TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 12
Number 1
March 2018
DOI: 10.12716/1001.12.01.15

# Logistic Conditions of Container Transportation on the Oder Waterway

J. Kulczyk & T. Tabaczek
*Wrocław University of Technology, Wrocław, Poland*

ABSTRACT: The paper contains the analysis of the possibility of container transportation on the Oder Waterway (the Gliwice Canal, the canalized stretch of the Oder River, and the regulated stretch of the Oder River), on the assumption that the waterway complies with conditions of class III European waterway. The analysis is based on the concept of modern motor cargo vessel, adjusted to hydraulic parameters of waterway. The vessel is designed for ballasting when passing under bridges. The amount of ballast water that enables transportation of two tiers of containers is given. The costs of waterborne transportation are compared to the costs of rail transportation of containers on selected shipping routes.

## 1 INTRODUCTION

The Oder Waterway (ODW) for many years will remain the most important waterway for inland waterborne transportation in Poland. Despite the considerable degradation it is still possible to transport cargoes from Szczecin to waterways of Western Europe, on the Gliwice Canal, and on the canalized stretch of the Oder River from Silesia (Koźle) to Wrocław. Construction and commissioning of the weir and lock in Malczyce will enable to restore the navigation along the entire Oder Waterway.

The Oder River connects five significant regions of Poland: Silesia, Opole Voivodeship, Lower Silesia, Lubusz Land and Western Pomerania. In year 2012 those regions provided almost 30% of gross domestic product (GDP). In year 2014 the share of those regions in the sold production of industry was 32% [7]. Besides the bulk cargo (coal, aggregates) that traditionally was transported on the ODW, also a number of cargoes that require special organisation of transportation gravitates towards the river. There is a considerable supply of dangerous cargoes in form of products from large chemical plants located by the Oder River and equipped with own loading berths that, at the moment, are not being utilised. There is a great number of factories of car industry, factories producing household appliances, equipment for energy production or chemical equipment, in the regions connected with the Oder River. Many products from above branches are highly demanding in terms of packing, packaging, composing of integrated freight units as well as in terms of safety in transportation. These products are perfectly fit for multimodal transportation in containers. Inland waterborne transportation is preferred for safety reason.

In economy of agglomerations located by the ODW the trade plays important role. It concerns in particular the agglomerations of Silesia, Wrocław and Szczecin. They are important centres of distribution, storage and logistics. There is a number of container terminals there, including the following [11]:

– Silesian Logistics Centre in Gliwice Port, handling capacity of 150,000 TEU per year;
– PCC Intermodal terminal in Brzeg Dolny, handling capacity of 110,000 TEU per year;
– PCC Intermodal terminal in Frankfurt (Oder), handling capacity of 100,000 TEU per year.

The agglomeration of Szczecin is connected to the Szczecin and Świnoujście Seaports where the amount of reloaded containers is continuously growing. In year 2016 there were 90,869 TEU reloaded only in Szczecin. It was about 55% more in comparison to year 2010. 5% growth was reported in first 7 months of year 2016 in comparison to corresponding period of year 2015 [12].

New container terminals are going to be built in Kędzierzyn-Koźle and in the region of Wrocław [1].

The Oder River is the part of a natural transport corridor connecting the Baltic Sea and the Adriatic Sea. Missing is the stretch connecting the Oder River and the Danube River. After the period of stagnation the problem of construction of the Oder-Elbe-Danube Canal is regarded as priority within the development of an integrated European system of inland waterways.

The basic feature of any transport corridor is the possibility of shipment using more than one mean of transportation. In such situation the advantages of each mean of transportation may be utilized. Than the optimization of transportation tasks in the transport corridor is possible.

Inland waterborne transportation is distinguished by numerous advantages, especially in comparison to road transportation. The main feature is its environment friendliness. It is the consequence of considerably lower demand for energy to carry out the transport work. Thereby the emission of greenhouse gases and total external costs are much lower. According to the EU records the demand for primary energy in transportation of containers amounts [9]:
– trucks and lorries: 0.49 - 0.50 MJ/tkm,
– rail transportation: 0.37 - 0.40 MJ/tkm,
– inland waterborne transportation: 0.14 - 0.29 MJ/tkm.

In many cases, as in the case of large-size cargo, the inland waterborne transportation is the only possible to implement. Such kind of cargo in road transportation requires the dedicated platform trailers and the arranged transit route. In the course of ride the traffic restrictions for other road users take place and may cause the disorganisation of traffic on large area. Such disturbances can be avoided when the large-size cargo is transported by water.

On the 22nd of July 2016 the Government of the Republic of Poland adopted the document "The assumptions to plan of development of the inland waterways in Poland in years 2016 - 2020 with the perspective till year 2030" („Założenia do planów rozwoju śródlądowych dróg wodnych w Polsce na lata 2016-2020 z perspektywą do roku 2030”). In long-term perspective defined are the following targets:
– the development of the Oder River to comply with the requirements of Va class waterway,
– the construction of the stretch of Oder-Elbe-Danube Canal on the territory of Poland,
– the construction of the Silesian Canal.

In order to achieve the parameters of Va class waterway along the entire Oder Waterway 21 more weirs and locks must be built downstream of the lock in Malczyce that nowadays is under construction [10]. The concept of the cascade of the Oder River is presented in Fig.1.

In short-term perspective planned are: the modernisation of the Gliwice Canal, the construction of two new weirs and locks downstream of Malczyce, i.e. in Lubiąż and in Ścinawa, and the upgrade of locks on the canalized stretch of the Oder River to meet the parameters of the Va class waterway.


Figure 1. The cascade of the Oder River as a Va class waterway [4]

The technology of container transportation proposed in this paper is based on the assumption that the operating conditions correspond to conditions on the III class waterway only. However, the operation of the proposed new motor cargo vessel would be possible even at present operating conditions.

## 2 SUPPLY OF CONTAINERS GRAVITATING TOWARDS THE ODW

The estimates of cargo gravitating towards the ODW published before the year 2000 usually did not include the containerised cargo.

In this paper it is assumed that about 20 million tonnes of cargo can be shipped on the ODW per year. Such amount of cargo was already shipped in year 1980. Then the bulk cargo was prevailing.

In the structure of transportation on the Rhine River in years 2013 - 2015 the amount of containerized cargo was 15.3 to 15.8 million of tonnes, that is 7.9% to 8.3% of total amount of shipped cargo [2]. At the average weight of cargo of 7.2 tonnes per TEU it yields about 2.2 million of TEU.

In European Union, in year 2015 the share of containerised cargo in total tonne-kilometres was 10.3%. The estimates for container transportation in year 2016 suggested the growth by 10% in comparison to year 2015 [3].

For the purpose of the following considerations one may assume that the structure of transportation on the Oder River will not differ significantly from that in Western Europe. Assuming the 8% share of goods in containers, and the above estimated total supply of cargo of 20 million of tonnes, about 1.6 million of tonnes of cargo may be transported in containers on the ODW. At the average weight of cargo of 7.2 tonnes per TEU [2] there is an estimate of 220,000 TEU per year. This number of TEU exceeds the number of containers handled in the Szczecin and Świnoujście Seaports considerably (90,869 TEU in year 206 [12]). However, besides the Szczecin and Świnoujście Seaports, significant for container transportation on the ODW is also the western direction to the waterways in other EU countries, including the port in Hamburg. In year 2013 560,200 of TEU were reloaded in Hamburg in connection to shipment to and from Poland [8]. 20% of them were next moved to the south of Poland, the majority to the regions located by the Oder River. The estimated average weight of cargo in a single TEU was about 10 tonnes. Assuming that 10% of containers that are moved from Hamburg to the south of Poland may be taken by waterborne transportation, the next 11,000 TEU are estimated to gravitate to the ODW.

## 3 THE ODER WATERWAY - HYDROLOGIC AND HYDRAULIC CONDITIONS

Hydrologic and hydraulic conditions are the basic factors that determine the functional parameters of a waterway. They include:

- the degree of river regulation (canalized river, regulated river, or a freely running river),
- parameters of hydraulic structures (horizontal dimensions of locks),
- air clearances under bridges,
- width of fairway,
- radii of meanders,
- transit depths of water,
- minimum and maximum discharge in a river,
- icing periods,
- pauses due to high or low water level,
- working hours of hydraulic devices.

The above factors determine the class of waterway and, in consequence, the main particulars of ships.

In the case of canalized rivers and navigation canals the hydraulic conditions are constant. Ships are designed to have the maximum acceptable dimensions. Main dimensions depend on the depth of water in canal, the area of cross-section, and the dimensions of locks. Due authorities determine the maximum ship speed on waterway, particularly in canals. Speed limits are intended for protection of banks against the destruction due to wash waves generated by going vessel, and for protection of vessel against grounding. Usually the speed limit in navigation canal is not higher than 10 km/h.

The ODW is, and will remain for very next years, the most important transport waterway in Poland. Is characterized by diverse hydraulic structures, varying functional parameters along its length, and, generally, by the significant wear and tear of structures. Considering:

- the different functional parameters of waterway,
- the diverse hydrologic conditions,
- the functions of waterway,
- the need and potential for development of navigation conditions,

the ODW is divided into the following stretches:

1 the Gliwice Canal with 6 doubled locks of dimensions 72 m x 12 m;
2 the canalized Oder River from Koźle to Brzeg Dolny with 23 locks including 20 locks of dimensions 187 m x 9.6 m and 3 locks of dimensions 225 m x 12 m;
3 the regulated Oder River from Brzeg Dolny to the mouth of the Lusatian Neisse River (after building and commissioning of the weir and lock in Malczyce this stretch will range from Malczyce to the mouth of the Lusatian Neisse);
4 the regulated Oder River from the mouth of the Lusatian Neisse River to the mouth of the Warta River;
5 the regulated Oder River from the mouth of the Warta River to Szczecin.

The rules of classification and the classes of Polish waterways are given in the regulation of the Council of Ministers of the 7th of May 2002. Table 1 shows the classes of individual stretches of the ODW.

Table 1. Classification of individual stretches of the ODW

| 5. The Oder River and the Gliwice Canal | Length and the kilometre of river | Class |
|---|---|---|
| a) the Gliwice Canal | 41.2 km | III |
| b) from the lock in Kędzierzyn-Koźle to the lock in Brzeg Dolny (the canalized stretch of the Oder River) | 183.5 km from km 98.1 to km 281.6 | III |
| c) from the lock in Brzeg Dolny to the mouth of the Lusatian Neisse River | 260.8 km from km 281.6 to km 542.4 | II |
| d) from the mouth of the Lusatian Neisse River to the mouth of the Warta River | 75.2 km from km 542.4 to km 617.6 | II |
| e) from the mouth of the Warta River to Ognica (to the Szwedt Canal) | 79.4 km from km 617.6 to km 697 | III |
| f) from Ognica to the Klucz-Ustowo Cut and farther as the Regalica River to its estuary to the Lake Dąbie | 44.6 km from km 697 to km 741.6 | Vb |
| 6. The Western Oder River from the weir in Widuchowa to the border of internal sea waters including the Klucz-Ustowo Cut | 36.5 km from km 0 to km 36.5 | Vb |

Own elaboration based on the map "Inland waterways in Poland", as of year 2007, National Water Management Authority (Annex No. 2 to the regulation of the Council of Ministers of the 7th of May 2002)

According to the classification of waterways binding in Poland the class III waterway shall allow for the operation of vessels of the following main particulars:

- length of motor ship ≤ 70 m,
- length of pushed barge train ≤ 118 m - 132 m,
- beam ≤ 8.2 m - 9.0 m,
- draught ≤ 1.6 - 2.0 m.

The regulation of the Council of Ministers of the 7th of May 2002 determines also the width of the fairway: 40 m on a river and 35 m on a canal, the minimum radius of the bends (meanders): 500 m, and the minimum dimensions of lock chambers: length of

72 m, width of 9.6 m. The minimum recommended air clearance under bridges at the highest navigable water level is 4 m. This parameter is a significant confinement in transportation of containers or large-size cargo.

In the following assessment of potentials of container transportation on the ODW the present authors assume that ODW conforms to the requirements of class III waterway. That ensures the operation of ships at draught of at least 1.4 m for 90% of navigation season. Such conditions prevailed on the stretch of regulated Oder River from year 1980 to year 2008. In that period the transit depth of 1.8 m was reported for 27% of navigation season.

Air clearance under bridges is a significant confinement in transportation of containers. The limiting bridge on the stretch from Wrocław to Szczecin is the railway bridge in Krosno Odrzańskie (at km 514.1 of the river) where the air clearance at highest navigable water level is 3.15 m. At the mean navigable water level when ships can operate at draught up to 1.6 m, the clearance is higher by 0.8 to 0.9 m [6].

On the stretch of canalized Oder River the lowest air clearance of 3.37 m is under the road bridge in Ratowice, over the lock. On this stretch one may assume that air clearances under bridges are constant, independent from the level of water.

## 4 THE TECHNOLOGY OF CONTAINER TRANSPORTATION ON THE ODW

With the confinements in mind, assuming that a motor cargo vessel will be the basic unit in transportation on the ODW, the dimensions of a ship that best utilises conditions on the waterway are as follows:
– length overall LOA = 70.0 m,
– breadth overall BOA = 9.1 m,
– design draught T = 1.70 m,
– draught of light ship T0 = 0.55 m,
– height H = 1.80 m,
– capacity (at T = 1.70 m) P ≈ 660 tonnes,
– length of hold Lh = 51.0 m,
– width of hold b = 7.0 m,
– estimated volume of ballast tanks V = 268 m3.

The concept of such vessel was presented in report "Logistic conditions of combined transportation of coal in the transport corridor of the Oder Waterway" [5]. Report was written in the framework of RTD project No. 10-0003-04 financially supported by the National Centre for Research and Development. General arrangement plan of that vessel is shown in Fig.2. Transverse cross section of vessel, including dimensions of ballast tanks, is shown in Fig.3. Ballast tanks are intended for increasing draught in the cases when air clearance under a bridge is insufficient and could cause a break in the voyage.

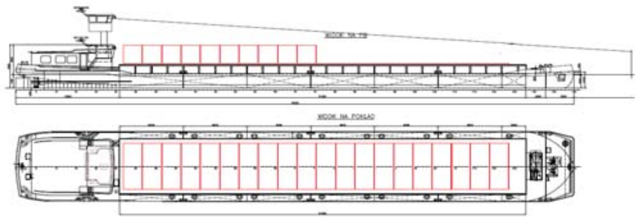

Figure 2. General arrangement plan of the motor cargo vessel BMN 700

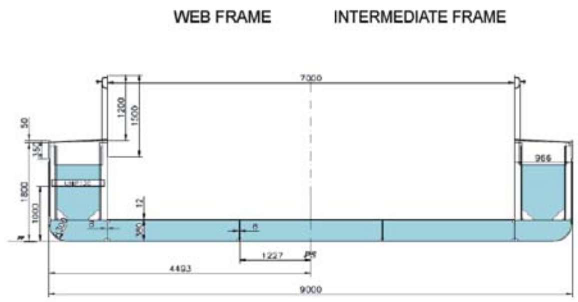


Figure 3. Transverse cross-section of the motor cargo vessel BMN 700

During the development of that concept it was assumed that vessel is a general-purpose ship for transportation of bulk cargo as well as containers. In the case of vessel dedicated for transportation of containers it is possible to increase the width of hold from 7.0 m to 7.512 m. That would increase the number of TEU in one tier from 20 TEU arranged transversely to 24 TEU arranged longitudinally in three rows. Net volumes of ballast tanks at hold 7.0 m wide and at hold 7.512 m wide are given in Table 2.

In analysis of actual draught of vessel the present authors assumed that, in the range of draughts possible during operation, the draught is a linear function of loading condition. Based on the draught of light ship $T_0$ and the capacity at draught of 1.70 m one may estimate that load of 5.74 tonnes increases draught by 0.01 m.

Air clearances required when one or two tiers of containers are transported are presented in Table 3 and in Fig.4.

Table 2. Volume of ballast tanks

| Tank | Length [m] | Width [m] | Height [m] | Volume [m3] | Correction factor | Corrected volume [m3] | Increment of ship draught [m] |
|---|---|---|---|---|---|---|---|
| Double bottom | 51.0 | 9.00 | 0.38 | 174.4 | 0.80 | 139 | 0.24 |
| Double side (hold 7.0 m wide) | 51.0 | 0.97 | 1.05 | 103.4* | 0.75 | 77* | 0.13 |
| Double side (hold 7.512 m wide) | 51.0 | 0.70 | 1.05 | 75.0* | 0.70 | 52* | 0.09 |

* Volume of both tanks at starboard and port side

Table 3. The required air clearance under bridges

| Motor cargo vessel BMN 700 | | | | | |
|---|---|---|---|---|---|
| Draught [m] | Payload [tonnes] | 1 tier (20 TEU) Average gross weight of one TEU [tonnes] | Required air clearance [m] | 2 tiers (40 TEU) Average gross weight of one TEU [tonnes] | Required air clearance [m] |
| 0.97 | 244 | 12.2 | 2.00 | 6.1 | 4.60 |
| 1.04 | 280 | 14.0 | 1.93 | 7.0 | 4.53 |
| 1.11 | 320 | 16.0 | 1.86 | 8.0 | 4.46 |
| 1.18 | 360 | 18.0 | 1.79 | 9.0 | 4.39 |
| 1.25 | 400 | 20.0 | 1.72 | 10.0 | 4.33 |
| 1.32 | 440 | 22.0 | 1.65 | 11.0 | 4.25 |
| 1.39 | 480 | - | - | 12.0 | 4.18 |
| 1.46 | 520 | - | - | 13.0 | 4.12 |
| 1.53 | 560 | - | - | 14.0 | 4.05 |
| 1.60 | 600 | - | - | 15.0 | 3.99 |
| 1.66 | 640 | - | - | 16.0 | 3.92 |

Own elaboration

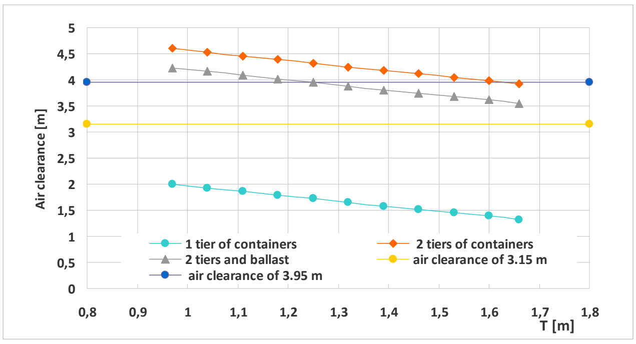


Figure 4. The effect of ship draught on required air clearance

Transportation of 1 tier of containers is possible regardless of the gross weight of one TEU. In the case of 2 tiers the required air clearance exceeds the limiting value of 4 m when gross weight of one TEU is equal or less than 14 tonnes.

Using ballast tanks the draught may be increased by 0.37 m. Then transport of 2 tiers of containers is possible at average gross weight of 10 tonnes per TEU, at ship draught of about 1.3 m without ballast and 1.64 m with ballast. Without ballasting the transport of 2 tiers is possible only when the average weight of one TEU equals at least 16 tonnes, at ship draught of at least 1.66 m.

Air clearance required when the hold is 7.512 m wide and 4 additional 20-feet containers are loaded in a tier is presented in Fig.5. Filling all ballast tanks increases the draught by 0.33 m. Then two tiers of containers can be transported at mean weight of 8 tonnes and ship draught of about 1.27 m.

Ballasting enables operation of the vessel carrying 2 tiers of containers at high water levels. It increases the utilisation of fleet and the rationalization of transport costs.

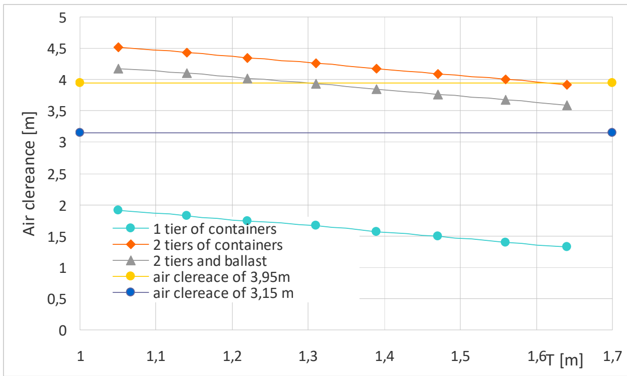


Figure 5. The effect of ship draught on required air clearance at 24 TEU in a tier

## 5 COSTS OF WATERBORNE AND RAIL TRANSPORTATION

The costs of transportation are determined for three example shipping routes. Distances are given in Table 4.

Table 4. Example shipping routes and distances

| Shipping route | Distance by water [km] | Distance by rail [km] |
|---|---|---|
| Gliwice - Wrocław | 200 | 149 |
| Gliwice - Szczecin | 680 | 512 |
| Szczecin - Wrocław | 480 | 363 |

The distance by rail was determined based on data given by PKP CARGO.

The costs of rail transport were determined based on the PKP CARGO price list binding since the 1st of January 2017 [13]. Costs depend on distance, type of container, weight of container, and the state of container loading (loaded or empty). The basic rates are as follows: for route Gliwice - Wrocław 1,913 zł/TEU, Gliwice - Szczecin 5,035 zł/TEU, Szczecin - Wrocław 3,766 zł/TEU. Basic rates were multiplied by correction factors according to the following guidelines. For a 20-feet container not heavier than 22.0 tonnes the correction factor equals 0.75 and 1.00 for a 40-feet container. For empty containers - 0.5 and 0.8, respectively.

For estimation of costs of waterborne transportation there were determined the duration of voyages, the costs of one return voyage, and the number of voyages in navigation season. The above values were estimated based on data given in [5]. The cost of one tonne-kilometre was estimated on the assumption that gross weight of a single 20-feet container amounts 12.5 tonnes.

The following assumptions were adopted for determination of the number of voyages:
– total number of navigable days per year: 275,
– number of lock working hours per day: 16,
– number of vessels that are locked at the same time: 1,
– coefficient of the average use of a vessel and of traffic irregularity: 0.85,
– margin for the duration of voyage: 10%.

Table 5. Duration of a voyage, number of voyages per navigation season and cost of voyage for motor cargo vessel BMN 700 on individual stretches of the ODW

| Stretch of ODW | Duration of voyage [h] downstream | upstream | Number of return voyages | Throughput [Mio tonnes per year] | Cost of single return voyage [zł] |
|---|---|---|---|---|---|
| Gliwice Canal | 6.5 | 6.5 | 340 | 4.1 | 5,860 |
| Canalized stretch of the Oder River (from Kędzierzyn-Koźle to Brzeg Dolny) | 25.2 | 38.3 | 69 | 2.8 | 20,625 |
| The stch of regulated Oder River (from Brzeg Dolny to Szczecin) | 41.9 | 122.0 | 26 | 10.8 | 37,720 |

Table 6. Unit cost of waterborne and rail transportation on selected shipping routes along the ODW

| Voyage | Duration of voyage [h] down-stream | up-stream | Number of voyages per navigation season | Cost of voyage [zł] | Unit cost [zł/TEU] Water-borne transp. | Rail transp. 20′ cont. | 40′ cont. |
|---|---|---|---|---|---|---|---|
| Gliwice - Wrocław - Gliwice | 28.0 | 38.7 | 66 | 23,250 | 581 | 1,435 | 1,913 |
| Gliwice - Szczecin - Gliwice | 73.6 | 166.7 | 18 | 64,200 | 1,605 | 3,776 | 5,035 |
| Szczecin - Wrocław - Szczecin | 45.6 | 128.1 | 25 | 39,970 | 1,000 | 2,824 | 3,766 |

The duration of voyage was calculated with account for actual velocity of stream in considered stretch of river.

The results of calculations based on data given in [5], for individual stretches of the ODW are presented in Table 5. The costs of voyages have been increased using the growth factor of gross domestic product (GDP), i.e. the ratio of GDP in year 2015 to the GDP in year 2011 [7] that amounts 1.125.

Throughput given in Table 5 was estimated on the assumption that the rated capacity of BMN 700 is 650 tonnes and that traffic is undisturbed. The number of voyages is defined as the number of voyages made by a single vessel during the navigation season.

Using data of Table 5 the duration of single voyage, the number of return voyages per year, and the costs of return voyage were determined for selected routes along the ODW (Table 6). Unit cost of transportation by water (zł/TEU) was estimated on the simplifying assumptions that two tiers of containers (40 TEU) are carried only in one direction (upstream or downstream), and that the costs of fuel and duration of voyage are the same for loaded and unloaded vessel. When containers are transported both upstream and downstream during single return voyage the unit cost is half as high as that presented in Table 6.

Unit costs of rail transportation include the correction factors applied to basic rates, as described before.

The costs of waterborne transportation per one tonne-kilometre when two tiers of containers are carried only upstream or downstream, calculated using data of Table 6 for the considered voyages amount:

– Gliwice - Wrocław - Gliwice: 0.1162 zł/tkm,
– Gliwice - Szczecin - Gliwice: 0.0944 zł/tkm,
– Szczecin - Wrocław - Szczecin 0.0832 zł/tkm.

When containers are transported in both directions (upstream and downstream) during one return voyage the unit cost of one tonne-kilometre is reduced by half.

Additionally, estimated were the costs of transportation by rail using a train of 40 platform carriages of kind S and type Sgs. One platform carriage can carry three 20-feet containers or one 40-feet container. It means that entire train can carry 120 20-feet containers or 40 40-feet containers. It was assumed that half of total number of containers on a train are empty. The costs of transportation of one TEU by rail on selected routes are given in Table 7.

The external costs were determined based on data on transportation in EU published in [9]. Exchange rate of 4.2 zł/euro was used for conversion. The external costs per one tonne-kilometre are: 0.047 zł/tkm for rail transportation and 0.015 zł/tkm for waterborne transportation.

Data presented in Tables 6 and 7 show that waterborne transportation is cheaper than rail transportation even when only one tier of containers is carried by vessel.

Table 7. Costs of container transportation on selected shipping routes

| Shipping route | Costs [zł/TEU] by rail 20′ cont. | 40′ cont. | External costs | by water 20′ cont. | External costs |
|---|---|---|---|---|---|
| Gliwice - Wrocław | 1,194 | 1,72253 | | 581 | 38 |
| Gliwice - Szczecin | 3,147 | 4,532180 | | 1,605 | 128 |
| Szczecin - Wrocław | 2,354 | 3,390128 | | 1,000 | 90 |

According to German data, assuming the above rate of exchange, the estimated mean costs are 630 zł/TEU (150 €/TEU) for waterborne transportation, and at 903 zł/TEU (215 €/TEU) for rail transportation [9].

## 6 CONCLUSIONS

The presented analysis shows that, in the transport corridor of the Oder River, the costs of container transportation by water are lower than the costs of transportation by rail. The application of ballasting enables the transportation of 2 tiers of containers in operating conditions assured on the class III waterway. It is possible despite low average weight of loaded containers, when the mean weight of cargo in a single 20-feet container is less than 10 tonnes. Hence, for most of the lifetime the capacity and the highest available draught (design draught) of a ship will not be utilised. It creates the opportunity for transportation of containers also at low water levels in the Oder Waterway. To this end it is necessary to build a fleet of innovative vessels capable of ballasting (changing draught) when the ship is sailing.

## REFERENCES


[1] Bogucki J., Lewandowski K., Kolanek Cz. et al.: Śródlądowy terminal kontenerowy. Uzasadnienie celowości budowy, Instytut Konstrukcji i Eksploatacji Maszyn Politechniki Wrocławskiej, Raport Nr SPR-94/2009

[2] Frühjahrssitzung 2016. Angenommene Beschlüsse (2016-I), ZKR Zentralkommission für Rheinschifffahrt, Strassburg, Juni 2016, www.ccr-zkr.org

[3] Market Insight, Europaische Binnenschifffahrt, Herbst 2016, Zentralkommission für Rheinschifffahrt, Europaische Kommission, Rotterdam 2016, www.ccr-zkr.org

[4] Kreft A.: Program rozwoju polskich śródlądowych dróg wodnych - wersja wstępna, Konferencja w Ministerstwie Gospodarki Morskiej i Żeglugi Śródlądowej, 09-02-2016

[5] Kulczyk J., Lisiewicz T., Nowakowski T. et al.: Logistyczne uwarunkowania transportu łamanego węgla w korytarzu transportowym Odrzańskiej Drogi Wodnej, Instytut Konstrukcji i Eksploatacji Maszyn Politechniki Wrocławskiej, Raport Nr SPR-45/2011

[6] Kulczyk J., Skupień E.: Uwarunkowania transportu kontenerów na Odrze, Zeszyty Naukowe Transport, Z. 73, Politechnika Warszawska, 2010, pp. 61 - 77

[7] Rocznik Statystyczny Rzeczypospolitej Polskiej 2015, GUS, Warszawa, 2016

[8] Teuber M.O., Wedemeier J. et al.: Przewozy towarów między portem w Hamburgu i Polską – perspektywy rozwoju Unii Izb Łaby i Odry, Hamburgisches Weltwirtschaftsinstitut (HWWI), 2015

[9] Verkehrswirtschaftlicher und ökologischer Vergleich der Verkehrstrager Strasse, Bahn und Wasserstrasse, PLANCO Consulting GmbH, Essen, November 2007, http://www.planco.de

[10] Wójcicki J.: Studium przystosowania rzeki Odry do europejskiego systemu dróg wodnych, Konferencja naukowo-techniczna: Szanse rozwoju dróg wodnych i żeglugi śródlądowej na tle polityki transportowej, SIiTK, Komitet Transportu PAN, Przełazy, 1995

[11] www.pccintermodal.pl

[12] www.portszczecin.pl

[13] www.pkpcargo.com