Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2016, 47 (119), 129–135
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/159

Received: *25.02.2016*
Accepted: *03.06.2016*
Published: *20.09.2016*

A new concept for utilising the Oder waterway in intermodal container transport

Mieczysław Hann, Leszek Piotrowski, **Krzysztof Woś**

Maritime University of Szczecin, Faculty of Economics and Transport Engineering
11 H. Pobożnego St., 70-507 Szczecin, Poland
e-mail: {m.hann; l.piotrowski; k.wos}@am.szczecin.pl
corresponding author

Key words: Oder waterway, container transport, river-land combined transport, profitability of transport, multilayer container transport, River – Class parameters, vertical clearance of bridges

Abstract

The article addresses the issue of the transport of goods on the Oder Waterway (Odrzańska Droga Wodna, ODW), in terms of its usefulness for the transport of containers in the face of limitations arising from the hydrotechnical conditions of the river and the modernisation programme. A realistic estimate leads to the conclusion that by 2030 the CEMT Class III classification may be achieved in the upper and middle sections. Combined river and land transport of containers has been proposed as an applicable solution, considering the present condition and the predicted development and modernisation of the waterway within the next years. The main feature of this transportation concept is the principle of transporting multiple layers of containers on inland ships, reducing the cost of transport of individual containers. Sections of the ODW that meet the parameters of the CEMT Class III, or higher, will be used in such a way. In points of contact with sections that do not meet those parameters, loading points will be organised where the upper layers of containers will be removed from the barge and transferred either to land transport or a loading barge capable of going under low bridges.

The article presents analysis of the effect of the main parameters of the river and land system of container transport on its economic effectiveness. Those parameters are: the number of layers of containers on a barge, percentage of the entire route covered by land transport means, number and time of transhipments, and speed relations. Relationships between these parameters have been established, together with the principles of their selection, assuming the main criterion to be gaining profit by using combined transport in comparison with land transport. Examples of combined transport have been presented on the Gliwice–Świnoujście and Gliwice–Hamburg routes, including progress in modernizing the Middle Oder.

Introduction

The issue of how to use the Oder Waterway (Odrzańska Droga Wodna, ODW) is still of interest (Restel & Skupień, 2011). The current state may only be characterised as highly unsatisfactory due to the failure to take advantage of certain features, such as the lowest transport and carriage costs compared to all other modes of transport. A report issued by the Supreme Audit Office (Supreme Audit Office, 2014) puts it rather bluntly by pointing to the marginal significance of inland water transport in state transport and financial policies. However, the financial plans that have been developed for the years 2014–2020 allow to determine that the real modernisation of inland waterways will happen in the 2030 perspective.

The ODW remains the only waterway in Poland which is at least partly prepared to serve as an international waterway. The middle, free flowing, section of the Oder presents the biggest hydrological problems. Works begun with the Program Dla Odry 2006, with the intent of reaching Class III parameters along the entire length of the waterway, are being carried out with delays (Kulczyk & Skupień, 2010). The immediate consequence is the loss of funds (Priority

VII of the Operational Programme 'Infrastructure and Environment'). A published assessment of the current situation points to the unprofitability of the undertakings required to achieve Class IV (Fundacja im. Micheala Otto, 2010). In addition, the necessary restructuring of road and rail bridges increases the costs to the point that it is not possible to predict the time required for completing the project. Moreover, these costs have yet to be adequately estimated (Kulczyk & Skupień, 2010). Lately there has been improvement in matters of planning finances (Priority VII) and implementing the modernisation. Stage I (until 2020) aims at achieving Class III parameters on the Brzeg Dolny–Bytom Odrzański section, Stage II (2030 perspective) is going to improve the rest of the middle Oder. A realistic estimate leads to the conclusion that by the 2030 Class III parameters will be achieved only in the upper and middle sections. The modernisation of the border Oder, which has just begun, shall, in the nearest future, improve Szczecin's connection with canals connecting the Oder with European inland waterways.

The range of cargo transported along the ODW is limited to dry bulk cargo (mainly coal and other mining products) (ECORYS, 2011; Fundacja im. Micheala Otto, 2010; Gawłowski, 2012; Niebieska Księga, 2002) and, periodically, oversized cargo. Container transport along the ODW is virtually inexistent, even though the cost of such transport would be 2.5 times lower than railroad transport and ca. 4 times lower than road transport.

The demand for supplying (and reclaiming) containers for the ports in the estuary region of the Oder is currently growing. The OT Logistics company requires a quick, quantitative development of reloading (next year it is hoping to achieve a reloading capacity of 200,000 containers per year). The limitations of the depth of the Szczecin port shipping lane will no longer exclude this port as works aimed at deepening the shipping route to 12.5 m have begun this year. The limitations to inland navigation arising from weather conditions on the Szczecin Lagoon should be viewed as a challenge in the implementation of sea and inland ships. The conditions which would allow inland container transport to the West coast are being established.

It has been estimated (Niebieska Księga, 2002) that the current condition of the middle Oder and the insufficient vertical clearance of some bridges eliminate the possibility to transport more than one layer of containers, whereas water transport should naturally allow transport of multilayer containers, further reducing the cost of transport of an individual container. Yet, should we wait another century to reach conditions allowing for cheap mass container transport on the ODW? The solution seems to be combined land and water transport (Piechociński, 2007).

A new look at the issue of container transport on the ODW

The state of affairs outlined above seems to justify our concept that modernisation works on the ODW aiming at achieving Class IV (Supreme Audit Office, 2014) on its entire length in the foreseeable future are unreal. Therefore, we propose the combined method of land and water transport as feasible in view of the modernisation works envisaged for the next few years.

The main feature of this concept is the transportation of multiple layers of containers on inland ships, which would lower the cost of transport of individual containers. Those sections of the ODW which meet the parameters of Class III and higher will be used for this purpose. In points of contact with sections which do not meet these parameters, loading points will be organised (Figure 1, item 1), where the upper layers of containers will be removed from barges and transferred to means of land transport (Figure 1, item 2). The barges would proceed with one layer of containers only (item 3) until navigational conditions would allow to continue the cruise with multilayer cargo. In such a place a return loading of the upper layers to the barges would be performed (item 4).

By using a loading barge (Figure 1, item 5) equipped with a reloading device, it would be possible to bypass low bridges using road transport. Such a barge may remove the upper layers of containers and arrange them on its deck in one layer. Then the barge would go under the bridge (Figure 1, item 6)

Figure 1. A concept of combined multilayer container transport on the ODW

and, having passed it, return the containers to the transport barges as their upper layers (item 7).

Such a system may be imagined as consisting of a few bypasses of low bridges and a few road bypasses on the entire middle Oder, or parts of it, taking into account the current progress of modernisation. Some of the bridges may be grouped together and in the section from Brzeg Dolny to the mouth of the Warta River one may bypass only the parts of the river that are shallow (there are apparently a few of them) or present significant meandering. Certainly, one should seek an optimum solution cost-wise but also in view of other factors, such as the number of navigable days in a year (ice, floods) and the sociological impact of the project.

Data gathered by us suggest that such an option has never been considered. There have been, however, attempts to solve the problem of coal transport by combining river and railroad transport (Piechociński, 2007).

An example of the scope of bypasses, which takes into account the scheduled modernisation of the middle Oder to the parameters of Class III, is shown in Figure 2. This modernisation will allow two-layer container transport on the new type INBAT barges (Figure 3) with a draft of 1.6 m. A convoy of two barges with an INBAT pusher may transport 84 containers at a time.

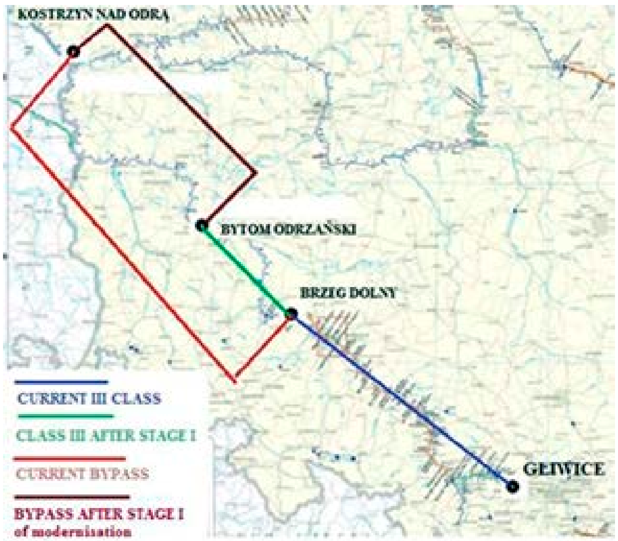

Figure 2. The scope of bypasses dependent on the progress of modernisation

The advantages of the proposed system are as follows:

1) large transport capacity (one water convoy takes twice as many containers as one train and the mean speed on land transport networks increases);

Figure 3. An INBAT barge may take 21 containers in one layer

2) low transport costs (benefit for the client) and low external costs (benefit for the carrier and the state);
3) flexibility (adaptation to the current condition of the ODW: the condition of the river channel, structures, ice, floods);
4) graduality (adaptation to the current progress of modernisation – implementation at the existing state of the ODW, fleet and ports);
5) patency of the ODW (possibility of using sections of international classes, including European waterways in the East-West and North-South systems);
6) stimulation of the growth and construction of inland fleet (the use of bankrupt shipyards, new solutions – especially for containers);
7) stimulation of the growth of ports and logistics centres (use of existing ones, e.g. Gliwice, Brzeg Dolny, Szczecin and the construction of new ones, e.g. Kostrzyn).

The specification of the main parameters of the system (percentage of land transport, number of transhipment points) ensuring its profitability is the subject matter of another academic paper (Hann, Piotrowski & Woś, 2014) and of an application to the National Centre for Applied Research to finance a project entitled "Combined Transport as a Basis for Effective Carriage of Containers by Oder Waterway in the Presence of its Limited Capacity".

Profitability Estimation

In order to assess the practical usefulness of this proposal, a preliminary assessment was performed concerning the profit that could be achieved by its implementation without waiting for change in the classification of ODW. The transport of one layer of containers on the entire length of the ODW has been adopted as a reference system (for example Gliwice–Świnoujście i.e. 744 km).

The choice of this reference has been made since the transportation of such a load along the ODW is currently considered admissible (Niebieska Księga, 2002). In particular, it is assumed that an insufficient clearance under bridges impedes the crossing with two layers of containers. This point of view has been questioned as the transport with two layers of containers from Szczecin to Koźle has occurred (Supreme Audit Office, 2014).

In practice, the vessel's draft (the state of loading and ballasting) and the water level are of importance as much as the height of the span. These are fortuitous conditions, whose assessment has not been made. Table 1 presents the parameters that determine the possibility of barge OBP500 to pass under the bridge. The following parameters are reported:

$H_{1.3}$ – Highest water level enabling passage under the bridge at a draught of 1.3 m;

$H_{1.7}$ – Highest water level enabling passage under the bridge at a draught of 1.7 m.

On the basis of these parameters, we can expect that the conditions causing a collision with the bridge during the transportation of two layers of containers may occur. Another question concerns the probability of such an event. The assumptions made regarding the construction of special barges equipped with ballast systems should also be specified.

The following have been assumed as the fundamental parameters of the system of combined transport (Hann, Piotrowski & Woś, 2014):

a) the entire length of the transport river way, L_0 (e.g. distance from Gliwice to Świnoujście);

b) the percentage, p, of land transport with respect to the entire length L_0:

$$p = L_L / L_0 \quad (1)$$

c) number of transhipments n, each including transhipment from a barge to another means of bypass transport and vice versa, along with necessary inter-operational storage;

d) the number of container layers, w, transported by water.

The preliminary profitability assessment has been based on the comparison between the cost, K_0, of transport of one container through the combined system on the entire route of the inland waterway, and using only the waterway along its entire length with the one-layer system.

The assumed system of reference is therefore the transport of one layer of containers along the entire route of the Oder Waterway (ODW; e.g. Gliwice–Świnoujście, i.e. 744 km). This is due to the fact that such transport is deemed possible with the current state of the ODW.

The cost of transport of one container (TEU) per one kilometre of the inland waterway has been assumed as the basic parameter. The following ratio has been accepted for the analysis as a comparative parameter:

$$\Psi = \frac{K_0}{K_1} \quad (2)$$

where:

K_1 – cost of transport on the ODW of one container in one-layer system per 1 km of the river way;

K_0 – cost of transport of one container in the combined w-layered system per 1 km of the river way.

The cost of the combined transport consists of the following:

$$K_o = K_1 \cdot p + K_w(1-p) + K_L + K_p \quad (3)$$

where: K_w – cost of transport only by waterway of one container in the w-layered system per 1 km of the river way.

Table 1. Parameters determining the possibility of passing under the bridge for barge OBP500

Sections of the ODW	Localisation of bridge	km ODW	Clearance at WWŻ [cm]	WWŻ [cm]	$H_{1.3}$ [cm]	$H_{1.7}$ [cm]
Sewered the Odra River	Opole – railway	151.25	384	400	378	WWŻ
	bridge – road bridge	151.25	370	400	348	387
	Brzeg	199.001	375	380	333	372
	Oława	216.42	370	550	498	517/537
	Ratowice	228.0	390	550	528	WWŻ
Brzeg Dolny – mouth of the Nysa Łużycka River	Głogów	393.3	390	485	453	WWŻ
	Nowa Sól	437.7	398	480	456	WWŻ
	Cigacice	470.7	372	460	410	429/449
	Nietków	490.5	379	420	377	386/416
	Krosno Odrzańskie	514.0	315	420	313	351/371
Mouth of the Nysa Łużycka River – mouth of the Warta River	Kostrzyn	615.1	367	535	480	519

Assuming that transport cost does not depend on the extent to which the barge is loaded:

$$K_w = \frac{1}{w} \cdot K_1 \tag{4}$$

K_L – the unit cost (per 1 km of the overland route) of land transport of one container per 1 km of the river way;

K_p – cost of transhipments of one container from a barge to land vehicle/train and vice versa, along with necessary inter-operational storage, per 1 km of the river way.

By defining the ratio of the rail or road transport cost to the cost of water transport in one layer:

$$\Psi_E = \frac{K_L}{K_1} \tag{5}$$

one may calculate the limit of the percentage of the land transport, p_E, with a given number n of transhipments with the criterion that:

$$\Psi \leq \Psi_E \tag{6}$$

In order for the combined transport to be profitable, one must assume that the percentage of the land transport shall be lower than the limit:

$$p = \eta \cdot p_E \ldots \eta \leq 1 \tag{7}$$

The profit of transporting one container by combined transport in comparison with land transport is given by:

$$Z_0 = K_L - K_0 = K_1(\Psi_L - \Psi) \tag{8}$$

One may then determine a profit ratio as the percentage of the cost of river transport of one container in one layer:

$$z_1 = Z_0 / K_1 = \Psi_L - \Psi \tag{9}$$

Two general variants of land transport have been analysed:

G1 – land transport of all containers (no river transport on sections under Class III),

G2 – land transport of containers over the first layer and river transport of the one remaining level along river sections under Class III.

The advantage of the G2 variant is clear, as well as the significance of the number of transhipments.

The results of calculations presented below have been obtained after the following figures were estimated:

1. The cost of inland water transport of one container of the average weight of 16 t in one layer (assuming 20 containers per layer) amounts to K_1 = 512 zł/L_0;
2. The cost of transport of one container by railroad: K_L = 2.5 zł/km/L_0;
3. The cost of transhipment of one container: K_p = 400 zł/L_0;
4. The duration of break caused by the transhipment of upper layers of containers: T_p = 24 hours.

Figures 4–6 present charts showing the limit value of the percentage of the land transport in the entire transport route depending on the number of transhipments. In order for combined transport to be profitable, i.e. meet condition (6), one should consider the p values above the curve. Negative figures point to the scope of inadmissible parameters. The chart in Figure 6 proves that, with 2 layers of containers, up to 8 transhipments are possible in order to achieve minimum profit. The chart in Figure 5 presents the connection between the profit ratio and the number of transhipments, calculated for η = 0.66.

The transport capacity has significant effect on the overall economic outcome. Combined transport is faster than river transport as part of the way "p" is covered with the speed of land transport, v_L. At the same time, the multilayer water transport must be adapted to the transport capacity of the land transport, e.g. in multi-carriage trains. The principle of

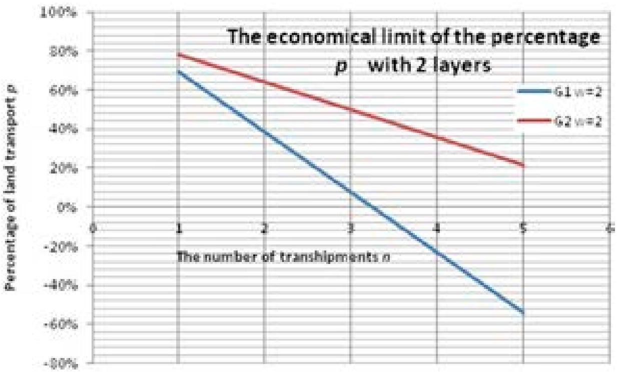

Figure 4. Dependence of the percentage of land transport on the number of transhipments and layers for two general variants of land transport. G1 and G2

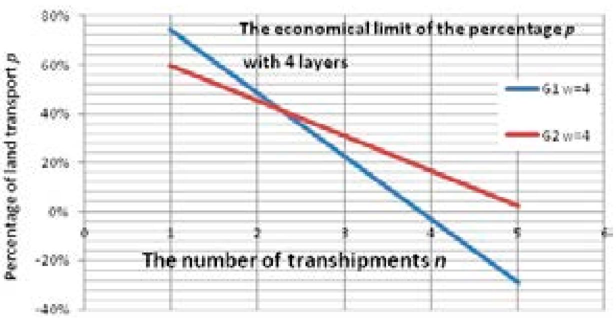

Figure 5. Dependence of the percentage of land transport on the number of transhipments and layers for two general variants of land transport, G1 and G2

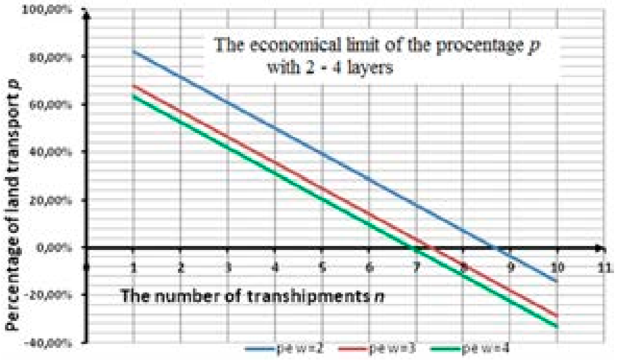

Figure 6. Influence of the number of transhipments and layers on the percentage, *p*, of land transport

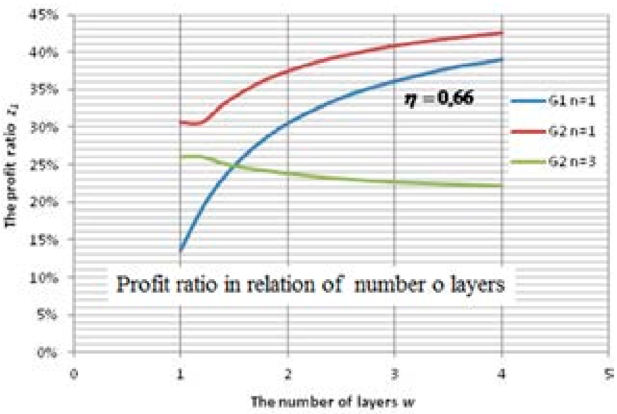

Figure 7. Dependence of the profit ratio on the number of transhipments, *n*, and layers, *w*, for two general variants of land transport, G1 and G2

combination may be the adaptation of the delivery time to transhipment and reception without storage, taking into account the lock capacity. The result will be a transport capacity higher than that of water transport in one layer. Such a state will multiply the profit as a result of the combination of water transport in a few layers with fast, multi-carriage railroad transport, in comparison with the results shown in Figure 5. The dependence of the equivalent velocity for the entire land and water route on the component velocities is set out by the following equation:

$$v_z = \frac{v_w}{1 - p(1-\gamma) + n \cdot \delta} \qquad (10)$$

where:

$\gamma = v_W / v_L$ – ratio of water transport velocity to land transport velocity;

$\delta = T_p / T_w$ – ratio of the duration of the storage break to the time of water transport on the entire route.

The transport capacity of the system is proportional to the number of layers, *w*. The ratio of increasing transport capacity by using *w* layers in comparison to the one-layer transport may therefore be described as:

$$\beta = \frac{v_z}{v_w} \cdot w = \frac{w}{[1 - p(1-\gamma) + n \cdot \delta]} \qquad (11)$$

The demonstration of transport capacity ratio dependence on the main system parameters is presented in Figure 6. As one can see, even with a low (a few percentage points) share of land transport and six transhipments, one may increase transport capacity by as much as 50% in comparison to one-layer transport.

Profit per unit (per one container) obtained in combined transport with the equivalent velocity (10) in comparison to the land transport, as the percentage of the cost of one-layer river transport, is:

$$z = \beta \cdot z_1 \qquad (12)$$

In practice, the frequency of deliveries is of great importance and it depends not only on the transport velocity but mainly on the logistics. Intermodal transport rises in Poland to the level of 6–8 trains per week. The combined water and land transport will be limited by the times of lockage and transhipments as well as waiting at the locks and in transhipment points. While it is not limited much by timetables and the access to transport way, it is obstructed by navigation conditions. It is predicted that it will be possible to achieve the frequency of deliveries of about 30–40 barges per week in the navigational season. With a similar figure (40 containers) for each delivery in the land and combined transport, one may reinforce the profit.

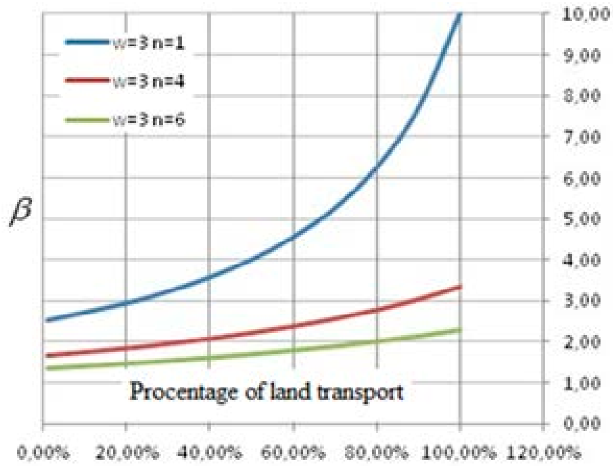

Figure 8. Example of transport capacity ratio

By $w = 3$, $\gamma = 0.1$, $p = 0.18 \cdot 0.66 = 0.12$, $n = 4$, $\delta = 0.2$, $\beta = 3$. This means that in the variant G2,

Table 2. Results of the analysis

Example	Number of Layers w	Number of Transhipments	Land transport % Limit p_E	Land transport % Done p	Profit ratio z_1	β	Individual profit z
	–	–	%	%	%	–	%
Variant IA: Gliwice–Świnoujście now	3	4	40	36	26	2.1	54
Variant IB: Gliwice–Świnoujście after stage I of modernisation	3	4	40	21	54	1.9	102
Variant IIA: Gliwice–Hamburg now	3	4	40	29	39	2.0	78
Variant IIB: Gliwice–Hamburg after stage I of modernisation	3	4	40	17	62	1.8	112

with 3 container layers, 4 transhipment operations and a 12% participation of land transport, the profit connected with the transport of 1 container may amount to about 66% of the water transport charges of this container in a single layer.

The capacity of land transport, ZPL, which may be defined as the quantity of trains used in 24 hrs and the quantity of wagons per train, must be adjusted to the transport capacity of the combined system, ZPK. This idea may be expressed through the following equation:

$$\text{ZPL} = \text{ZPK} = \beta \cdot \frac{v_w}{a} \cdot W_D \qquad (13)$$

and:

W_D – quantity of layers transported by barges every 24 hrs;

a – distance between barges (assumed as a constant on the whole route).

In order to assess possible profits for the buyer of services, two examples of using the proposed system have been analysed:

Variant 1: Gliwice–Świnoujście route

- Now – 3-layer transport (60 containers) to Brzeg Dolny (including bypass of 3 bridges), unloading upper layers and bypass to Kostrzyn, loading upper layers and transport to Świnoujście;
- After the 1st stage of modernisation – 3-layer transport (60 containers) to Bytom Odrzański (including bypass of 3 bridges), unloading upper layers and bypass to Kostrzyn, loading upper layers and transport to Świnoujście.

Variant 2: Gliwice–Hamburg route

- Now – 3-layer transport (60 containers) to Brzeg Dolny (including bypass of 3 bridges), unloading upper layers and bypass to Kostrzyn, loading upper layers and transport to Hamburg;
- After the 1st stage of modernisation – 3 layer transport (60 containers) to Bytom Odrzański (including bypass of 3 bridges), unloading upper layers and bypass to Kostrzyn, loading upper layers and transport to Hamburg.

The results of the analysis are presented in Table 2. They justify the idea that it is possible to lower the transport cost of one container in this system two fold compared to railroad transport.

Conclusions

The first, tentative attempts at an economic evaluation point to the fact that there are organisational and terrain combinations which lead to establishing the percentage of use of relief roads and the number of transhipments required for the whole length of the route (Oder Waterway + sections of European roads). This indicates it may be possible to achieve a beneficial economic effect. This effect will be a cheaper transport of multi-layer containers by bypasses rather than by direct railroad transport.

References

1. ECORYS (2011) *Program rozwoju transportu wodnego śródlądowego w Polsce – for the Ministry of Infrastructure*. Rotterdam, Warszawa.
2. Fundacja im. Micheala Otto (2010) *Analiza uwarunkowań i efektywności ekonomicznej rozwoju odrzańskiej drogi wodnej*. Warszawa: Fundacja im. Micheala Otto na rzecz ochrony środowiska.
3. Gawłowski, S. (2012) Sekretarz stanu w Ministerstwie Środowiska R.P.: *Bieżące i planowane działania państwa polskiego w celu zrównoważonego działania w dorzeczu Odry.* Słubice.
4. Hann, M., Piotrowski, L. & Woś, K. (2014) Wstępna ocena efektywności multimodalnego transportu kontenerów na odrzańskiej drodze wodnej. *Logistyka* 6.
5. Kulczyk, J. & Skupień, E. (2010) *Transport kontenerowy na Odrzańskiej Drodze Wodnej*. Prace Naukowe Politechniki Warszawskiej Wydz. Transportu. Warszawa.
6. Niebieska Księga (2002) *Metodyka sporządzania analiz dla projektów realizowanych w Polsce. Annex 1. Part 4. Projekty transportu kombinowanego / intermodalnego*. Phare PL2002/000-580.01.08.
7. Piechociński, J. (2007) *Transport kombinowany jako przyszłość rozwoju przewozów towarowych*. [Online]
8. Restel, F. & Skupień, E. (2011) Analiza niezawodności transportu łamanego na przykładzie korytarza transportowego odrzańskiej drogi wodnej. *Logistyka i Nauka* 6.
9. Supreme Audit Office (2014) Report NIK-4101-04/2013. *Funkcjonowanie żeglugi śródlądowej*. Warszawa.