	24	4
G	Losinj	15:41	1:47	Pag	17:28	1:00	19	4
E	Pag	18:28	2:03	Vir	20:31	12:15	22	1
	Voyage time		10:01	Time in port		5:45	TOT.	TOT.
	Voyage time for 1st STAGE					15:46	106	23
2	Vir	5:00	1:32	D.Otok	6:32	12:15	16	1
S	D.Otok	6:47	0:24	Ugljan	7:11	0:45	4	3
T	Ugljan	7:56	1:32	Pasman	9:28	0:30	16	2
A	Pasman	9:58	2:03	Murter	24:01	0.45	22	3
G	Murter	12:46	4:22	Ciovo	17:08	0.30	46	2
E	Ciovo	17:38	0.46	Solta	18:24	12:15	8	1
	Solta	18:39	1:17	Brac	19:56	1:30	13	6
	Voyage time		11:56	Time in port		4:30	TOT.	TOT.
	Voyage time for 2nd stage					16:26	112	18
3	Brac	5:00	2:18	Hvar	7:18	1.15	24	5
S	Hvar	8:33	2:18	Vis	10:51	0.30	24	2
T	Vis	11:21	2:34	Korcula	13:55	1.45	27	7
A	Korcula	15:40	5:23	Mljet	21:03	12:15	57	1
G	Voyage time		7:10	Time in port		3:45	TOT.	TOT.
E	Voyage time for 3rd stage					10:55	76	15
4	Mljet	5:00	23:08	Rijeka	4:08		243	
S	Voyage time		6:18	Time in port		12:00	TOT.	TOT.
T	Voyage time for 4th stage					6:18	243	0
TOTAL	Voyage time		52:15	Time in port		14:00	NM	TEU
	Voyage time for coastal route Rijeka - Rijeka					56:15	537	56

A.2) Coastal policy with one home port – Rijeka – Ploče -Rijeka

The coastal transportation network route Rijeka - Ploce - Rijeka serves not only as islands supply but also as the link between ports of Ploce and Rijeka. This option requires a fleet of five ships of capacity of 56 TEU where it is assumed that on the return voyage (Ploce - Rijeka) can be transported 40 containers. To enable the same for the direction of Rijeka - Ploce the ship capacity should be increased but this case will not be considered. Order times remain the same as for the coastal policy A.1) Rijeka - Rijeka. Order time of the return route for container transport from Ploce to the Rijeka is one day without stops.

B.1) Coastal policy with two home ports: Rijeka – Ploce (home port Rijeka) and Ploce-Rijeka (home port Ploce)

In this coastal policy the cargo will be loaded in both ports Rijeka and Ploce and it is assumed that the returning schedule is the same as for the returning policy A.2) from Ploce to Rijeka. Operation of coastal policy with two home ports requires a fleet of four ships with 56 TEU. Order times for the islands in particular stages are the same as for the route Rijeka – Rijeka and depend on the navigation direction. This means that in the direction Ploce - Rijeka order time for the fourth stage, which turns into the first stage, is one day, and for the first stage is four days which reduces the competitiveness of distant places. In the same time this policy reduces the navigation distance and thus the cost of fuel.

C.2) Southern and Northern policy with two home ports

Northern transportation network along the route Rijeka – Rijeka, requires two ships with 32 TEU. Order time for the first stage islands is one day and for the islands on the second stage two days. Southern transport network along the route Ploce – Ploce requires two ships with 24 TEU. Order time for the first stage islands is one day and for the islands on the second stage two days. Since the northern and southern transportation network is viewed as one policy, it is assumed in the following analysis that we have four ships with 32 TEU.

4. Preliminary calculation of costs for the transportation networks

With the following budget (Table 9) the preliminary costs per TEU for the three policies (A, B, C) are calculated. Two supplying conditions will be taken into account: daily and every second day supply. Previously estimated number of containers satisfies daily supply while for the every second day supply this number has to be doubled. This second case reduces the required fleet of ships and the maintenance costs but the first cost for each ship will be increased because larger ships are needed. Such a supply chain also doubles the order time which reduces the supply competitiveness. The cost analysis must show if this disadvantages will be compensated by significant life cost savings. The following calculation gives an overview of the costs of certain policy. This budget does not include the cost of goods distribution around the island. It is assumed that the freight will be unloaded on a central place on the islands. Voyage and loading times are taken from the calculations done for all policies. The number of ships is equal to the number of stages. It is assumed that there are two crew shifts per ship, so while one is sailing, second is resting.

Table 9 All routes - calculation input data

Tablica 9. Ulazni podaci za proračun svih ruta plovidbe

All routes - calculation input data		
First cost per ship-56TEU every day - coastal	900,000	€
First cost per ship-112TEU every other day - coastal	1,700,000	€
First cost per ship - 32TEU every day two routes	500,000	€
First cost per ship-64TEU every other day two routes	1,000,000	€
Capital invested in infrastructure	1,700,000	€
Years of repayment	10	years
Month salary for the entire crew of 4 members (Gross)	8,000	€
Shifts a week sailing week	2	
Working days	365	days
Req. fuel up to 56 TEU each day - coastal	0.112	t / h
Req. fuel to 112 TEU every other day - coastal	0.224	t / h
Req. fuel to 32 TEU each day two routes	0.064	t / h
Req. fuel up to 64 TEU every other day two routes	0.128	t / h
Req. fuel in the harbour - the percentage of consumption in navigation	30	%
Fuel prices	534	€/t

The calculation takes into account the different size of the ships for the different policies of transportation networks. The ship size affects the first cost, power of engine and the fuel consumption. For each policy the costs are calculated considering an exploitation capacity in the range of 50% to 100%.

Table 10 Daily supply cost comparison

Tablica 10. Usporedba troškova za opskrbu svaki dan

Coastal policy with one home port every day, €/t				
	Coastal policy			
Exploitation, %	A.1) Ri-Ri	A.2) Ri-Pl-Ri	B.1/2) Ri-Pl/Pl-Ri	C.1/2) Ri-Ri/Pl- Pl
100	20.7	14.1	18.3	15.2
90	23.3	15.7	20.3	16.9
70	29.5	20.2	26.1	21.7
50	41.3	28.3	36.5	30.4
78	26.7	18.3	23.6	19.6

Table 11 Every second day cost comparison

Tablica 11. Usporedba troškova za opskrbu svaki drugi dan

Comparison of network supply every other day, €/t				
	Coastal policy			
Exploitation, %	A.1) Ri-Ri	A2.) Ri-Pl-Ri-	B.1/2) Ri-Pl/Pl-Ri	C.1/2) Ri-Ri/Pl-Pl
100	17.4	12.8	14.9	11.8
90	19.3	14.2	16.9	13.1
70	24.8	18.2	21.4	16.9
50	34.7	25.5	29.9	23.7
78	22.4	16.5	19.3	15.3

Option of supplying the islands every second day can reduce supply costs by 19 % to 28.5 %, depending on the policy. The savings achieved are not justifying the doubled order time, so no further consideration will be given for the every second day policy.

5. Analysis of the transport policies and the final selection

When observing the individual costs (every day policy), it can be concluded that the one home port policy Rijeka – Ploce – Rijeka is most favourable with 18.3 €/t at 78% average efficiency (Table 10.). The competitiveness of this policy lies in the additional transport of containers on the return stage Ploce - Rijeka. In this case, the ship with a total capacity of 56 containers will transport 96 containers in one circulation. Despite of a smaller fleet of ships, the one home port policy Rijeka-Rijeka is the most expensive one with cost 26.7 €/t (Table 10.). The main cause of this lies in the fuel consumption needed for the return from the last island to the home port where this cost, in coastal policy with two home ports, does not exist. Because of that the cost for transportation falls to 23.6 €/t. Northern and southern policy with transport networks Rijeka–Rijeka and Ploce–Ploce needs 19.6 €/t (Table 10). This two policies can be compared because the number of ships and the number of crew for the northern and southern policy is the same as for the coastal policy with transport network along the route Rijeka-Rijeka. It is obvious that the costs are lower for 7.1 €/t if the coastal route is divided into the northern and southern route. Such savings are only possible if the system has two ports. This network of supply, where there are two or more starting places, for either truck or ship requires good logistics network and trucks on mainland that connects the starting places. The exact network (existing flows of goods) of supplying these starting places is not known, what makes the choice of home ports and comparison of truck and ship transportation difficult. The basic question is how much the supply of goods to some islands costs by truck or by ships. It is assumed that the goods are available in both home ports. Using the northern and southern transportation network, it is possible to reduce required ship's container capacity. If we assume that the main goods flows are going through or near the Rijeka the selection falls on the coastal policy with one home port Rijeka – Ploce – Rijeka A.2) with 5 ships (Table 10). How this coastal policy is competitive with conventional truck transportation only the cost calculation of truck the transport network will show.

6. Cost calculation of a truck transport network

It is realistic to expect that trucks drive from every major city to the islands, but the freight has to come from some warehouses to these cities. The goods are imported from abroad most likely from Trieste, Zagreb, Rijeka and Ploce. In this budget calculation the supply problem is viewed as northern and southern policy. One cargo warehouse is located in Rijeka and one in Ploce. It is assumed that a single truck will be driven only in two shifts of 8 h, so this means that one truck has

16 working hours. The costs of the transportation of the goods depend on the route from the warehouse placed on the mainland to the warehouse placed on the island. The time for loading and unloading includes the time of loading the truck in the main warehouse and unloading it in the warehouse on the island. The following input data (Table 12) is the same for all directions for the all trucks. These costs estimations are arbitrary but based on experience.

Table 12 Input data for freight transport by truck

Tablica 12. Ulazni podaci za prijevoz tereta kamionom

Input data for freight transport by truck		
Capital costs per truck	300,000	€
Year repayment	10	Years
Month salary of a driver (Gross)	1,400	€
Workdays	365	days
Working hours of a driver	8	hours
No of shifts per truck = classified drivers	2	
Working hours per truck	16	hours
Fuel consumption	30	l/100km
Max. load trucks	21.74	tons
Utilization	35	%
Capacity	7.61	tons
Fuel prices	1.1.	€/ t
The cost of fuel per km	0.33	€/km
Average speed	35	Km / h
Time of loading-unloading per tonne	0.15	hours / t
Exchange rate against the euro	7.3	Kn= 1 €

At the end all the daily costs for every transportation route are summed and divided by the total weight of the load being carried. Additional cost for the truck distribution of the goods around the islands can be roughly calculated using the data from Table 15.

Table 13 Costs of transportation by truck to the islands

Tablica 13. Troškovi prijevoza kamionom prema otocima

Costs of transport truck	
Number of trucks	41
Utilization	t
100 %	66
90	72
70	80
50	97
78%	78

Table 14 Costs for truck transportation of goods around all islands

Tablica 14. Troškovi za razvoz tereta na svim otocima kod kamionskog prijevoza

Average (78%), costs for transportation of cargo on all islands		
Total daily average (78%) of goods on all islands	290	t
The real number of trucks	41	-
One truck is driven daily	80	km
All vehicles are driven daily	3,280	km
All vehicles are driven annually	1,197,200	km
Fixed costs per year		
Equity	0	€
Administration 2% of capital	0	€
Salary of all drivers	0	€
Operating costs per year		
The cost of fuel	395,076	€
Total daily cost	1082.4	€
TOTAL AVERAGE ADDITIONAL COST	4	€/t

Table 15. Additional costs for goods distribution around all islands in ship transportation

Tablica 15 Dodatni troškovi za razvoz tereta na svim otocima kod brodskog prijevoza

Average (78%), costs for goods distribution on all islands		
Total average daily needs for supplies on all islands	290	t
Real number of trucks more than the number of islands	20	-
One truck drives daily	300	km
All vehicles are driven daily	6,000	km
All vehicles are driven annually	2,190,000	km
Number of drivers per truck	2.	-
Number of spare drivers per truck	0	-
The total number of drivers per truck	2.	-
Fixed costs per year		
Equity	600,000	€
Maintenance administration 2% of capital	120,000	€
Driver earnings	672,000	€
Operating costs per year		
Fuel cost	722,700	€
Total annual costs	2,114,700	€
Fixed costs per day		
Equity	1,644	€
Maintenance administration 2% of capital	329	€
Drivers earnings	1,841	€
Operating costs per day		
Fuel costs	1,980	€
TOTAL DAILY COST	5,794	€
TOTAL ADDITIONAL COST	20	€/t

The total average cost of the transportation and distribution of goods to the islands is 82 €/t (Table 13, Table 14). The time of order in the truck transportation network is just one day. This is the reason why alternative ship transportation can only compete with lover prices. To obtain the real cost of the goods transportation by ships it is necessary to calculate the additional costs for further distribution of cargo around the islands.

7. Additional costs of ship transportation for the cargo distribution

Additional costs for the goods distribution around the islands will be significantly higher comparing to truck transportation, since the additional capital investment in the fleet and drivers is required. Taking into account this addition (Table 15), the total price of the selected policy with one home port and transportation network with the route Rijeka - Ploce - Rijeka (Table 10) are: 18.3 €/t + 20 €/t = 38.3 €/t. At the end if you compare this shipping policy with conventional truck transport you will see that the ship transportation policy safes 53.3 % of the costs.

8. Additional content

Since this coastal route allows us the connection of certain islands in the direction of Rijeka to the island Mljet it could be also possible to provide limited passenger transportation. This additional offer to the transportation network leads to additional costs and different dimensions of the ship design. Size of these changes depends on the required number of passengers, the required comfort and the sailing route. Until now, it was assumed that the ship is sailing directly from the port of Ploce to the port of Rijeka, which means that the passengers can only disembark on the islands in the direction Rijeka - Ploce. To establish a passenger line to these islands in the opposite direction, we have to anticipate the time for passengers boarding in the fifth stage. This will increase the sailing time, time in port and consequently increasing of the fuel costs. It should also be taken into account that the ship must arrive on time to the port of Rijeka so to have enough time for unloading, loading and to be ready for the next tour first stage. Since the ship, according to the schedule sails a 40.5 hours it is necessary to increase the transportation network Rijeka - Ploce - Rijeka for one stage more. In this case there will be five stages with six ships for ensuring daily supply with the return voyage on the same route. It is assumed that the sailing time on such return route is non-stop, with the only short breaks for passengers boarding in the direction of Rijeka. This requires extra crew effort. Additional to the extra crew the passengers have to accept a late night and early morning boardings. Considering the above changes and assuming the monthly gross salary of 8,000 € for the crew the cost for the transportation of goods rises up to 22 €/t at 78% of the ship transportation efficiency. All this requires increasing the number of the crew members for ship handling. Larger crew requires more accommodation, larger ship dimensions and thus larger capital ship investment. Here we must be aware that the larger ship dimensions can become constrain for the ships berthing into the ports.

If we double the crew monthly gross salary from 8,000 € to 16,000 € and increase the capital investment for the each 56 TEU ship from 900,000 € to 1,500,000 €, transportation costs rise to 33 €/t at 78% efficiency. Resulting costs are valid for the case that 40 TEUs (with 78% efficiency) are transported from the port of Ploce to the port of Rijeka without the costs for the distribution around the islands. For the distribution of goods around the islands additional cost of 33 €/t must be included. The total cost of goods transportation amounts 66 €/t, which is still 19.5 % less than the transportation by trucks. It is a matter of fact that this kind of extended shipping can´t be realistically compared to truck transportation since the costs like food for the passengers, crew, etc. are not taken into account. Further consideration of such costs exceeds the limits of this paper but it can be assumed that such costs would be covered by the price of the passenger tickets.

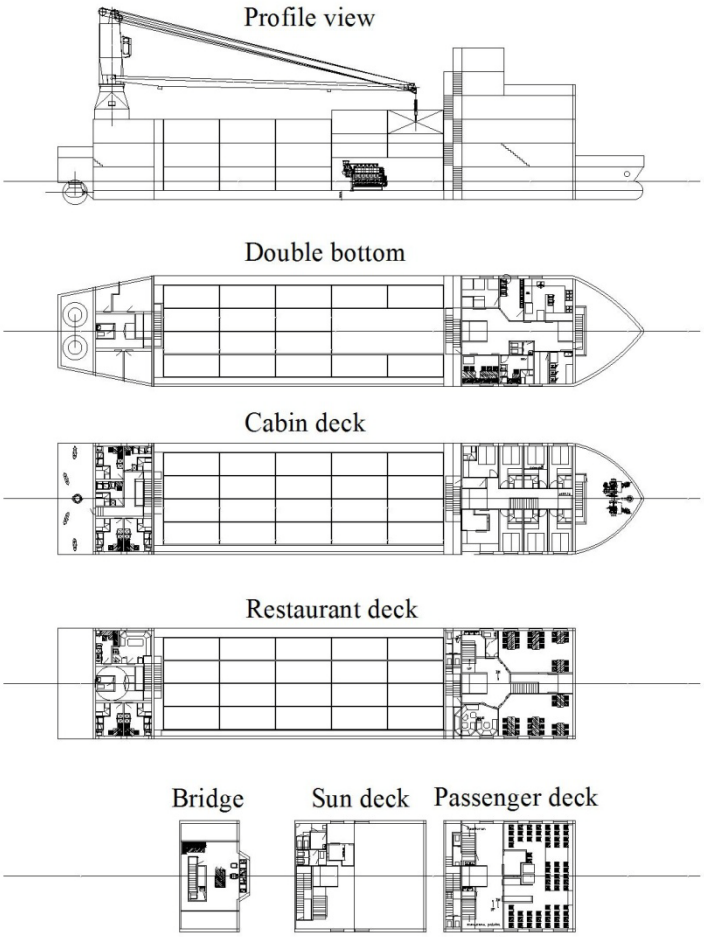
9. Floating terminal

In the case that the ship cannot berth in all foreseen ports the idea of usage of a floating terminal should be considered. This floating terminal would be anchored at each port where the ship cannot berth and will serve as the ship to shore connection. Usually the first step is to lift the empty container on the ship by the crane while the second step is to lower a full container on the terminal free place. Since such situation can be expected on the less populated islands one to three containers will be loaded and stored on such terminal.

10. Preliminary ship

From the previous analysis it is concluded that the transportation network Rijeka - Ploče - Rijeka with additional content, as described in Section 8 suits for the supply of Croatian islands with cargo and in the same time for passenger transportation.

Characteristics preliminary ship named "HRislands" (Figure 2.):



- Length over all: 64.15 m
- Width over all: 12.15 m
- Project draft: 2 m
- Design speed: 10.5 knots
- Pass. capacity: cabins 16, restaurant 40
- Close deck capacity, passengers 69
- Sun deck capacity, passengers 50
- Accommodation, crew: 14
- Characteristics of crane: boom: 33 m
- Useful boom (from the stern): 27 m
- Diesel electric propulsion
- 2x Azipod
- 1x bow thruster

Fig. 2 Vessel for supplying islands with more than 1,000 inhabitants

Slika 2. Brod opskrbu otoka s više od 1000 stanovnika

This paper did not consider solving the problem of loading the containers from the islands to the ship and vice versa, this s a task for further research.

11. Conclusion

One can conclude that the observed ship transportation of goods on Croatian islands with the ability of passengers transport is an economic and competitive alternative to the conventional by trucks. It should be stressed that this work has not developed the supply policy with three home ports since it is difficult to realize passengers transport as an additional content. In future work this supply policy should be developed further on and compared with the results of this paper. All supply policies should be extend to the all islands with inhabitants with the latest available data, not only the islands with more than 1000 inhabitants. There is a possibility that this extended approach can change the proposed one and have more successful operation. The real savings of ship transportation costs depends on how many large and small enterprises are willing to get involved in this new transportation network. The problem is that the major retailers have already their own logistics networks and small businesses can complain on to goods extended time of order. The success of any ship supply policy to the islands depends on real implementation possibilities in the current supply system. Only when we know exact costs of transportation within the mainland and to the Croatian coastal areas are, we can realistically compare the current truck transportation to the islands with the container ship transportation network. Such a review is more than necessary if we want to improve the already existing system of supply, which is based on the existing transportation structure.

The advantages of containerized goods ship transportation to the islands:

- A good network will reduce congestion on ferries and allow different network system for passengers
- Can contribute to return of young people to the islands
- Can contribute to development of some industries on the islands
- Can make islands competitive to mainland
- A good network can contribute for cheap transport of the waste to the one of centres on the mainland, recycles and if necessary burns.

Finally, it should be noted that it must be carefully considered the technical solution of loading and unloading of containers from the island to the ship and vice versa. Results of transport costs in this paper are based on the assumption that the time needed for loading and unloading of one container is 7-8 min. In order to fulfil this requirement in all weather conditions it is not enough to carefully choose the berthing locations and utilization of the existing infrastructure on the islands (ports, roads, etc.), but additional solutions should be considered. These solutions can be in the form of implementation some kind of dynamic positioning or appropriate floating / fixed terminals, but in any case they must be simple and cost effective

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