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Time and cost competitiveness of inland waterway transport in relation to alternative modes of transport for hinterland of the Szczecin–Świnoujście port complex (case studies)

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Abstract: The article presents the analysis of competitiveness of time and cost of carriage charges by three transport branches: road, rail, and inland navigation. The authors tried to take into consideration all costs involved in transporting a particular type of cargo for different branches of transport. The cost of transportation and cargo handling costs are adopted in force at April 2015. The authors try to prove by what class of waterways, inland navigation would become competitive with other branches of transport.

Introduction

Ports complex of The Lower Oder estuary has a direct connection via the Oder river and the Oder – Havel Canal to the Western Europe waterway network. It is the only shipping way in Poland which hosts a regular shipping freight (after the suspension of coal transport on the route Gliwice–Wroclaw in 2012). The transport of goods from the river basin of the Oder river could be directed to the ports of Szczecin and Świnoujście (Wiśnicki 2013). Many years of neglect resulting from the lack of financial resources necessary to maintain the river have reduced the depth of the transit especially in the middle section of the Oder. The article presents the analysis of competitiveness of time and cost of carriage
charges by three transport branches: road, rail, and inland navigation. The analysis was performed for five transportation options. The analyzed variants of potential cargoes and transport routes consider relations with the sea ports of Szczecin and Świnoujście. Assumptions of the analysis:

1. The proposed variants were adopted on the basis of the existing infrastructure point.
2. The cost of transportation and cargo handling costs are adopted in force at April 2015.
3. Means of transport by road and rail, and their parameters have been selected (depending on the cargo) currently available on the market. Their technical parameters have been characterized in descriptions of various options.
4. For inland navigation it was assumed to use push-convoys consisting of push-ship and push-barges BP-500 or SL (a maximum draft of 216 cm) which are mainly used for transport on the Oder river. Depending on the class of waterway adopted:
   a) current state of the waterway – draft permitted 120 cm – push-ship Bizon + 2x push-barge BP 500 (63% of capacity);
   b) current state of the waterway – the draft permitted 130 cm, push-ship Bizon + 2x push-barge BP 500 (71% of capacity);
   c) III class of waterway – the draft permitted 160 cm, push-ship Bison + 2x push-barge BP 500 (100% of capacity); 
   d) IV class of waterway – the draft permitted 216 cm, push-ship Bison + 3x push-barge SL (Ger. Schubleichter – 100% of capacity). For IV class of waterway (guaranteed transit depth of 280 cm), draft permitted is 260 cm. This option gives the possibility to use other solutions than the commercially available push-barges or motor-barges. Due to the lack of such units on the part of Polish shipowners, they were not included in the study.
5. The costs of inland water transport for variants with a draft of 120 cm and 130 cm (current state) additionally include the costs of reaching by an empty vessel the place of loading or of an empty return (except variant III). In the variants with a draft of 160 cm (III class of waterway) and 260 cm (IV class of waterway), as well as for other modes of transport, such costs were not included because of the high possibility of obtaining return freight.
6. The costs of transport to/from the port of loading or the railway station, and handling costs depend on the distance to which such services must be performed.
7. The costs of rail transport include a discount for large shipments. The discount can be changed each time due to the changes in the transport policy of railway companies.
8. Transportation time is specified in decimal in days with an accuracy of one decimal place.
9. For container transportation, it is assumed to use 20’ container. In road transport,
one should only take into account the reduction of the maximum permissible mass for the transportation of two containers of 20’.

1. Variant I – transport of granulated fertilizers on the route Kędzierzyn-Koźle–Szczecin

The first variant assumed the transports of granulated fertilizers on the route Kędzierzyn-Koźle–Szczecin. In road transport, a standard set trailer of “Benalu” with a capacity of 24 t was adopted. In rail transport, included a set with a capacity of 1400 t with a four-axis self-unloading wagons “Tadds” (430s-Bg, four-chamber) designed for the transport of bulk materials sensitive to weather conditions (24 pieces after 58 t). In inland waterway transport, pushed convoys with closed holds were adopted.

Journey times have been determined by the carriers. In the road transport, average speed of 50 km/h is assumed, whereas in railway transport – 20–30 km/h (Wiśnicki and Dyrda 2016). The inland waterway transport for the current state considered a waste of time to travel empty in one direction. With the increase of the class of waterway to class III and higher, this time was not included due to the profitability of carrying other cargo on the way back.

In the adopted variant, the shipping distance for each mode of transport varies from 485 km by rail to a 650 km by inland shipping. The biggest load capacity is offered by rail transport – 1,400 t, whereas the lowest – 24 t – by road transport. In inland navigation, the load capacity depends on the draft, from 600 t – at the draft up to 120 cm, till 1,250 t after the modernization of waterway to IV or higher class of waterway (Wiśnicki, Jędrzychowski and Jędrzychowski 2015)

Table 1. Variant I – transport of granulated fertilizers on the route Kędzierzyn-Koźle–Szczecin

| Variant I | Road transport | Railway transport | Inland navigation |
|-----------|---------------|------------------|------------------|
|           |               |                  | Current state – draft to 120 cm | Current state – draft to 130 cm | upgrading to III waterway class – draft to 160 cm | upgrading to IV waterway class – draft to 260 cm |
| 1         | 2             | 3                | 4                | 5                | 6                | 7                |
| capacity (metric ton) | 24 t | 1,400 t | 600 t | 670 t | 950 t | 1,250 t |
| cost of transportation to / from the inland port (railway station) | – | – | – | – | – | – |
| 1         | 2             | 3                | 4                | 5                | 6                | 7                |
| cost of handling | — | — | — | — | — | — | — |
| transport distance | 520 km | 485 km | 650 km | 650 km | 650 km | 650 km | — |
| cost of transport | 65 PLN/t | 198.40 PLN/t | 96 PLN/t | 86 PLN/t | 33 PLN/t | 25 PLN/t | — |
| discount | — | 60% | — | — | — | — | — |
| cost after discount | 65 PLN/t | 79 PLN/t | 96 PLN/t | 86 PLN/t | 33 PLN/t | 25 PLN/t | — |
| AMOUNT | 1,560 PLN | 110,600 PLN | 57,600 PLN | 57,600 PLN | 31,600 PLN | 31,600 PLN | — |
| estimated time of transport [day] | 0.4 day | 2 days | 15 days | 15 days | 7 days | 7 days | — |

Source: own elaboration – road transport based on the current market rates based on telephone surveys to trucking carriers; railway transport – based on the tariff of PKP Cargo and catalogue of distances and discounts for regular customers and large batches of goods; inland navigation – based on a telephone survey to shipowners.

The cost of transport per 1 t is diverse – from 25 PLN/t to 96 PLN/t. With the current state of waterways, inland navigation is unprofitable, but after raising the waterway class barge transport, the cost is about 50–60% (depending on the class of the waterway) lower than in the case of the road transport.

Source: own elaboration.
2. **Variant II – coal transportation on the route Gliwice–Szczecin**

In the second variant, we analyzed the costs and time of coal transport from a coal mine in Dabrowa Górska through the port in Gliwice (for waterway variants) to the port of Szczecin. The parameters of vehicles for road and rail transport change depending on the type of the transported goods. In the road transport, semi-trailers “bath” with a capacity of 24 t were assumed to be used. In the railway transport, wagons used a “coal carriage” with the capacity of 60 t. In the composition of heavy transport, consisting of 40 pieces of wagons, 55 t each, the total loading capacity is 2,200 tons. The inland waterway transport parameters remain basically the same as in the first variant. Barges in the case of this type of cargo can remain open – they do not need to be covered with hatch covers.

The shortest transport distance and at the same time the largest capacity occurs in the case of the rail transport through Gliwice to Szczecin. In addition, the price drop is granted more favorable from those used at the present maximum draft of inland vessels. If the modernization of waterways up to class III was made, relatively large load capacity at a much lower cost would make the inland option more favorable. And by far the best option would be to transport cargo by waterways class IV at an estimated cost of individual row twice lower compared to the railways or transport vehicles.

**Table 2. Variant II – coal transportation on the route Gliwice–Szczecin**

| Variant II | Road transport | Railway transport on route Dabrowa Górska–Szczecin | Railway transport on route Dabrowa Górska–Gdańsk | Inland navigation |
|------------|----------------|---------------------------------------------|---------------------------------------------|------------------|
|            |                | Current state – draft to 120 cm | Current state – draft to 130 cm | upgrading to III waterway class – draft to 160 cm | upgrading to IV waterway class – draft to 260 cm |
| capacity (metric ton) | 24 t | 2,200 t | 2,200 t | 600 t | 670 t | 950 t | 1,250 t |
| cost of transportation to / from the inland port (railway station) | – | – | – | 11.0 PLN/t | 11.0 PLN/t | 11.0 PLN/t | 11.0 PLN/t |
| cost of handling | – | – | – | 5.0 PLN/t | 5.0 PLN/t | 5.0 PLN/t | 5.0 PLN/t |
| transport distance | 550 km | 512 km | 590 km | 680 km | 680 km | 680 km | 680 km |
| cost of transport | 68.75 PLN/t | 198.40 PLN/t | 211.88 PLN/t | 111 PLN/t | 98 PLN/t | 42 PLN/t | 33 PLN/t |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| discount | – | 75% | 75% | – | – | – | – |
| cost after discount | 68.75 PLN/t | 50 PLN/t | 53 PLN/t | 111 PLN/t | 98 PLN/t | 42 PLN/t | 33 PLN/t |
| AMOUNT | 1,650 PLN | 110,000 PLN | 116,600 PLN | 76,200 PLN | 76,300 PLN | 55,100 PLN | 61,250 PLN |
| estimated time of transport [day] | 0.3 day | 2 days | 2 days | 17 days | 17 days | 9 days | 9 days |

Source: own elaboration – road transport based on the current market rates based on telephone surveys to trucking carriers; railway transport – based on the tariff of PKP Cargo and a catalog of distances and discounts for regular customers and large batches of goods; inland navigation – based on a telephone survey to shipowners.

This variant includes also the cost of transport on the route Dąbrowa Górnicza–Gdańsk in order to provide an alternative transport corridor. In the present case, the cost of rail transport to the port of Szczecin and Gdańsk is practically the same. The cost of transporting coal by barge afforded to III or IV class of waterway is lower than 20% to nearly 40% from transport by rail. Modernisation of the Odra River, beyond the transfer cargo on river can result in transfer direction of cargo handled so far to ports of Trójmiasto.

![Fig. 2. Variant II – comparison of transport costs per 1 t](source)

Source: own elaboration.
3. Variant III – coal transportation on the route Szczecin–Wrocław

In variant III, the transport of coal from Szczecin to Wroclaw was analysed, where the distance depending on the route varies from 400 km (car/rail) to 490 km by inland navigation. In this variant, unlike in the others, the cost of transport by barge at the current state of infrastructure, do not include the cost of carriage on empty. This assumption stems from the fact that it is not a problem to find return loads transported down the river. As compared to option II, despite a shorter distance, the cost of carriage by rail has not changed by more than 20%. For all other methods of transport, the cost is reduced accordingly. In this, as well as in the previous variant, barge transportation is beneficial only after upgrading waterway to at least class III. However, transport is many times greater than in other sectors.

Table 3. Variant III – transport of coal from Szczecin to Wroclaw

| Variant III | Road transport | Railway transport | Inland navigation |
|-------------|----------------|-------------------|-------------------|
|            |                |                   | Current state – draft to 120 cm | Current state – draft to 130 cm | upgrading to III waterway class – draft to 160 cm | upgrading to IV waterway class – draft to 260 cm |
| capacity (metric ton) | 24 t | 22,000 t | 600 t | 670 t | 950 t | 1,250 t |
| cost of transportation to/from the inland port (railway station) | – | – | – | – | – | – |
| cost of handling | – | – | 7 PLN/t | 7 PLN/t | 7 PLN/t | 7 PLN/t |
| transport distance | 400 km | 512 km | 490 km | 490 km | 490 km | 490 km |
| cost of transport | 48.75 PLN/t | 198.40 PLN/t | 72 PLN/t | 63 PLN/t | 34 PLN/t | 25 PLN/t |
| discount | – | 75% | – | – | – | – |
| cost after discount | 48.75 PLN/t | 50 PLN/t | 72 PLN/t | 63 PLN/t | 34 PLN/t | 25 PLN/t |
| AMOUNT | 1,170 PLN | 110,000 PLN | 47,400 PLN | 46,900 PLN | 38,950 PLN | 40,000 PLN |
| estimated time of transport [day] | 0.3 day | 2 days | 9 days | 9 days | 8 days | 8 days |

Source: own study – road transport based on the current market rates based on telephone surveys to trucking carriers; railway transport – based on the tariff of PKP Cargo and a catalog of distances and discounts for regular customers and large batches of goods; inland navigation – based on a telephone survey to shipowners.
4. Variant IV – transport of cellulose between Szczecin and Kostrzyn nad Odrą

In variant IV, the transport of cellulose between Szczecin and Kostrzyn nad Odrą has been analyzed. Due to the nature of the cargo in road transport, curtain semi-trailer with a load capacity of 24 tonnes is used, however, a real use of this means of transport oscillates around 18 tonnes. On rail transport, 24 wagons of covered type “Hais” were used with a capacity of 50 tonnes, giving a total load capacity of 1,000 tonnes. On the inland waterway transport, due to the fact that Kostrzyn nad Odrą has at the moment III class of waterway, it is possible to use, instead of barges BP-500, a larger type of barges BP-800, with a larger capacity without changing the parameters of draft. For IV class of waterway, two barges BP-800 were used with raised coaming. Hypothetically, one can apply a set of four barges with a capacity of about 2500–3000 tonnes, but it is uncertain whether there would be demand for such large batches of cargo.
Table 4. Variant IV – transport of cellulose between Szczecin and Kostrzyn nad Odrą

| Variant IV | Road transport | Railway transport | Inland navigation |
|------------|----------------|-------------------|-------------------|
|            |                |                   | **Current state – draft to 120 cm** | **Current state – draft to 130 cm** | **upgrading to III waterway class – draft to 160 cm** | **upgrading to IV waterway class – draft to 260 cm** |
| capacity (metric ton) | 24 t | 1,000 t | 680 t | 800 t | 1,100 t | 1,600 t |
| cost of transportation to / from the inland port (railway station) | – | – | – | – | – | – |
| cost of handling | – | – | 7 PLN/t | 7 PLN/t | 7 PLN/t | 7 PLN/t |
| transport distance | 120 km | 100 km | 125 km | 125 km | 125 km | 125 km |
| cost of transport | 27.70 PLN/t | 64.04 PLN/t | 27.5 PLN/t | 23 PLN/t | 10 PLN/t | 6.8 PLN/t |
| discount | – | 45% | – | – | – | – |
| cost after discount | 27.70 PLN/t | 30 PLN/t | 27.5 PLN/t | 23 PLN/t | 10 PLN/t | 6.8 PLN/t |
| AMOUNT | 500 PLN | 35,200 PLN | 23,460 PLN | 24,000 PLN | 18,700 PLN | 22,080 PLN |
| estimated time of transport [day] | 0.3 day | 2 days | 9 days | 9 days | 8 days | 8 days |

Source: own study – road transport based on the current market rates based on telephone surveys to trucking carriers; railway transport – based on the tariff of PKP Cargo and a catalog of distances and discounts for regular customers and large batches of goods; inland navigation – based on a telephone survey to shipowners.

At a comparable distance transport (ranging from 100 to 125 km), the cost transportation per 1 tonne is very diverse. On railway transport, despite the discount (for this distance amounting to 45%), the cost is nearly five times higher than in the case of inland waterway transport with class IV waterway. Also, in terms of the capacity, it remains the most competitive inland waterway. At this distance, the estimated transport time is shorter than the rail waterway.
5. Variant V – transport of containers on the route Świnoujście–Wrocław

Unitary goods in container transport requires the adoption of other criteria. For cost analysis, the transport of one 20’-container was adopted. It should be noted, however, that during the transport of a container by road with a maximum weight of 20’-container 22 tonnes, it is possible to exceed the maximum total weight of the car kit. The load capacity of rail transport is set at 60 20’-containers (30 wagons with two containers on each).

The estimation of the cost includes transportation to the place of loading, transport, and handling costs. On inland waterway, the transport of containers is provided by means of a set of pushed/pusher type Bison + 2 x SL (Ger. Schubleichter) (one large barge SL with a length of 67 m and one small SL with a length of 33.5 m increased width allowing the user to 3 containers width of 7.5–8 m. In one layer 12 + 24 = 36 TEU, two 36 x 2 = 72 TEU). This kind of container transport by barge is implemented, for example, at Elbe river.
Table 5. Variant V – transport of containers on the route Świnoujście–Wrocław

| Variant V | Road transport | Railway transport | Inland navigation |
|-----------|----------------|-------------------|-------------------|
|           | Current state – draft to 120 cm | Current state – draft to 130 cm | upgrading to III waterway class – draft to 160 cm | upgrading to IV waterway class – draft to 260 cm |
| capacity (metric ton) | 2 x 20’ | 60 x 20’ | 26 x 20’ | 26 x 20’ | 38 x 20’ | 72 x 20’ |
| cost of transportation to / from the inland port (railway station) | – | 400 PLN per unit | 400 PLN per unit | 400 PLN per unit | 400 PLN per unit | 400 PLN per unit |
| cost of handling | 290 PLN | 290 PLN per unit | 290 PLN per unit | 290 PLN per unit | 290 PLN per unit | 290 PLN per unit |
| transport distance | 500 km | 455 km | 555 km | 555 km | 555 km | 555 km |
| cost of transport | 750 PLN/20’ | 3,040 PLN/20’ | 2,080 PLN/20’ | 2,080 PLN/20’ | 900 PLN/20’ | 470 PLN/20’ |
| discount | – | 75% | – | – | – | – |
| cost after discount | 750 PLN/20’ | 760 PLN/20’ | 2,080 PLN/20’ | 2,080 PLN/20’ | 900 PLN/20’ | 470 PLN/20’ |
| AMOUNT | 2,080 PLN | 87,000 PLN | 72,020 PLN | 72,020 PLN | 60,420 PLN | 83,520 PLN |
| estimated time of transport [day] | 0.4 day | 2 days | 12 days | 12 days | 7.5 days | 7.5 days |

Source: own study – road transport based on the current market rates based on telephone surveys to trucking carriers; railway transport – based on the tariff of PKP Cargo and a catalog of distances and discounts for regular customers and large batches of goods; inland navigation – based on a telephone survey to shipowners

The number of containers transported depends on the maximum draft, which determines the parameters of waterway. At its present state, it is possible to transport 26 containers and not to exceed the weight of 300 tonnes per one barge. With greater immersion load capacity increased up to 72 containers per transport, waterways were upgraded to IV class of waterway.

Extra costs should include the cost of handling and the cost of transportation to or from the inland waterway port or the train station where loading is carried out. On inland waterway, in the first two options, the cost is high because it includes additional fees for returning the ship with empty cargo holds or with empty containers. These costs are not included in III and IV class of waterway, where another return transportation would be carried out.
At the present moment, the transport of containers by inland navigation is unprofitable. Only raising the class of waterway to at least IV and the realization of return transport gives a competitive edge to inland waterway transport.

Summary

Based on this analysis, we can draw the following conclusions:

1. In each of the inland waterway transport competitiveness variants, it is possible to be profitable only after the modernization of the Oder River to the third and upper-class of waterway.

2. Currently, due to the low demand for transport by inland waterway, while planning the transport, the cost of returning vessel on empty should be taken into consideration. Most often, in such a case, services are not profitable and therefore uncompetitive.

3. In the perspective of raising the quality of waterways, it should be considered to bring or build new ships with higher capacity and draft. At class IV of waterway, the transit depth is 280 cm (safe operating depth would be maximum 260 cm). In Poland, the most frequently used for inland ships is a pushed system. In Germany, ships are self-propelled and pushed convoys occur mainly on the Rhine. Standard barge “Reńska” is “Europe Class-2” with a capacity of 2500–3000 tons. Currently,
on Polish market, there are several units of barge type BP-800 (with a capacity of about 850, and draft 219 cm), and several units of type SL-42xx (with a capacity of 950 tonnes and draft 216 cm). At the moment, pushed barge designed to be used on IV class of waterway are not available on the Polish market.

4. In the perspective of the next few years, it is expected to improve the conditions of transport by rail (currently the average speed is 26 km/h and is planned to be 60 km/h) and the increase in the prices of transport vehicles (increase in fees for the use of roads, fuel prices).

5. The competitiveness of rail is conditioned by the increase of flexibility in shaping the train schedules of PKP Cargo. Currently, the relatively rigid policy in this area allows changes with 3 months in advance. On the other hand, new transport companies appear on the Polish market, which are more flexible in this area.

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