UDC 65.626:627.626.9

Kateryna GRUSHEVSKA

PhD in Transport and Maritime Economics,
Faculty of Applied Economics,
University of Antwerp, Belgium
Email: kate.gr@gmail.com

Theo NOTTEBOOM

PhD in Applied Economics,
Shanghai Maritime University, China; Faculty of Applied Economics, University of Antwerp, Belgium; Maritime Institute, Ghent University, Belgium; Antwerp Maritime Academy, Belgium
Email: theo.notteboom@gmail.com

Lyudmyla CHYZH

PhD in Economics,
Department of Financial and Economic Security, Accounting and Auditing
Odessa Maritime University, Ukraine
Email: chizj@rambler.ru

NETWORK DESIGN AND COST MODEL FOR CONTAINER TRANSPORTATION VIA THE DNEPR RIVER

Grushevska, K. Network design and cost model for container transportation via the Dnepr [Текст] / K. Grushevska, T. Notteboom, L. Chyzh // Український журнал прикладної економіки. – 2016. – Том 1. – № 3. – С. 41-59. – ISSN 2415-8453.

Abstract
Inland waterway transport (IWT) in Ukraine is currently in its infancy stage in comparison with other land based transport modes (rail and road) and with other countries that possess navigable rivers. This paper is an extension of the research initiated by Grushevska and Notteboom (2015, 2016) where the concepts of intermediacy and centrality are introduced in order to assess the role of Ukraine in the global and regional transport networks. The list of key obstacles for Ukraine's intermediacy function includes such IWT related barriers as: (i) deficient inland waterway infrastructure, (ii) high IWT costs (fees for bridges, locks etc.) and (iii) pilotage charges. To date the transportation to/from ports is mainly fulfilled by road or by rail-based multimodal transport solutions. We have analysed the unutilized potential of Ukrainian IWT that needs to be efficiently exploited for the benefit of the national economy and national transport system. This study intends to enrich the limited academic research on IWT systems in a transition stage, as exemplified by the case of Ukraine.

Keywords: *inland navigation; cost and time calculation; network design; port regionalization; system analysis.*

JEL classification: N74, O18, R4

1. Introduction

Since its independence in 1991, Ukraine has been subject to many lost opportunities and let-downs, economic mismanagement and hesitant reforms holding back growth, corruption and oligarchy undermining the market economy, and episodes of power undercutting democracy. Ukraine's per capita income at the time of the country's independence was higher than Poland's. Twenty years later in 2013, even before the current political and economic crisis erupted, the standard of living had fallen more than 60 % behind Poland. During period 2009-2014, Ukraine entered into eight IMF programs, none of which achieved the objective of inducing sustained reform. For several years, wages and costs rose, but productivity did not. Eventually competitiveness had slipped so much that GDP stopped rising and exports stagnated. Budget imbalances and gas sector deficits widened enough to add another drag on growth.

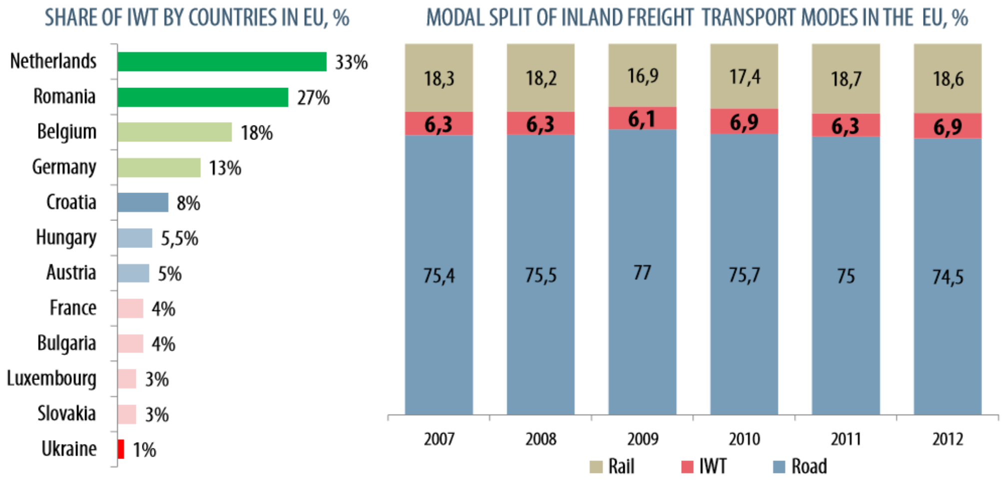
Ukraine's financing needs considerably surged. While the geopolitical conflict imposed direct costs, there also were indirect costs induced by the geopolitical instability such as uncertainties in the finances of banks and the public sector, and the foreign exchange market destabilization. Exports were affected negatively by the disruption of trade with Russia and by the low international prices for grains and steel, which are major export products of Ukraine. External private financing dried up and capital outflows accelerated. The local currency hryvnia lost two-thirds of its value during 2014-2015. Furthermore, inflation spiked above 40 %, reflecting the currency depreciation but also rising energy prices.

Despite the rugged current situation in Ukraine, the new government is strongly motivated and active in implementing long-awaited reforms of outdated legislation in many areas such as finance, taxes, trading and transport. The combination of exchange rate depreciation and flexibility at the hryvnia's new level is an important step toward the creation of a potential basis for Ukrainian businesses to compete again on international markets.

As stated by Grushevska and Notteboom (2014) logistics is a key area to improve Ukraine's competitiveness and to improve the ease of doing business in the country. The seaports in Ukraine play a substantial role in the transport industry and the national economy. The active involvement of the Ukrainian port entities in the effective hinterland distribution of port-generated cargo could bring the port system to a more advanced stage of port system development, i. e. the port regionalization stage as coined by Notteboom and Rodrigue (2005). At the same time such initiatives could increase the competitive position of Ukrainian ports in comparison with other ports serving some of the same shared hinterland regions such as the Baltic ports (Grushevska and Moskvichenko, 2012).

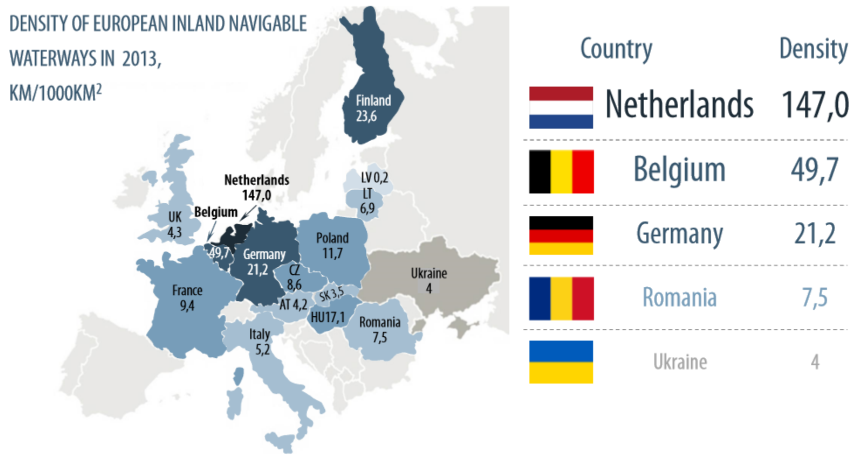
Currently the transportation to/from ports is mainly fulfilled by road or by rail-based multimodal transport solutions. These modes are currently in a progressing defective state (Grushevska et al., 2015). Grushevska and Notteboom (2015) identified the weak condition of the road system in Ukraine as one of the main bottlenecks (ranked 12 out of 26 bottlenecks) for the Ukrainian transport system. The roads are deteriorating rapidly and their condition worsens further. Given that road and rail are deficient and excessive investments would be needed to ameliorate the situation, we could think of an alternative transport solution for Ukraine. We believe there is a huge unutilized potential in Ukrainian IWT that needs to be identified and efficiently exploited for the benefit of the national economy (see figures 1 to 2). In the early 1990s IWT was heavily used in Ukraine with a modal share of 3% to 4.5%, or about 60 million tons per annum. Currently the popularity of IWT dramatically decreased with a share of only about 1% in the modal split (equal to about 6 to 4 million tons per annum in 2013 and 2014 respectively).

Figure 1. Role of IWT in the European Union



Source: Shkliar (2015)

Figure 2. Density of Europe inland navigable waterways in 2013, km/1000km2



Source: Shkliar based on Bakker Tilly (2015)

This paper is an extension of the research initiated by Grushevska and Notteboom (2015) who used the concepts of intermediacy and centrality in order to assess the role of Ukraine in the global and regional transport networks. It intends to enrich the limited academic research on IWT systems in a transition stage, as exemplified by the case of Ukraine. The list of key obstacles for Ukraine's intermediacy function is dominated by (i) factors of a general nature (e. g. regulatory/ legislative issues, customs formalities, etc.); (ii) port-related factors (e. g. high port dues and costs, and seaport legislation) and (iii) inland shipping related (e. g. the legislation on inland waterway transport or IWT). There are other IWT related barriers identified in the analysis of Grushevska and Notteboom (2015), such as: (i) deficient inland waterway infrastructure, (ii) high IWT costs (fees for bridges, locks etc.) and (iii) pilotage charges. It should be noted that IWT in Ukraine currently is in its infancy stage in comparison with other land based transport modes (rail and road) and with other countries that possess navigable rivers.

2. Theoretical background

Transportation is an ecosystem where goods are produced and consumed in various locations which drives the need of transportation. The transport system (TS) as defined by

Rodrigue (2006) consists of three main components: *nodes, networks and demand*. The improvements in TS change the relationship between time and space. Due to cheaper, faster and easier access between locations, space-time convergence takes place (Rodrigue, 2006).

Academic research on IWT networks as part of national or supranational transport systems highlights several matters such as:

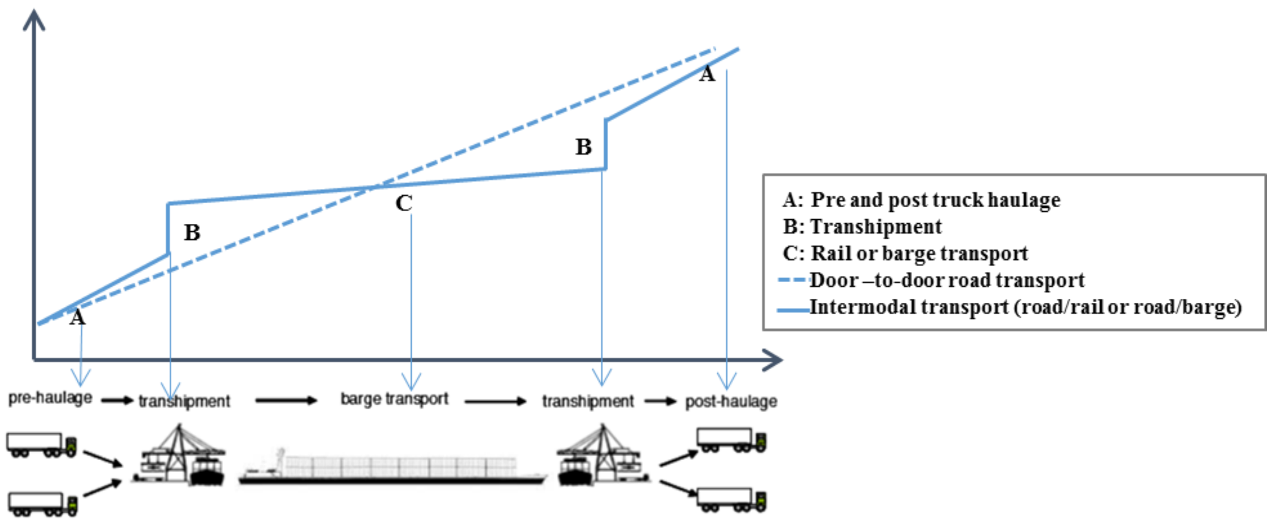
- *Service network design* – mainly related to the transport service providers considering selection and scheduling of the services, specifications of terminal operations and the routing options (Crainic, 2000). Woxenius (2007) proposes a general framework for routing principles/options in a transport network based on the following factors: direct link, corridor, hub-and-spoke, connected hubs, static routes and dynamic routes. Kreuzberger (2008) made a synthesis of the bundling networks for intermodal rail traffic which are very much alike as the IWT based. Notteboom and Konings (2004) analyzed the spatial dynamics and evolution of the barging network in Europe. Notteboom (2007) made a substantial conclusion that "a sustainable network of inland terminals is not necessarily the same as having many terminals, but it does mean a network that makes maximum use of the functional interdependencies with seaports and other transport modes, offering value in logistics activities". Konings (2009) evaluated the opportunities to improve the competitiveness of container barge transport in the hinterland of Rotterdam through a reorganization of container barge services.
- *Terminal operators* – Kreuzberger (2008) investigated the importance of terminals in the bundling of flows through the network. There has been other research carried out afterwards showing the high importance of rail terminals in traffic bundling and routing (e. g. Ballis and Golias, 2002; Bontekoning, 2006; Rodrigue, 2008).
- *Pre- and post- haulage* and full supply chain control – it has been underlined in a number of researches that the pre- and post- haulage has a strong influence on the overall transport cost, and so on the competitiveness compared to road transport. The cost saving in the pre- and post- haulage was illustrated by means of (i) concentrating all traffic in one carrier or (ii) centralizing the planning of pre- and post- haulage trips (Walker, 1992; Morlok and Spasovic, 1994; Transcare, 1997); or (iii) selecting the pre- and post- haulage options based on their cost and transport landscape characteristics (the spatial and temporal pattern of transport volumes in a terminal service area) (Nierat, 1997; Kreutzberger et al., 2006).
- *Hinterland coordination of the container transport chains* was discussed by van der Horst and De Langen (2008). The importance of coordination and cooperation between the actors of the network (such as among terminal operators, vessel operators, etc.) may lead to denser freight, economies of scale and improve the overall performance of the hinterland network (Caris et al., 2008; Groothedde, 2005). Konings et al. (2009) made a comparative analysis between hinterland barge transportation in the US and the Netherlands. A major conclusion from their work is that in both regions there are important roles for multiple public and private sector players in order to further develop the container barge hinterland system. Specific problems in the Netherlands are connected with the inefficient handling of the barges in the deep sea ports. The reasons for the underdevelopment of container barging in the US are country specific and are of a broader character. Rodrigue and Notteboom (2010) made a comparative analysis of gateway logistics in the US and Europe. They show that hinterland distribution in the US is highly rail dependent even for long distances. In Europe, the short and medium distances are barge and truck based; and the medium distance is served by rail.

- *Improvement of container handling in sea ports* was investigated by Douma (2008). The potential way of adjustment and negotiation of the time schedules between the deep-sea operators and vessel operators is proposed.
- *Software support* is addressed by De Langen et al. (2006) aimed to secure the efficient access to the hinterland.

In this paper we address two research questions related to IWT as part of TS:
RQ1: What is the contribution of terminals to the cost and quality performance of inland navigation?
RQ2: What is the optimal network design for container transportation via IWT in order to increase the IWT share in the modal split?

We use the system analysis approach as applied by Konings (2009) covering three chain activities: (i) barge transport itself, (ii) transshipment; and (iii) truck haulage (pre- and post-). They are looked at from an operations perspective and their relevance is asserted for the overall intermodal chain performance and for the competitiveness to other transport solutions.

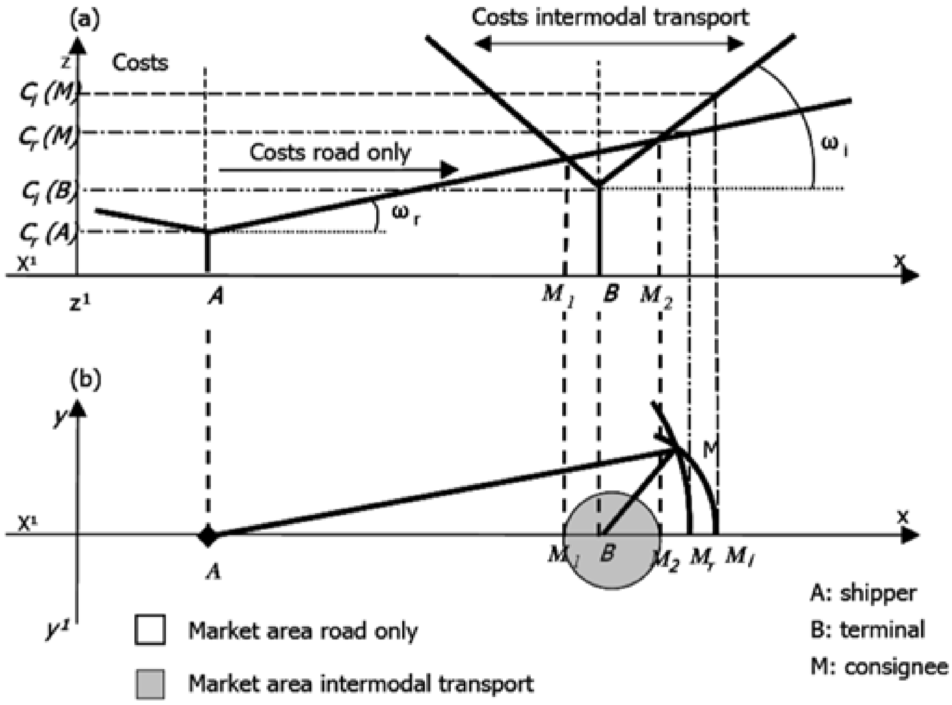
Figure 3. System analysis of intermodal barge transport



Source: adapted from Konings (2009)

Figure 4 visualizes a conceptual model for intermodal transport which was adopted by Konings based on Nierat (1997) and on the economic theory of market areas (Palander, 1935; Hyson & Hyson, 1950). It follows the same logic as the concept used by Konings (2009). The comparison between intermodal transport and road transport is based on the transport from A to M, which in case of road transportation is a direct connection, although for intermodal transport through an intermediate terminal B (part b of figure 4). The cost curve of transportation is coned shaped and starts in point A for road transport where some costs already occurred (part a) of the figure 4). B represents the intermodal transport costs at the terminal where the barge or rail haul ends (part a) of the figure 4). At this point several of the costs already occurred such as a truck haul operation from the shipper to the terminal, the rail or barge haul, and transhipment. The only cost not included is the last mile post-haulage to the destination M. The costs for this component will be presented by a fixed and variable part proportionally to the distance between B and M. The cost curve for intermodal transport starts at the point B and intersects the cost curve of the road only mode. This intersection is the break-even point of the costs for pure road and intermodal transport.

Figure 4. Derivation of the market scope of intermodal transport



ω_r : variable costs road-only transport

$C_r(A)$: fixed costs road-only transport

$C_r(M)$: total costs road-only transport

ω_i : variable costs drayage to consignee

$C_i(B)$: costs intermodal link AB (drayage from shipper, rail or barge haul) plus fixed costs drayage to consignee

$C_i(M)$: total costs intermodal transport

Source: Konings (2009)

The presented theoretical model inclines that there are several factors that shape the viability and market scope of intermodal transport. As indicated earlier, these factors correspond to three main processes that can be identified in the intermodal transport chain: terminal transhipment, the barge or rail haul and pre-/post- haulages.

- Terminal handling.

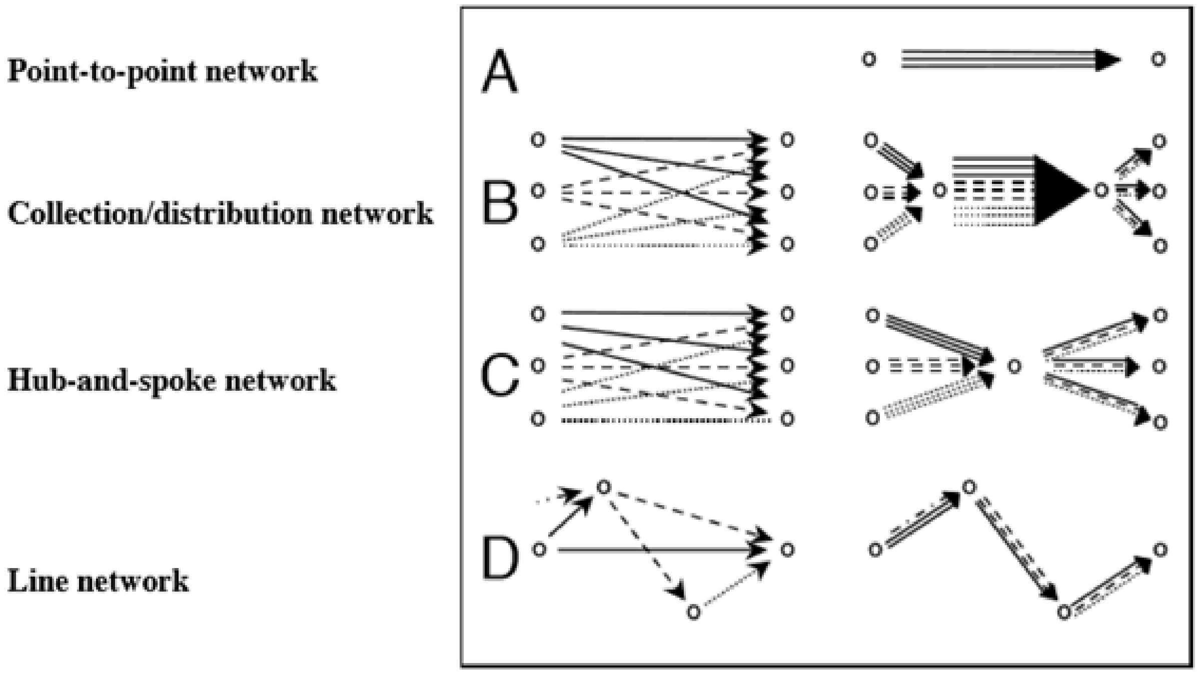
Transhipment of load units is an inevitable and costly activity in the intermodal transportation. Their costs vary significantly, depending on (i) the location of the terminal where the handling is fulfilled, (ii) type of transport mode, (iii) type of equipment used, (iv) government subsidies, (v) availability of quay or rail tracks depending whether this is barge or rail based intermodal transport, and even depending on (vi) the land ownership of the terminal (whether it is owned or rented). The share of the terminal handling in the total cost of the intermodal transport chain diminishes with the increase of the distance of the transportation. From the empirical research the share of the handling operations in the total cost of the intermodal transport chain is said to be between 10%-30% (Rutten, 1995; Arcadis, 1991; Macharis and Verbeke, 2001), but it is very much case dependent and can be either lower or higher than these marks in other particular cases.

- The intermodal network (barge or rail based).

The cost per load unit in rail and barge transportation is dependent on the economies of scale, more precisely factors like: (i) the size of the train/barge, (ii) load factor of the train/barge, (iii) the distance overcome and (iv) the frequency of the services (Konings, 2009).

Dependent on how freight flows are bundled, different types of networks can be used. The four basic bundling network models are presented in figure 5 (Kreutzberger, 2008). These principles were previously applied to barge navigation by Notteboom (2007) and by Veenstra and Notteboom (2011) to barge transport on the Yangtze and Rhine rivers. The main goal in their research was to select an appropriate network design to the particular spatial spread of the freight flows (volume and direction wise). Usually the direct intermodal connections require large volumes, whereas the bundled networks required fewer volumes from certain destination, since they can combine the flows. However, bundling drives the costs for additional transhipments up as well as lengthens the distance and the delivery times (thus potentially decreasing reliability). The benefits and drawbacks have to be compared against each other in order to choose a network design type.

Figure 5. Four basic principles of freight bundling



Source: Kreutzberger (2008)

From the available freight bundling concepts the types A and D are used in rail and barge based intermodal transport. The collection/distribution network is not yet practically implemented, while hub-and-spoke is mainly used only in rail transport (Konings, 2009). The line network is enabling the train/barge to fulfil intermediate stops to transport more cargo and so to increase the loading utilization rate of the vessel. At the same time this design increases the transit time. This scheme is widely used on the Rhine River and for larger distances. The preference of point-to-point and line network can be explained by the fact that there are mainly direct deliveries and that the container barge transport is mainly hinterland transport of the containers to the end users. The containers have always a sea port as an origin or destination which makes the other bundling designs less suitable.

- Pre- and post-haulage.

Pre- and post- haulage transportation is often inevitable since the end destination and/or the shipper are not located at a terminal. Distance wise the length of these sections is relatively limited (usually around 25 km) whereas the cost share of these hauls in the intermodal chain costs in significant (Konings, 2009).

These findings clearly reveal that the success and viability of intermodal container barge transportation heavily depend on other operations beside the pure barge haulage.

3. Network design: the Dnepr Case.

In this section we analyze the competitive potential of IWT in Ukraine by zooming in on the most important river in the region, i. e. the Dnepr. We first provide an overview of the current IWT services on the Dnepr. Next, we analyse two scenarios of alternative network design.

3.1. Current services on the Dnepr

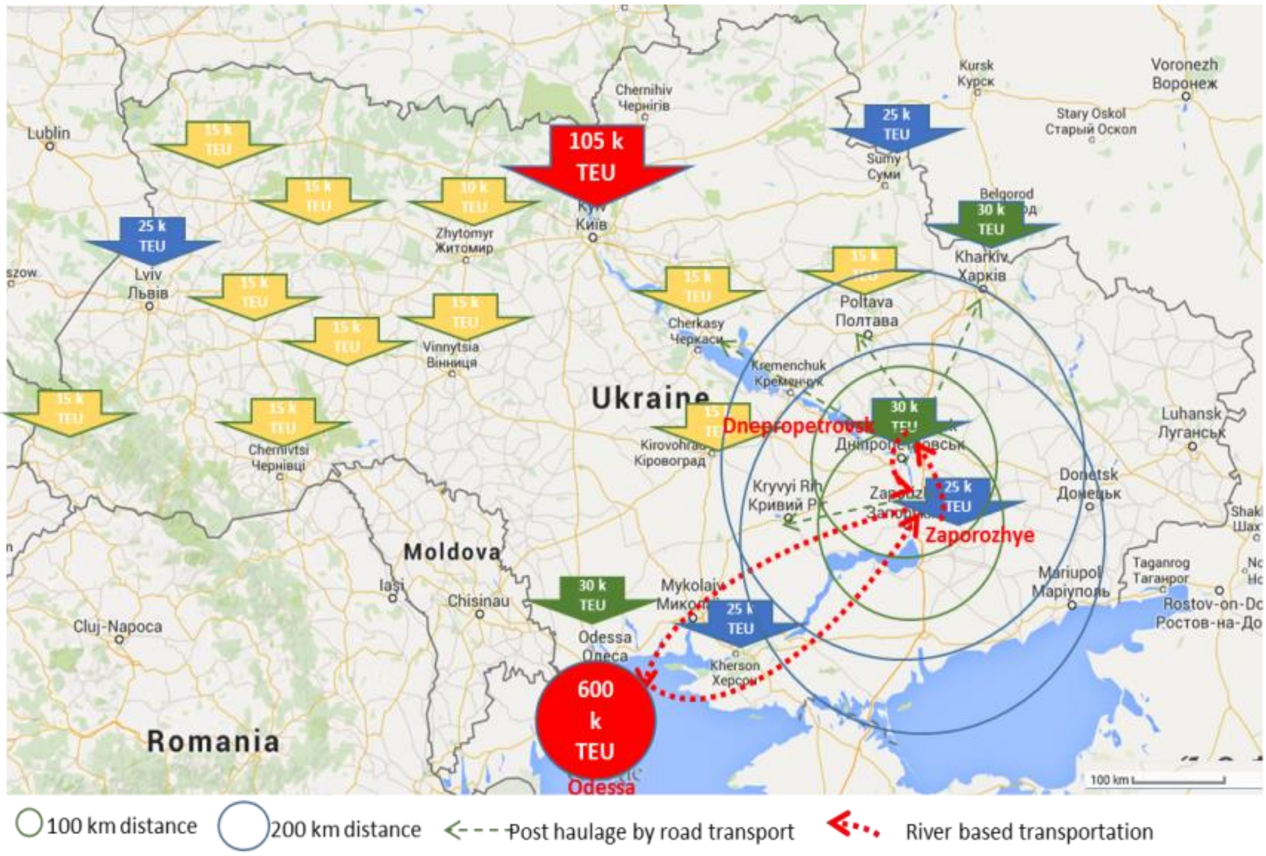
The average distance from the Dnepr estuary in the Black Sea, West of Kherson, to the closest deep sea ports (Iliychevsk, Odessa or Yuzhniy) is more than 100 km. This distance does not allow purely river vessels (such as barges) to reach these deep sea ports. The maintenance of the infrastructural inland waterway facilities has generated high costs, however, the existing facilities are not being used to a significant extent. As a result, the Ukrainian IWT can hardly compete with other modes of transport. However, there are two modest container services operating on Dnepr River: CMA-CGM and Ukrrichflot.

CMA CGM and Tavria Line container service. This weekly service between Constanta and Dnepropetrovsk exists since 2010. The yearly container volume is about 40,000 TEU of import containers. This service includes only a post-haulage, which makes it more price competitive and attractive.

Figure 6. CMA CGM and Tavria Line container service

Ukrrichflot service. The service of Ukrrichflot started in May 2015 with an expected frequency of 3 times a month. There are two vessels deployed with a capacity of 3,800 DWT and 150 TEU each. Voyage time from Odessa to Dnepropetrovsk is up to 3 days. The vessels call Odessa port at HPC terminal and go to the Dnepr ports of Zaporozhye and Dnepropetrovsk. Currently it is an export oriented service with a mixed cargo (general cargo, mainly metals and containers). Currently this service is an export oriented connection allowing eliminating the pre-haulage of containers by organizing the staffing and other service in the inland port itself. The ports host customs offices and offer good rail and road connections. Unfortunately, Ukrrichflot has not succeeded yet in attracting import containers to its new service.

Figure 7. Ukrrichflot service



3. 2. New container network design

In a new network design we propose to introduce Kiev in the service and Dnepropetrovsk to the loop. The purpose of this network design is to distribute import containers into the hinterland of Ukraine. Certain constraints exist for this service: (i) the current 3 m draft limitation near the Kaniv Lock (south from Kiev) which restricts the draft of the vessels to this mark (though in fact it might have a limited effect, since vessels arriving to Kiev will be partly loaded with containers, respectively have less draft); (ii) the Kiev river port is a separate joint stock company independent of any other existing active IWT market player which makes its inclusion in the container service more complicated and more competitive; and (iii) the container handling equipment in Kiev port is currently obsolete. Taking into consideration its great future potential and definitely the support from local and foreign investments the upgrade of the necessary infrastructure and superstructure in Kiev river port is very visible.

We propose two network design scenarios.

3.2.1. Network design scenario 1

The first one has a total voyage time one way of about 5 days and a round trip time of 7 days. The frequency of a multimodal container service needs to be about 3-4 times per week not less than that. This number comes from intermodal operators' experience in order to make the services more attractive for shippers (Konings, 2009; Fremont et al. 2009). If the proposed network design is applied to the Ukrainian container hinterland, a frequency of at least 4 times per week and a fleet of 4 river-sea vessels would be necessary in order to be able to attract a share from the "road only" haulage to intermodal river based transport.

The service is delivered 4 times per week (excl. Wednesday) and the schedule is follows: on Monday the sea-river vessel receives containers that have arrived in Odessa before and during the weekend, after that she sails to Dnepropetrovsk and arrives there on Wednesday. On that day the containers assigned to Dnepropetrovsk are discharged and the vessel continues to sail towards Kiev where she arrives on Friday. In Kiev river port the needed handling operations are fulfilled and the vessel can sail back to Odessa after a new container batch. Since the sailing from Kiev to Odessa is direct without intermediate stops, this sailing part will take about 2 days. Accordingly on Monday she can start the following voyage.

Figure 8. Container network design using river-sea vessels: Odessa-Dnepropetrovsk-Kiev

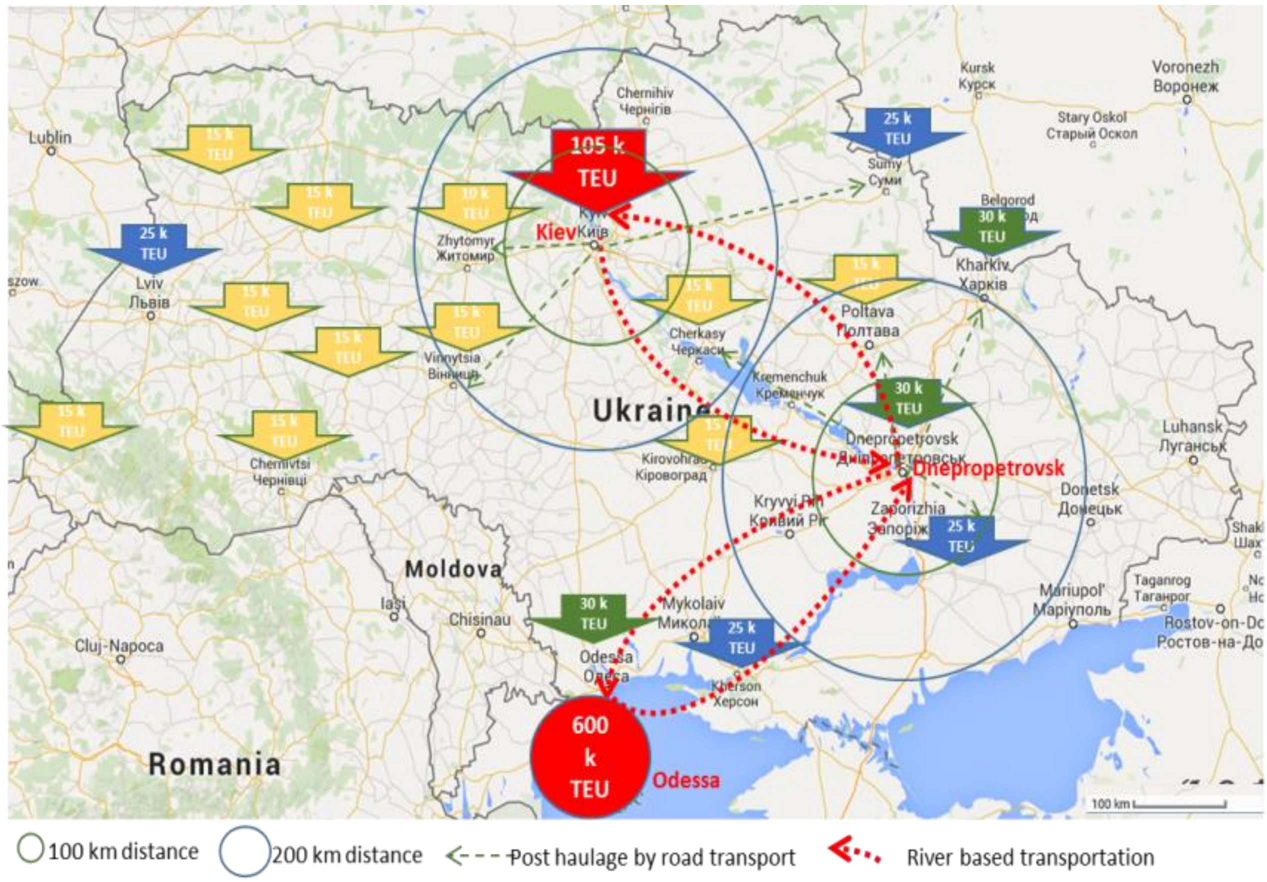


Table 1. The estimated schedule of the route: Odessa-Dnepropetrovsk-Kiev

	Week							Week							
# Day / Vessel	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	...
1	Odessa		Dnepr'k		Kiev			Odessa		Dnepr'k		Kiev			...
2		Odessa		Dnepr'k		Kiev			Odessa		Dnepr'k		Kiev		...
3				Odessa		Dnepr'k		Kiev			Odessa		Dnepr'k		...
4					Odessa		Dnepr'k		Kiev			Odessa		Dnepr'k	...

Table 2. Transportation costs from Odessa to Dnepropetrovsk for both ways, in USD/TEU

Intermondal TEU transportation from Odessa to Dnepropetrovsk (both ways) in USD $				Share of costs %	30 % discharged in Dnepr, 70% in Kiev			
					TEU	105.0	TEU	150.0
Vessel (150 TEU)				Per TEU	0,7 loading factor	per TEU in $	1 loading factor	per TEU in $
General costs	seven days time charter		17,500.00	15.0%	17,500.0	166.7	15,000.0	100.0
	time charter rate per day		2,500.0	0.0%				
	river dues+costs		17,333.1	14.9%	17,333.1	165.1	17,333.1	115.6
Port costs Odessa (20")	handling in Odessa port		340.0	30.7%	35,700.0	340.0	51,000.0	340.0
	port infrastructure		12.0	1.1%	1,260.0	12.0	1,800.0	12.0
	Agency fee		60.0	5.4%	6,300.0	60.0	9,000.0	60.0
Port costs Dnepr (20")	handling in Dnepr port		230.0	20.8%	7,245.0	230.0	10,350.0	230.0
	Agency fee		60.0	5.4%	1,890.0	60.0	2,700.0	60.0
Bunkering cost (Odessa	609.0	245.0						
On the go (tone/day)	2.5				87,228.1	1,033.7	107,183.1	917.6
Stay (tone/day)	0.3							
Bunnkering cost per voyage (go and stay)	3,045.3			2.6%	3,045.3	29.0	3,045.3	20.3
River based transportation Odessa-Dnepropetrovsk					90,273.4	1,062.7	110,228.4	937.9
Post haulage by road (50 km) 0,9 $ per km				4.1%	1,417.5	45.0	2,025.0	45.0
TOTAL INTERMODAL Odessa-Dnepropetrovsk hinterland				100.0%	91,690.9	1,107.7	112,253.4	982.9
Auto transport Door-toDoor Odessa-Dnepropetrovsk						1,100.0		1,100.0

Table 3. Transportation costs from Dnepropetrovsk to Kiev for both ways, in USD/TEU

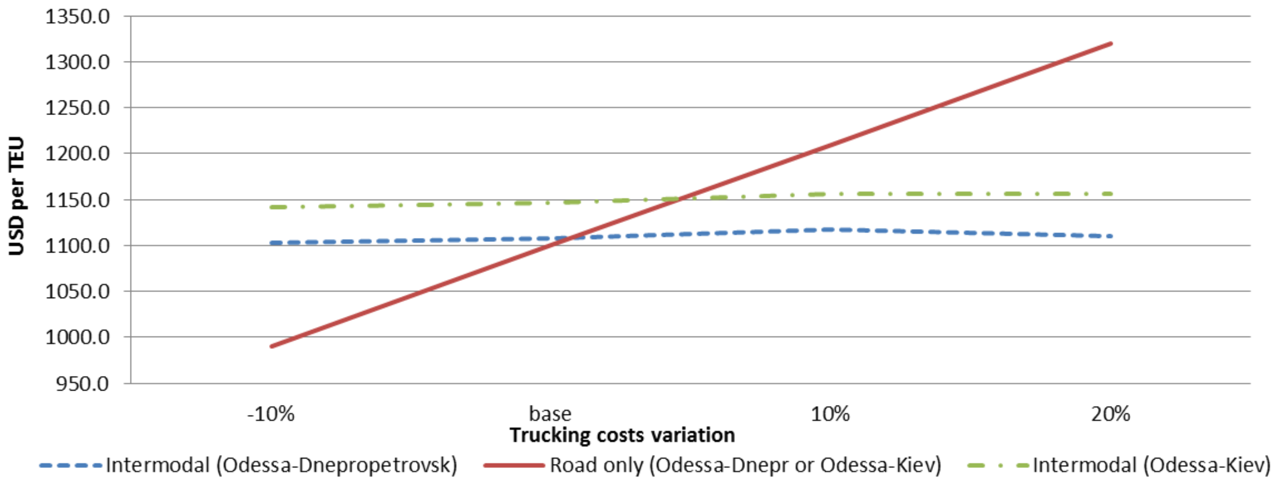
		30 % discharged in Dnepr, 70% in Kiev			
Extra costs for the section Dnepropetrovsk-Kiev (2 ways)	Share of costs % Per TEU	Loading factor 0,7		Loading factor 1.0	
		Total $	*per TEU 105*	*Total $*	*per TEU 150*
Kremenchug Lock	0.04%	47.3	0.5	47.3	0.3
Kaniv Lock	0.04%	47.3	0.5	47.3	0.3
Kyiv Lock	0.04%	47.3	0.5	47.3	0.3
Total until Kiev (inland) 822 km + Sea leg (100 km)					
Total Sea-River distance from Odessa to Kiev 922 km					
Distance from Odessa to Dnepropetrovsk 520 km					
Remainiang distance Dnepropetrovsk - Kiev 402 km					
*Bunkering (1 day go + 1 day unload)*2 ways*	3.1%	3,410.4	32.5	3,410.4	22.7
Handling in Kiev 200$+ 60$ agency fee (150 TEU or 105 TEU)	19.0%	20,580.0	280.0	29,400.0	196.0
Total costs from Dnepropetrovsk to Kiev (105 or 150 TEU)		24,132.4	328.3	32,952.4	219.7
Post haulage by road (50 km) 0,9 $ per km	3.0%	3,307.5	45.0	4,725.0	45.0
COSTS PER TEU by river (from Odessa to Dnepropetrovsk)	74.7%	81,138.4	772.7	97,178.4	647.9
TOTAL From Odessa to Kiev with a stop in Dnepr(2 ways)		105,270.8	1,101.1	143,180.8	867.5
TOTAL INTERMODAL Odessa to Kiev hinterland	100.0%	108,578.3	1,146.1	147,905.8	912.5
Auto transport Door-to Door Odessa-Dnepropetrovsk			1,100.0		1,100.0

We carried out several calculations using the cost model. We considered two main cases: (i) a load factor of 70% on average per year (meaning that the total containers transported on the vessel will be on average 70%) and (ii) the second case where we run the calculations for a fully loaded vessel (though in practice this full load is never achieved).

Taking into consideration the demand and consumption pattern we also suppose that about 1/3 of containers on average per year are discharged in Dnepropetrovsk and 2/3 respectively in Kiev. If that case is considered, then container transportation from Odessa to Dnepropetrovsk will cost the multimodal operator slightly above 1000$ per TEU (with the average loading factor of 0.7). The cost of a container to ship from Odessa to Kiev will be slightly over 1100$ (for the loading factor 0.7). Road only option for the same route (Odessa Kiev) is about 1100$ per TEU. So the calculated intermodal tariffs (i) to Dnepropetrovsk is almost equal to the road only option (1107$ vs 1100$ road only) but (ii) the multimodal tariff until Kiev seems somewhat high and non-competitive especially if a post-haulage of about 50 km is needed (1146$ vs 1100$ road only). Another disadvantage of the multimodal transportation is a longer delivery time. In our case road transport is completed within a day to both inland locations (Dnepropetrovsk and Kiev), whereas the multimodal option under current assumptions can guarantee only 3 and 5 days of delivery time to Dnepropetrovsk and Kiev respectively. However, the current condition of roads in Ukraine is quite poor and land based transportation becomes riskier and not so prompt. Another acute limitation of the IWT transportation is the navigable period which is currently quite limited during the period of March 25 to December 1. We have to keep in mind that these commercial aspects will definitely play a role in the modal choice decisions by shippers and forwarders. Multimodal transportation has to become more efficient and cost effective in order to be able to incentivize a shift away from the road only option.

In order to test the robustness of our cost model we run a sensitivity analysis which showed that in case of a further decrease of the road freights the river based container transportation becomes economically unattractive. Thereafter the further increase in road freights makes the intermodal solution a lot more viable.

Figure 9. Cost sensitivity analysis: intermodal versus pure road transport solutions



We run a sensitivity analysis by deploying a bigger size of river-sea of 4800 t instead of 2930 t with a total container capacity of 245 TEU. The load factors considered in our model were (i) 0.7 and (ii) 1.0 for the whole voyage. The distribution per city stayed the same (Dnepropetrovsk 30 % and Kiev 70%) as in previous case. Having a larger vessel means the vessel cannot call at any other port above Dnepropetrovsk due to the draft limitations. Thereafter all the containers with the destination to Kiev will be discharged in Dnepropetrovsk port and further loaded on a barge accompanied by a tugboat. This inclines the deployment of only 2 sea-river vessels that guarantees a call in Odessa port every second day of the week. After two days of sailing the containers with the destination Kiev are discharged from the sea-river vessel and loaded on the barge. The tug boat brings the container barge within two days to Dnepropetrovsk, takes the second free standing barge (with or without empty containers) and sails back to Dnepropetrovsk where the new sea-river vessel has arrived with the next container batch. This change in the sea-river vessel size led to the network and schedule change. Among the positive changes: (i) the frequency is slightly higher than in previous model; and (ii) the costs from Odessa to Dnepropetrovsk slightly decreased. The negative changes: (i) the costs per TEU up to Kiev increased significantly above the only road option, which makes the whole network configuration economically unviable.

Table 4. Transportation costs from Odessa to Dnepropetrovsk for both ways, in USD/TEU

Intermondal TEU transportation from Odessa to Dnepropetrovsk (both ways) in USD $				Share of costs	100 % discharged in Dnepr			
				%	TEU (0.7 loadfactor)	172.0	TEU (1 load factor)	245.0
Vessel (245 TEU)				Per TEU	0,7 loading factor	per TEU in $	1 loading factor	per TEU in $
General costs	seven days time charter		17,500.00	9.6%	17,500.0	101.8	17,500.0	71.4
	time charter rate per day		2,500.0	0.0%				
	river dues+costs		33,841.1	18.5%	33,841.1	196.8	33,841.1	138.1
Port costs Odessa (20")	handling in Odessa port		340.0	32.0%	57,800.0	340.0	83,300.0	340.0
	port infrastructure		12.0	1.1%	2,040.0	12.0	2,940.0	12.0
	Agency fee		60.0	5.6%	10,200.0	60.0	14,700.0	60.0
Port costs Dnepr (20")	handling in Dnepr port (100%		230.0	21.6%	39,100.0	230.0	16,905.0	230.0
	Agency fee		60.0	5.6%	10,200.0	60.0	4,410.0	60.0
Bunkering cost (Odessa	609.0	245.0						
On the go (tone/day)	2.5				170,681.1	1,000.5	173,596.1	911.6
Stay (tone/day)	0.3							
Bunnkering cost per voyage (go and stay)	3,045.3			1.7%	3,045.3	17.7	3,045.3	12.4
River based transportation Odessa-Dnepropetrovsk					173,726.4	1,018.2	176,641.4	924.0
Post haulage by road (50 km) 0,9 $ per km				4.2%	2,554.0	45.0	3,307.5	45.0
TOTAL INTERMODAL Odessa-Dnepropetrovsk hinterland				100.0%	176,280.4	1,063.2	179,948.9	969.0
Auto transport Door-toDoor Odessa-Dnepropetrovsk						1,100.0		1,100.0

Table 5. Transportation costs from Dnepropetrovsk to Kiev for both ways, by barges in USD/TEU

		70% of containers with destination Kiev area			
Extra costs for the section Dnepropetrovsk-Kiev (2 ways)	Share of costs % Per TEU	Loading factor 0,7		Loading factor 1.0	
		Total	*per TEU*	*Total*	*per TEU*
		$	*134*	*$*	*190*
Time charter - 1 tug boats and 2 barges	3.3%	8,750.0	65.3	8,750.0	46.1
Handling in Dnepr 230$+ 60$ agency fee (134 TEU or 190 TEU)	14.6%	38,860.0	290.0	55,100.0	290.0
Kremenchug Lock	0.02%	47.3	0.5	47.3	0.3
Kaniv Lock	0.02%	47.3	0.5	47.3	0.3
Kyiv Lock	0.02%	47.3	0.5	47.3	0.3
*Bunkering (1 day go + 1 day unload)*2 ways*	1.3%	3,410.4	25.5	3,410.4	22.7
Handling in Kiev 200$+ 60$ agency fee (134 TEU or 190 TEU)	13.1%	34,840.0	260.0	49,400.0	260.0
Total costs from Dnepropetrovsk to Kiev (134 or 190 TEU) (Subtotal)	*32.4%*	85,955.1	641.7	116,755.1	614.5
Post haulage by road (50 km) 0,9 $ per km	2.3%	6,030.0	45.0	8,550.0	45.0
COSTS PER TEU by river (from Odessa to Dnepropetrovsk)	65.4%	173,726.4	1,018.2	176,641.4	924.0
TOTAL From Odessa to Kiev with a stop in Dnepr(2 ways)		259,681.5	1,659.9	293,396.5	1,538.5
TOTAL INTERMODAL Odessa to Kiev hinterland	*100.0%*	265,711.5	1,704.9	301,946.5	1,583.5
Auto transport Door-to Door Odessa-Dnepropetrovsk			1,100.0		1,100.0

Table 6. The estimated schedule of the route: Odessa-Dnepropetrovsk-Kiev

	Week							Week							Week						
# Day Vessel	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
River-Sea vessel	Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa
2 Barges+ 1 tugboat			Dnepr'k		Kiev		Dnepr'k		Kiev		Dnepr'k		Kiev		Dnepr'k		Kiev		Dnepr'k		Kiev
River-Sea vessel			Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa		Dnepr'k		Odessa		Dnepr'k
2 Barges + 1 tugboat					Dnepr'k		Kiev		Dnepr'k		Kiev		Dnepr'k		Kiev		Dnepr'k		Kiev		Dnepr'k

3.2.2. Network design scenario 2

An alternative service based on the same network design could be barge based container transportation. In this case the service network will have a slight design change – there will be an extra stop and handling operation in Kherson. So ultimately the River-Sea vessel will call as before the Deep Sea port in Great Odessa region, after which she heads to Kherson port situated at the mouth of Dnepr. On this section of the network no barges are allowed, only a Sea-River vessel type can be deployed. Here some containers with the destination for Kherson region can be unloaded and more importantly the rest of containers from the sea-river vessel have to be reloaded on one or two barges to go upstream to Dnepropetrovsk and Kiev. That is an interesting option but it requires different vessels deployment. Instead of 4 river-sea vessels proposed in the first scenario, the deployment of one sea-river vessel, four tug boats and 8 barges will be necessary. Besides this, some extra costs for container handling in Kherson port are going to occur. More importantly this network cannot be easily implemented since there is no necessary handling equipment either in the Kherson river or in Kherson sea ports. Potentially this vessel/barge network design could look like in figure 10. This service can last up to 5-6 days if the tug boat sails with two barges from Kherson port and exchanged in each inland port one barge and sails back to Kherson port. Thus the turnaround time of the one full loop with this network design can be one day shorter than with four river-sea vessels in first scenario.

Though the second service network design provides 4 services per week, it is less attractive to the end user since it has one sliding day per week out of service (in the 1st week Friday no departures from Odessa, in the 2nd week Thursday etc.). In order to guarantee a regular and uniform service, additional ships should be deployed (one River-Sea vessel, one tug boat and 2 barges) that would have a one-day overlap with other vessel upon arrival. Another difference in comparison with the first network design- the delivery time to Dnepropetrovsk from Odessa is one day longer than (4 days instead of 3) because of an additional port call in Kherson. The delivery time to Kiev remains the same (5 days).

Applying a cost model for the second scenario we made some assumptions:

- the following fleet will need to be deployed in order to guarantee this 4/week container service: 4 pairs of river barges, 4 tugboats and one river-sea vessel. The sum of the time charters for 2 barges, 1 tugboat and ¼ of the sea-river vessel time charter is assumed to be the same as the whole time charter of one sea-river vessel.
- the existence of needed handling equipment and storage areas in Kherson port and assumed container handling fee of 300 $ for both operations (unloading the sea-river vessel and loading the barges)+ 60$ agency fee per TEU, making up in total 360$ per TEU.

Running the calculations for the second scenario we can see that it turns out to be more expensive per TEU than the first scenario. This is not surprisingly, since the handling fees in Ukrainian ports are quite high and additional transhipment in the total intermodal chain increase the overall cost per TEU for the end user.

Figure 10. Container network design using river-sea vessels and barges: Odessa-Kherson-Dnepropetrovsk-Kiev

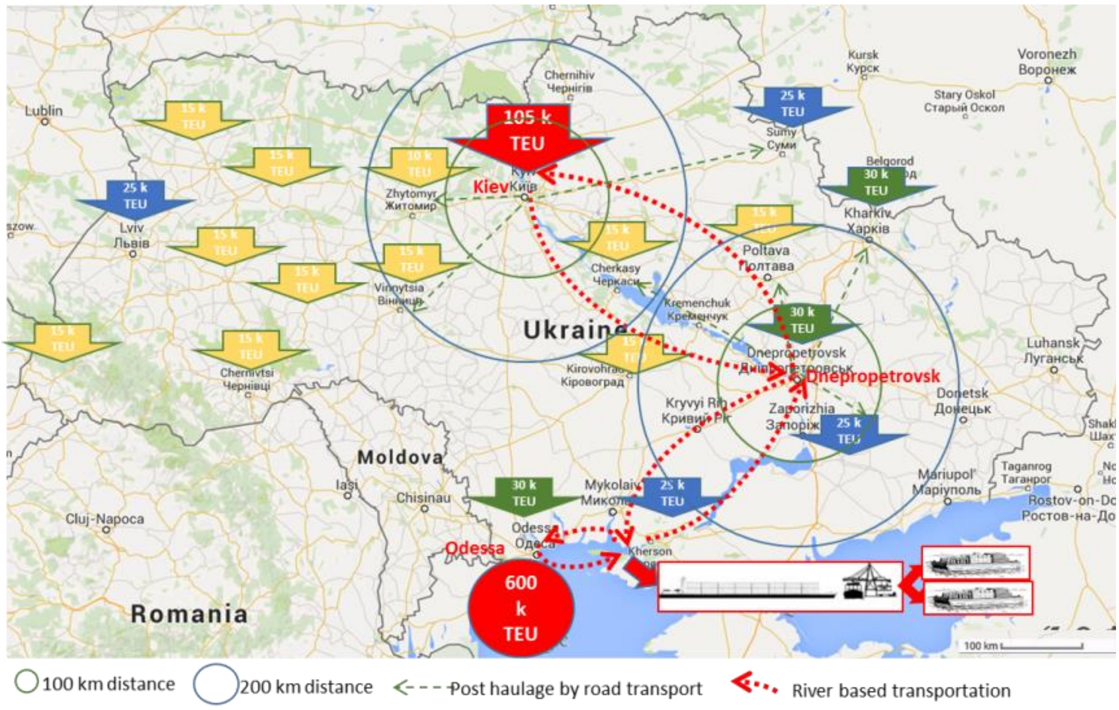


Table 7. Container service schedule: Odessa-Kherson-Dnepropetrovsk-Kiev

	Week							Week							Week						
# Day / 2Barges+tugboat	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson	
2		Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson
3			Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa
4				Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson	Odessa	Kherson		Dnepr'k	Kiev	Kherson

Table 8. Transportation costs from Dnepropetrovsk to Kiev for both ways, in USD/TEU using river-sea vessels and barges.

Intermondal TEU transportation from Odessa to Dnepropetrovsk (both ways) in USD $				Share of costs	30 % discharged in Dnepr, 70% in Kiev			
				%	TEU	105.0	TEU	150.0
Vessel (150 TEU)				Per TEU	0,7 loading factor	per TEU in $	1 loading factor	per TEU in $
General costs	seven days time charter		17,500.00	11.4%	17,500.00	166.7	17,500.0	116.7
	time charter rate per day		2,500.0	0.0%				
	river dues+costs		17,333.1	11.2%	17,333.1	165.1	17,333.1	115.6
Port costs Kherson (20")	handling in Kherson port		300.0	20.4%	31,500.0	300.0	45,000.0	300.0
	Agency fee		60.0	4.1%	6,300.0	60.0	9,000.0	60.0
Port costs Odessa (20")	handling in Odessa port		340.0	23.2%	35,700.0	340.0	51,000.0	340.0
	port infrastructure		12.0	0.8%	1,260.0	12.0	1,800.0	12.0
	Agency fee		60.0	4.1%	6,300.0	60.0	9,000.0	60.0
Port costs Dnepr (20")	handling in Odessa port		230.0	15.7%	7,969.5	230.0	11,385.0	230.0
	port infrastructure		60.0	4.1%	2,079.0	60.0	2,970.0	60.0
Bunkering cost (Odessa and Novorossiysk) per ton	609.0	245.0						
On the go (tone/day)	2.5				125,941.6	1,393.7	164,988.1	1,294.2
Stay (tone/day)	0.3							
Bunnkering cost per voyage (go and stay)	3,045.3			2.0%	3,045.3	29.0	3,045.3	20.3
River based transportation Odessa-Dnepropetrovsk					128,986.9	1,422.7	168,033.4	1,314.5
Post haulage by road (50 km) 0,9 $ per km				3.1%	1,559.3	45.0	2,227.5	45.0
TOTAL INTERMODAL Odessa-Dnepropetrovsk hinterland				100.0%	130,546.1	1,467.7	170,260.9	1,359.5
Auto transport Door-toDoor Odessa-Dnepropetrovsk						1,100.0		1,100.0

Table 9. Transportation costs from Dnepropetrovsk to Kiev for both ways, by barges in USD/TEU

		30 % discharged in Dnepr, 70% in Kiev			
Extra costs for the section Dnepropetrovsk-Kiev (2 ways)	Share of costs % Per TEU	Loading factor 0,7		Loading factor 1.0	
		Total	*per TEU*	*Total*	*per TEU*
		$	*105*	*$*	*150*
Kremenchug Lock	0.03%	47.3	0.5	47.3	0.3
Kaniv Lock	0.03%	47.3	0.5	47.3	0.3
Kyiv Lock	0.03%	47.3	0.5	47.3	0.3
*Bunkering (1 day go + 1 day unload)*2 ways*	2.3%	3,410.4	32.5	3,410.4	22.7
Handling in Kiev 200$+ 60$ agency fee (150 TEU or 105 TEU)	15.2%	22,638.0	280.0	32,340.0	215.6
Total costs from Dnepropetrovsk to Kiev (105 or 150 TEU)		26,190.4	323.9	35,892.4	239.3
Post haulage by road (50 km) 0,9 $ per km	2.4%	3,638.3	45.0	4,725.0	45.0
COSTS PER TEU by river (from Odessa to Dnepropetrovsk)	79.9%	118,938.4	1,132.7	153,678.4	1,024.5
TOTAL From Odessa to Kiev with a stop in Dnepr(2 ways)		145,128.8	1,456.7	203,925.8	1,263.8
TOTAL INTERMODAL Odessa to Kiev hinterland	100.0%	148,767.0	1,501.7	208,650.8	1,308.8
Auto transport Door-to Door Odessa-Dnepropetrovsk			1,100.0		1,100.0

Despite our finding that the IWT container transportation is somehow expensive in comparison with the road only option, there is reasonable room and potential for the competitiveness increase of IWT based intermodal transportation:

- Specifically, we considered a vessel under Ukrainian flag that is taken in time charter and operated by a 3rd party. In reality however, there are several local shipping companies that own the necessary fleet under Ukrainian flag for an alike container service. For those companies the vessel costs are lower than the time charter rates we used in our calculations, since they do not have to pay a premium to the third-party vessel owner and slightly lower lock passage fees.
- From our calculations we can see that the biggest share in the intermodal barge transportation chain falls to the handling fees in deep sea and inland ports (e. g. 23. 2%, 15. 7% and 15. 2% for Odessa, Dnepropetrovsk and Kiev respectively). In the presented cost model we used the handling fees of sea port of Odessa and Dnepropetrovsk which were valid until 2014 (according to the basic import tariffs of 340$ and 230$ respectively). We believe they are significantly overestimated and there is room for a container handling tariff discount. Note that since 2014 the deep sea ports terminals are free to set up handling tariffs themselves, and not centralized by the Ministry of Infrastructure as before. For the handling tariffs in Kiev port we made an assumption of having a tariff of 200$ and 60$ agency fee which seems quite comparable to other empirical handling fees we used in the model. We believe that the handling tariffs in the inland ports are quite high, so there is some room for significant reduction.
- According to the new Law on IWT the river dues and costs are going to become less, so that could diminish the total IWT based intermodal chain costs.
- The fuel bunkering was considered to be realized in Odessa port, where the cost of bunker is among highest in the basin. If certain supplies could be made from other ports (Novorossiysk port) the cost per TEU would decrease by about 3%.
- The current containerization level of the cargo handled in Ukraine of only 5% is quite low in comparison with other regions in the world (average world containerization level is about 67%) (Ports of Ukraine, 2015).
- Alternatively in order to support the IWT intermodal transportation, the national government could stimulate and support this initiative by providing certain tax subsidies to the parties involved in the intermodal transportation. Though this step must be further well thought through and analyzed by: (i) determining their size ; (ii)

the beneficiary parties; and (iii) the effect on the market competition distortion. A more acceptable potential solution for the state and the private sector would be a public-private partnership model for the maintenance and transportation via IWT of Ukraine.

4. Conclusions

This paper intended to enrich the limited academic research on IWT systems in a transition stage, as exemplified by the case of Ukraine. We introduced two research questions which were further analyzed in the paper:

RQ1: Terminals – what is their contribution to the cost and quality performance of inland navigation?

We have demonstrated that in order to have primarily a critical juncture within IWT and ultimately a well-functioning inland navigation market its features have to be beneficial and attractive. A large contribution to the IWT market conditions relate to the availability and functioning of inland terminals. The inland terminals being the nodes of the barge intermodal TS play a crucial role especially in the case of Ukraine. The inconsistent fact for the IWT of Ukraine is that there are about 23 terminals and ports though a large majority of them is not well equipped and not suitable for container handling. Over and above, the few inland terminals offering container handling services have very high handling rates (21.2% from total supply chain costs of handling costs in Dnepropetrovsk port). The deep-sea terminal involved in the proposed barge service adjoins some 32% more to total chain costs. So ultimately more than half of the total intermodal chain costs are generated by the handling activities in inland ports. This is quite a tremendous difference in comparison with empirical records of the handling costs shares within the total intermodal barge chains (10%-30%). The high port dues, costs and handling fees were mentioned in the previous research of Grushevska and Notteboom (2015) as a considerable barrier for Ukraine's intermediacy function. Thus the outcome of the current research reaffirms the previous findings and importance of the overpriced port related costs.

Additionally to that, the sensitivity analysis carried out (based on network scenario 1) showed that in case of a further decrease of the road freight rates the river based container transportation becomes economically unattractive. In contrast the further increase in road freight rates makes the intermodal solution a lot more viable.

An extra condition has to be satisfied to support the river based intermodal transportation solutions: a rail-based container transportation back-up solution. This implies the following:

- creation of railway stations within the main inland ports (e. g. Kiev, Dnepropetrovsk) or alternatively improve the efficiency of the available rail intermodal terminals operated by the state railway logistics provider "Liski";
- in order to guarantee the flexibility and reliability of the container service the river terminals should be easy replaceable by rail terminals mainly during the ice period

RQ2: What is the optimal network design for container transportation via IWW in order to increase the IWT share in the intermodal split?

Based on the regional peculiarities and available methodologies from previous researches on intermodal transport we proposed two base network designs for container transportation via IWT. We found that the design of employing a fleet of 4 river-sea vessels in order to deliver a 4/week service is more economically viable and uniform than the network design with a fleet of one river-sea vessel, 8 barges and 4 tugboats.

References

1. Beelen, M. (2011). *Structuring and modelling decision making in the inland navigation sector* (Doctoral dissertation, UNIVERSITEIT ANTWERPEN (BELGIUM)).
2. Bontekoning, Yvonne Margaretha. *Hub Exchange Operations in Intermodal Hub-and-spoke Operations: Comparison of the Performances of Four Types of Rail-rail Exchange Facilities*. IOS Press, 2006.
3. Caris, A., Macharis, C., & Janssens, G. K. (2008). Planning problems in intermodal freight transport: accomplishments and prospects. *Transportation Planning and Technology*, 31(3), 277-302.
4. Crainic, T. G. (2000). Service network design in freight transportation. *European Journal of Operational Research*, 122(2), 272-288.
5. de Langen, P. W., van der Horst, M. R., & Konings, R. (2006). *Cooperation and coordination in container barging*. Martime Transport, 3, 91-107.
6. Doubrovsky, M. (2005). *Ukrainian and Russian waterways and the development of European transport corridors*.
7. Douma, A. M. (2008). *Aligning the operations of barges and terminals through distributed planning*. University of Twente.
8. European Commission (2011). White Paper (2011). *Roadmap to a Single European Transport Area—towards a competitive and resource efficient transport system*. Brussels, 28. March 2011 COM (2011) 144 final
9. Egis International / Dornier Consulting. (2013). *Logistics Processes and Motorways of the Sea II*. LOGMOS Master Plan – Annex 6, Part I, TRACECA Inland Waterways – Dnepr Case Study
10. Frémont, A., Franc, P., & Slack, B. (2009). Inland barge services and container transport: the case of the ports of Le Havre and Marseille in the European context. Cybergeo: *European Journal of Geography*.
11. Groothedde, B. (2005). Collaborative logistics and transportation networks–A modeling approach to hub network design.
12. Grushevska, K., and Notteboom, T. (2015). From centrality to intermediacy in the global transport network? Ukraine's trials and tribulations as a potential transit country. *Proceedings of the International Association of Maritime economists conference*, Kuala Lumpur, August 2015.
13. Grushevska, K., Notteboom, T. and Shkliar, A. (2014). *Ukrainian railways – the need for institutional change*. In: Vervoerslogistieke werkdagen. Breda.
14. Grushevska, K., & Notteboom, T. (2014). An Economic and Institutional Analysis of Multi-Port Gateway Regions in the Black Sea Basin. *Journal of International Logistics and Trade*, 12(2), 3.
15. Grushevska, K., Notteboom, T. (2016). The development of river-based intermodal transport: the case of Ukraine. CEMS *Research Seminar on Supply Chain Management*, Riezlern, Austria, 12-16 January 2016.
16. Grzelakowski, A. S. (2010). Inland water transport as a factor influencing mega-ports and seaport cities development (from the European North Sea perspective). *Logistics and Transport*, 11(2). Gunthner Ginkels, Inland waterways, Maritime days in Odessa, May 2015
17. Konings, J. W. (2009). *Intermodal barge transport: network design, nodes and competitiveness*. TU Delft, Delft University of Technology.
18. Konings, J. W. (2008). *The future of intermodal freight transport: operations, design and policy*. Edward Elgar Publishing.
19. Kreutzberger, E. (2008). The innovation of intermodal rail freight bundling networks in

Europe; *Concepts, developments and performances, TRAIL Thesis Series nr*. T2008/16, Delft.
20. Kreutzberger, E., R. Konings and L. Aronson (2006) Evaluation of the cost performance of pre- and post-haulage in intermodal freight networks: analysis of the interaction of production models and demand characteristics, in: B. Jourquin, P. Rietveld and K. Westin (eds.), *Towards better performing transport networks*, Taylor & Francis Group, Routledge, pp. 256 – 284.
21. Macharis, C., & Verbeke, A. (2001). Het intermodale transportsysteem vergeleken met het unimodale wegvervoer. *Review of Business and Economics*, 46(1), 39-64.
22. Macharis, C. (2000, August). *Hybrid Modeling: System Dynamics combined with Multi-criteria Analysis. In An application to intermodal transport*. Bergen Noorwegen: System Dynamics Conference.
23. Notteboom, T. E., & Rodrigue, J. P. (2005). Port regionalization: towards a new phase in port development. *Maritime Policy & Management*, 32(3), 297-313.
24. Notteboom, T., & Konings, R. (2004). Network dynamics in container transport by barge. Belgeo. *Revue belge de géographie*, (4), 461-478.
25. Notteboom, T. (2007). Container river services and gateway ports: Similarities between the Yangtze River and the Rhine River. *Asia Pacific Viewpoint*, 48(3), 330-343.
26. Palander, Tord. "Beiträge zur standortstheorie. " (1935).
27. Rodrigue, J. P., & Notteboom, T. (2010). Foreland-based regionalization: Integrating intermediate hubs with port hinterlands. *Research in Transportation Economics*, 27(1), 19-29.
28. Rodrigue, J. P., Comtois, C., & Slack, B. (2013). *The geography of transport systems*. Routledge.
29. Rodrigue, J. P. (2008). The Thruport concept and transmodal rail freight distribution in North America. *Journal of Transport Geography*, 16(4), 233-246.
30. Rutten, Bernardus Johannes Catharina Maria. *On medium distance intermodal rail transport: a design method for a road and rail inland terminal network and the Dutch situation of strong inland shipping and road transport modes*. TU Delft, Delft University of Technology, 1995.
31. Shkliar A, Inland waterways . Role and means of river transportation in Europe, *Maritime days in Odessa*, May 2015
32. Svitlovodsk River Terminal. http://www.ukragrocom.com/index. php/en/view/sv_construction/18/all.
33. Ukrrichflot official website http://ukrrichflot.ua/en/
34. Van Der Horst, M. R., & De Langen, P. W. (2008). Coordination in hinterland transport chains: a major challenge for the seaport community. *Maritime Economics & Logistics*, 10(1-2), 108-129.
35. Veenstra, A., & Notteboom, T. (2011). The development of the Yangtze River container port system. *Journal of Transport Geography*, 19(4), 772-781.
36. Walker, W. T. (1992). Network economies of scale in short haul truckload operations. *Journal of Transport Economics and Policy*, 3-17.
37. Winter, S. G., & Nelson, R. R. (1982). An evolutionary theory of economic change. *University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship*.
38. Woxenius, Johan. "Generic framework for transport network designs: applications and treatment in intermodal freight transport literature". *Transport reviews* 27, no. 6 (2007): 733-749.

Стаття надійшла до редакції 12.08.2016 р.