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Transport and economic effects related to navigational restoration of the Lake Dąbie fairway

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Abstract

The aim of this paper is to identify and quantify the direct economic effects resulting from navigational restoration of the Dąbie Lake inland fairway, a part of the West Pomeranian region (PL) transport system that runs across the Dąbie Lake. This narrow and shallow inland fairway constitutes the bottleneck for inland waterway freight transport, which must therefore use the sea fairway and thereby incur extended time, increased cost, and reduced efficiency of inland waterway transport. The paper's second section presents the transport and microeconomic effects that restoring the fairway's navigability across Lake Dąbie would have on the inland navigation system, thereby increasing the capacity, effectiveness, and safety of inland waterways freight traffic. Restoration of the inland fairway would significantly reduce generalized and external costs of inland waterways transport.

Introduction

The investment being considered is located in north-western Poland, in the West Pomeranian Voivodship, on Lake Dąbie. Specifically, the subject of this analysis is the inland waterway connecting the final section of the Regalica River with the sea fairway (connection with the sea fairway through the currents of Czapin and Babina). This inland fairway runs across Lake Dąbie, connecting from the south with the region's main waterway (the Regalica River) and from the north with the sea fairway, which, in turn, via the Szczecin Lagoon provides access to the sea ports, terminals, and wharfs of the lower Odra River and with the Baltic Sea (see Figure 1).

Currently, the depth of the inland fairway ranges from 1.8 m to 2.3 m, and locally the fairway's bed is not properly shaped or is too narrow in places, with a width of only 30 m to 40 m, to accommodate barge navigation and, hence, inland waterways freight traffic. Consequently, at present, no barge navigation whatsoever can take place on the fairway, which is not navigable in its present state.

Freight transport by inland navigation in the West Pomeranian region is entirely directed towards Germany, and two waterways are used for inland cross-border transport:

1. the Hohensaaten-Friedrichsthal channel (HFW, Hohensaaten-Friedrichsthaler-Wasserstrasse) – West Odra – Ustowo-Klucz Ditch – Regalica with the use of the Szczecin-Świnoujście sea fairway; and
2. the Odra-Havela channel (OHW, Oder-Havel-Wasserstrasse) – West Odra – Regalica, with the use of the Szczecin-Świnoujście sea fairway.

Figure 2 below depicts the waterways of the region on which inland waterway transport is carried out near Lake Dąbie.

In both the routes listed above, due to the current depth limitations of the Lake Dąbie inland fairway,

Figure 1. Inland waterway fairway on Lake Dąbie (UZS, 2019)

Figure 2. Forced by the lack of navigability on the inland fairway across Lake Dąbie, the movement of barges on the Regalica River–sea fairway connection (UZS, 2019)

barge transports travel via the Świnoujście-Szczecin sea fairway after leaving the Regalica River, navigating on the sections of waterways, i.e., the Parnica River and Mielenski Ditch alongside the cargo transhipment areas of the Szczecin port. From there, these barges' navigation on the sea fairway is affected by the intense movement there of sea-going vessels to which these barges are required to yield and so must move at a slower speed and with a relatively large number of manoeuvres, thereby increasing their risk of collisions and accidents.

In addition to transport functions related to inland navigation, Lake Dąbie also plays an important role in preventing floods if ice ramparts are allowed to form on the Odra River. To prevent their formation, and the floods they could cause, the ice that forms on the lower section of the Odra River must be broken up over an area covering several kilometres to enable the resulting ice fragments to float out to sea. Lake Dąbie serves as a receiving area for this river ice, but the current hydrographic conditions on the fairway running across the Lake prevent ice breakup operations from being conducted there. Specifically, the current width and depth of the inland fairway are insufficient for the safe and effective operation of icebreakers, thus exacerbating threats of flooding. Efficient and effective ice-breaking action, on the other hand, would guarantee the maintenance of a navigational period for inland navigation in the region.

In summary, there is a bottleneck in the inland waterway system of the Odra River estuary. The narrow and shallow inland fairway running across the Dąbie Lake constitutes a bottleneck for inland waterways freight transport, which must therefore use the Świnoujście-Szczecin sea fairway, extending the time and increasing the costs of inland waterway transport and reducing the efficiency of inland waterway transport, as well as increasing the danger of collision with seagoing vessels.

The restoration of freight traffic navigability would require the following:

- deepening of the fairway down to 3.4 m on its 8144 m length, together with widening the channel at its bottom up to 150 m; the volume of resulting dredged spoil has been estimated at 1,052,700 m^3;
- construction of a spoil-dumping area, adapted for storage of spoil, with a surface of 440,000 m^2.

The end product of the proposed investment would be an inland fairway having the following technical parameters: a length 8144 m, a transit depth at average water level of 3.4 m, and an 800 m turning radius on the fairway's bends. Moreover, the proposed investment would not be an income project. Rather, the fairway would be used by all users free of charge and on an equal, non-discriminatory basis.

Methodology

The aim of this paper is to identify and quantify the direct economic effects resulting from the restoration of inland fairway's navigability. In the research, a microeconomic approach was applied, meaning that the economic effects were measured directly on the transport system and so were classified as internal or direct impacts of infrastructural improvements (Mackie, Graham & Laird, 2013; Pawłowska et al., 2015). Thus, no wider impacts of this transport project were elaborated upon. Moreover, it is assumed that restoration of the inland fairway's navigability would either reduce the distance between the origins and destinations and/or reduce the time required for freight transportation, in the latter case as a result of shortening transport distances and enhancing velocity of inland ships. Transport users, shippers of goods, and inland shipping operators would thereby benefit from reduced, generalized transport costs. The notion of generalized transport cost is widely recognized in transport economics (Button, 2010) and often has different meanings within the literature according to the context of the research being conducted. Limited to main components and adopted to freight transport, generalized transport costs are the sum of the transport price/cost and the value of the time needed to complete the trip. In the cost function, the transport cost and the monetary value of time are assumed to be homogeneous and addable elements. The generalized freight transport costs GC may be defined as below (Sandberg Hansen, Mathisen, & Jørgensen, 2012):

$$GC(D) = P(D) + H \cdot T(D) \tag{1}$$

where $\partial P/\partial D, \partial T/\partial D > 0 \Rightarrow \partial GC/\partial D > 0$.

As shown above, the generalized transport cost GC in (1) is the sum of two elements: pecuniary costs P, which are related to vehicle operating costs or price for the transport service and are a function of distance travelled D (measured in kilometres), and the total time cost, which is the product of the hourly time cost H and the transport time T measured in hours. P and T, and therefore also GC, are assumed to be positively related to transport distance D, whereas H is independent of the transport distance. Transport users (shippers of goods, transport operators) seek to minimize total transport costs and therefore choose the transport solution that gives the lowest generalized costs.

The pecuniary component of the cost function can be represented by the operating costs of the transport service providers, i.e., all monetary costs paid by the operator for the provision of a transport service (Bąk et al., 2010). The non-monetary part can be the value of time in relation to the urgency of the delivery and the reliability of a safe and on-time journey.

The economic analysis was carried out using the quantification method of direct effects in the inland waterways freight transport. The analysis was carried out using the differential method, i.e., by calculating the net difference in effects across the proposed variants: deepening the fairway for inland navigation (below, this is designated as the WI investment variant) and without deepening the fairway (below, this is designated as the non-investment variant W0), and so the differential formula is WI – W0. The conditions for satisfying the demand for inland waterway transport were compared in the variant without deepening the fairway and in the variant with deepening of the fairway, and then the resulting differences in transport time, transport performance, and operation of means of transport were also quantified.

In the next stage, the economic valuation of transport effects was made using GCI and GC0, the generalized costs of using inland waterways transport after and before the investment, respectively. A negative difference in the economic account, i.e., GCI – GC0 < 0, is interpreted as an advantage related to the reduced (savings) transport costs resulting from the implementation of the proposed investment project. A daily operating cost function was used to estimate unit operating costs of barges, and the cost of barge transport per ton-kilometre was then calculated. To calculate the cash values related to time costs, we used the calculated values of time and reliability of freight inland waterways transport estimated in the Netherlands with the application of stated preferences and willingness to pay (de Jong et al., 2014). For external costs of inland waterways transport, the unit cost indicators were adopted from the updated study of external transport costs in Europe (van Essen et al., 2011). The above-mentioned unit cost indicators were converted for Poland, updated for 2017, and indexed for the period of conducting the calculation (Archutowska et al., 2016).

The time horizon for which the analysis was carried out includes the fairway operation phase, which is 27 years (2023–2049), with the average economic lifetime of the fairway estimated at 40 years. The real social discount rate used in the analysis was 5.0%, with fixed prices from the account year and without taking into account inflation throughout the analysis period. In the calculation, unit values of economic benefits are presented in net terms (excluding VAT). The first year of exploitation of the deepened fairway was projected to be 2023 and, from that year forward, economic benefits were calculated. For calculations of economic benefits, EUR 1 = PLN 4.2950 was adopted.

Forecast of demand for the capacity of the fairway on Lake Dąbie

The forecast of demand for the results of the investment project, i.e., on the inland waterway capacity on Lake Dąbie, was prepared using the forecast of demand for inland waterway transport services developed for seaports and for selected sea terminals located in the region.

Forecast of demand for inland waterway transport with respect to the seaport in Świnoujście

The forecast of demand for inland waterway transport with respect to the seaport in Świnoujście was made using the following assumptions:

- real transport volumes of dry bulk cargoes (coal, ore, other bulk, grain) were determined by individual types of hinterland transport (barges, railways, lorries) in seaports Szczecin and Świnoujście, and then the average share of inland waterway transport in these groups of cargoes was calculated; for the years 2009–2014, this share was assumed to be 15%;
- the forecast of the volume of dry bulk cargo handling for quays in the port of Świnoujście was determined based on the extrapolation of current trends for basic cargo groups;
- the forecast of the volume of dry bulk cargo handling in the port of Świnoujście was obtained as a result of the conversion of chain indexes of GDP by the handling volumes in particular years of the forecast;
- the forecasted volumes of dry bulk cargo handling were multiplied by the pre-determined (15%) average rate of the share of barges in dry bulk transport and thus a forecast of demand for inland waterway transport in relation to the port in Świnoujście was obtained.

The forecast of transhipment of dry bulk cargoes in the port of Świnoujście and the forecasted volume of inland navigation are presented in Table 1.

Table 1. Forecast of the transhipment volume of dry bulk cargo in the port of Świnoujście and of the inland waterway transport with respect to the port (Bernacki & Lis, 2019)

Year	Forecasted volume of transhipments in the port of Świnoujście (tons)					Forecast volume of inland navigation (tons)
	Coal	Ores	Other bulk	Grains	Total	
2023	1 807 317	1 660 137	130 403	788 046	4 385 903	658 872
2025	1 836 350	1 686 805	121 568	830 204	4 474 927	672 245
2030	1 910 989	1 755 365	101 464	898 135	4 665 953	700 942
2035	1 988 661	1 826 713	83 676	925 707	4 824 757	724 799
2040	2 069 491	1 900 960	67 726	957 115	4 995 292	750 417
2045	2 143 554	1 968 991	47 191	985 172	5 144 908	772 893
2049	2 204 992	2 025 426	32 281	1 008 469	5 271 169	791 861

Forecast of demand for inland waterway transport with respect to the seaport in Police and with selected sea transhipment terminals

At Zakłady Chemiczne Police (ZCH Police), a large investment aimed at the production of polypropylene as from 2023 has begun. Butane and propane for the production of propylene will be delivered by seagoing vessels to the LPG gas transhipment terminal being constructed at the port of Police. In the production program of ZCH Police, the volume of production of propylene has been established and from 2023 is forecasted to be 400,000 tons per year, with half of the production to be exported. It was assumed that 75% of polypropylene (150,000 tons per year) will be exported to Germany with tanker barges. In addition, ZCH Police has long been exporting fertilizers, including fertilizer in export by inland transport estimated at 150,000 tons per year. The forecast of the volume of inland transport of polypropylene and fertilizers has been made conditional on the GDP per capita, with an elasticity ratio of 0.8. For the sea terminal Alpha, the forecast of freight transport by inland waterway was prepared using the same procedure, but with the initial assumption that the share of inland waterway transport in exports is 30% for dry bulk transport from that terminal. For many years, diesel fuel has been transported by barges from the terminal in the port of Świnoujście to the port of Szczecin, from which it has further been distributed by tank trucks to domestic and foreign customers. The forecast for inland waterway transport for all port centres presented above is shown in the Table 2.

Complete forecast of inland waterway transport on the fairway on Lake Dąbie

The total forecasted demand for freight transport by the Lake Dąbie inland fairway will consist of transports related to the Świnoujście and Police seaports as well as selected transhipment sea terminals on the lower Odra River. Intensity of traffic of inland waterway vessels on the inland waterway on Lake Dąbie was determined with the following assumptions:

- Dead-weight of a pushed train of barges (push-boat + 2 × pushed barge of 500 tons each) 1000 ton, dead-weight of a motor barge 650 ton;
- Share of motor barges and pushed trains of barges (push-boat + 2 × pushed barge) in the total movement of barges amounts to 30% and 70%, respectively.

Table 2. Forecast of the volume of inland waterway transport with respect to the Police seaport and selected sea terminals (tons) (Bernacki & Lis, 2019)

Year	Police Port (fertilizers)	Police Port (polypropylene)	Alfa-Terminal (dry bulk)	Diesel from the port of Świnoujście	Total
2023	174 587	150 000	380 604	580 717	1 285 909
2025	183 851	157 959	400 798	611 529	1 354 136
2030	208 030	178 733	453 510	691 956	1 532 230
2035	233 107	200 278	508 177	775 366	1 716 927
2040	257 652	221 367	561 687	857 011	1 897 717
2045	283 442	243 525	617 909	942 793	2 087 669
2049	304 494	261 612	663 804	1 012 818	2 242 728

The total forecasted demand for freight transport by inland waterway on the inland fairway on Lake Dąbie is presented in the Table 3.

Table 3. Total forecasted demand for freight transport by inland waterway on the inland fairway on Lake Dąbie (Bernacki & Lis, 2019)

Year	Volume of inland waterway transport (tones)	Number of inland waterway vessels
2023	1 970 746	2 289
2025	2 062 129	2 395
2030	2 294 455	2 665
2035	2 529 491	2 938
2040	2 761 821	3 208
2045	3 001 485	3 486
2049	3 197 744	3 714

Analysis of socio-economic benefits of the project

The analysis of the distance and time of navigation by barges in the variant without the use of the Lake Dąbie inland fairway (W0) and in the variant with barges using the Lake Dąbie fairway (WI) was made. The following reference points were adopted for measuring the distance and time of cargo transport by inland navigation:

- Reference point A – the intersection of the Odra River axis with the Ina River axis at the height of Inoujście;
- Reference point B – intersection of the Parnica axis with the axis of the Regalica River.

For the WI variant, i.e., the route using the fairway on Lake Dąbie:

- the transport distance is 13.15 km,
- the time of transportation by barges is 1.096 h.

For the W0 variant, i.e., the route using the Parnica River, Mieleński Ditch, and sea fairway:

- the transport distance is 14.74 km,
- the time of transportation by barges is 1.843 h + 1.5 h (additional time spent on manoeuvres, including turning on the route, speed limits associated with passing ships and barges, stops at pass-by places), totalling 3.343 h.

The inability of inland waterways barges to use the Lake Dąbie inland fairway will result in an increase in transport time from 1.096 h in variant WI up to 3.343 h in variant W0 (namely, the transportation time will increase by 2.247 h for WI – W0) and will increase the transportation distance from 13.15 km in WI up to 14.74 km in W0 (namely, the transportation distance will increase by 2.247 km for WI – W0).

The economic benefits identified in direct connection with the implementation of the proposed investment project are as follows:

- savings in the time needed to transport goods by inland waterways transport,
- savings in the operating cost of transporting goods by inland transport, and
- savings in external costs related to shortening the distance of transport in inland navigation.

The equation of the total socio-economic benefits related to the deepening of the inland fairway may be presented as the sum of individual savings obtained jointly over the lifetime of the investment project given in equation (2) below:

$$TB = \sum_{i=1}^{k}\sum_{t=1}^{n} TB_{it} = \sum_{t=1}^{n} CT_t + \sum_{t=1}^{n} C_t + \sum_{t=1}^{n} Ext_t \quad (2)$$

where:

$$\sum_{t=1}^{n} CT_t = \sum_{t=1}^{n} L_t \cdot T_t \cdot c_t(T) \quad (3)$$

$$\sum_{t=1}^{n} C_t = \sum_{i=1}^{k}\sum_{t=1}^{n} L_t \cdot \Delta D \cdot u_i \cdot c_i \quad (4)$$

$$\sum_{t=1}^{n} Ext_t = \sum_{t=1}^{n} L_t \cdot \Delta D \cdot c_t(AP) + \sum_{t=1}^{n} L_t \cdot \Delta D \cdot c_t(CC) = \\ = \sum_{t=1}^{n} L_t \cdot \Delta D \cdot \left[c_t(AP) + c_t(CC)_t\right] \quad (5)$$

The symbols used in formulas (2)–(5) are defined as follows:

TB – total socio-economic benefits of the project;
TB_{it} – i-th socio-economic benefit received in the t year of project exploitation;
CT_t – savings in the costs of time of cargo transport by inland waterway in t-th year;
C_t – savings in operating costs of inland waterway transport in t-th year;
Ext_t – savings in external costs caused by shortening the distance of inland waterway transport in t-th year;
L_t – forecasted volume of cargo transport in inland waterway transport on the Lake Dąbie in t-year in tons;
ΔT – shortening the time of transporting cargo in inland navigation on the Lake Dąbie fairway in relation to transport on the sea fairway, in hours;
$c_t(D)$ – the cost of a ton-hour for carriage of cargo in inland navigation in t-th year;

ΔD – the difference in the distance of cargo transportation on the Lake Dąbie fairway and the sea fairway, in km;

u_i – share of i-th type of barge (according to barge size) in cargo transportation on inland waterways;

c_i – unit cost of transport with i-th type of barge (according to barge size) in the carriage of cargo in inland navigation per 1 tkm;

$c_t(AP)$ – unit cost of pollution of lower atmosphere layers in inland navigation calculated per 1 tkm;

$c_t(CC)$ – unit cost of climate change in inland navigation calculated per 1 tkm.

Savings in the cost of transporting cargo by inland waterways caused by shortened transport distances

By multiplying the forecasted volume of inland waterways transport expressed in tons by the average time of cargo transport by inland navigation established for the W0 and WI variants, in the WI – W0 differential variant, the total volume of transport performance of barges expressed in ton-hours was obtained.

By multiplying the total number of operating hours of barges assumed for the WI – W0 differential variant by the unit cost of cargo transport time in inland transport, the total savings in the costs of inland waterway transport time were calculated. In order to determine the economic benefits resulting from shortening the time needed for cargo transport by inland navigation, unit time values in inland freight transport were used, to estimate average values for lock-in time and thereafter indexed for the period over which the analysis was conducted (Archutowska et al., 2016). In 2017, the value of time in freight inland navigation in Poland was PLN 0.45 / ton-hour.

Reducing the operating cost of inland waterways freight transport

By multiplying the forecasted volume of inland waterways freight transport expressed in tons by the distance of cargo transport determined for the W0 and WI variants, the total working volume of barges expressed in ton-kilometres was obtained.

By multiplying the total number of ton-kilometres of barge transport performance for W0 and WI variants by the unit operating cost determined for individual barge sizes, the total savings in the costs of waterways freight transport were obtained for the WI – W0 differential variant.

The function of the daily cost of operating a sea-going vessel was used to determine the cost of unitary freight transport by pushed barges of 1000 tons and motor barges of 650 tons. The relation of the daily operating cost of the bulk carrier with its load capacity (DWT) can be described by means of the following power model (Bernacki & Lis, 2016):

$$\mathrm{Cost}_i = 1336.6 \cdot \mathrm{DWT}_i^{0.2909} \tag{6}$$

where 1336.6 is the parameter of the cost model relative to DWT and 0.2909 is the parameter b (cost point elasticity) of the cost function model on the DWT background.

Based on the established functional dependence, a daily operating cost was calculated for barges with a capacity of 1000 tons and barges with a capacity of 650 tons. The net daily operating cost of a barge with a capacity of 650 tons is assumed to be 8 796 EUR/day, and for a barge with a load capacity of 1000 tons 9970 EUR/day. The unit cost of barge transport per ton-kilometre was calculated as follows:

- using the voyage speed of barges, then recalculated from sea knots to the speed expressed in km/h, the maximum possible distance of inland waterway travel performed by a barge within 24 hours was determined (×24 hours); dividing the daily operating cost of barges by the maximum distance of the voyage within 24 hours, the barge's cost per one kilometre was obtained;
- dividing the cost of one kilometre of the barge's voyage by the mass of the barge's full load, the cost of one ton-kilometre of the barge's carriage/operation was calculated;
- the unit cost obtained in EUR (for 2010) was indexed with the 19.71% nominal GDP growth rate for the EU 28 calculated for the period 2010–2017, and then converted into PLN at the exchange rate used in this analysis.

The calculation of the cost of one ton-kilometre for particular barge sizes is presented in Table 4.

The deadweight of barges in the investment variants is unchanged; however the speed of the barges differs. Voyage speeds of barges under the W0 variant correspond to the determined speeds of barges moving on the sea fairway, while the voyage speeds of barges for the WI variant correspond to the determined speeds of barges moving on the inland fairway on Lake Dąbie. Lower speeds in the W0 variant result from navigational restrictions for barges navigating on the sea fairway (barges must give way to sea-going ships navigating on a sea fairway), from

Table 4. Unit net cost of freight transport in inland waterway in 2017 (Bernacki & Lis, 2019)

Specification	Barge size W0	Barge size W0	Barge size WI	Barge size WI
DWT	650	1000	650	1000
Barge operating cost EUR/day	8796	9970	8796	9970
Degree of capacity utilization	1	1	1	1
Load weight at full load in tons	650	1000	650	1000
Voyage speed of barges in knots (NM / h)	4.32	4.32	6.5	6.5
Conversion knot/km/h	1.85	1.85	1.85	1.85
Voyage speed of barges in knots (NM / h)	8.00	8.00	12.04	12.04
Maximum travel distance of a barge km/day	192.02	192.02	288.91	288.91
Barge operating cost EUR/km	45.81	51.92	30.44	34.51
Net cost of transport by barge in EUR/tkm	0.0705	0.0519	0.0468	0.0345
Net cost of transport by barge in EUR/tkm 2017	0.0844	0.0622	0.0561	0.0413
Net cost of transport by barge in PLN/tkm 2017	0.3623	0.2670	0.2408	0.1774

the greater number of manoeuvres carried out by barges navigating on the Parnica River and Mielenski Ditch along transhipment areas of the Szczecin port, and from the need to limit speed and stop at pass-by places on the sea fairway. In the W0 variant, the voyage speed of a barge is 8.00 km/h, whereas in the variant WI the voyage speed of a barge is 12.04 km/h.

Reduction of external costs caused by shortening the distance of barge transport

By multiplying the total number of ton-kilometres of barge transport performance for the W0 and WI variants by the unit cost of pollution of the lower atmosphere layers and the unitary cost of climate change determined for inland waterway transport, total savings in external costs of inland waterways navigation were obtained for the WI – W0 variant. The calculations used the values of the appropriate external cost categories for inland waterway transport in Poland per 1000 tkm (Archutowska et al., 2016) and indexed for the period of the analysis. In 2017, the value of external costs in inland freight transport per 1000 tkm amounted, respectively, to the following: the cost of pollution of the lower atmosphere layers 15.41 PLN, the cost related to climate change (greenhouse effect related to CO_2 emissions) 4.31 PLN.

Results of the analysis

The total and discounted (at a discount rate of 5.0%) benefits of the proposed investment project are presented in the Table 5.

The implementation of the investment project will contribute socio-economic benefits totalling PLN 115,586,139.90, including savings in the transportation time by inland navigation amounting to 42,857,280.59 (37.1% of the total economic benefits of the investment project) and savings in the inland waterway transport operating cost amounting to PLN 57,540,810.52 (49.8% of the total economic benefits of the investment project). Total savings in external transport costs amounted to PLN 1,545,320.29 (1.3% of the total socio-economic benefits of the project).

Conclusions

The end beneficiaries of the proposed project will be the following:
- inland waterways operators who will benefit from reduced transport operating costs;

Table 5. Total discounted economic benefits of the investment project (Bernacki & Lis, 2019)

Benefits	Discounted total value	% of total benefits
Savings in the operating cost of inland navigation	57,540,810.52	49.8%
Savings in the time of inland freight transportation	42,857,280.59	37.1%
Savings in external transport costs	1,540,335.29	1.3%
Residual value	13,647,713.50	11.8%
Total	115,586,139.90	100.0%

- exporters and importers in result of the reduction of time-related costs in inland waterways freight transportation, which will increase the effectiveness of the international trade exchange conducted with the use of inland waterways transport;
- the society as a whole due to the decrease in external transportation costs, including air pollution and limitation of CO_2 emissions.

In connection with the deepening of the inland fairway, certain socio-economic benefits could not be determined and quantified in an unambiguous manner, namely:

- resulting from the improved navigational safety of inland waterway vessels dedicated to transport on the Lake Dąbie inland fairway;
- resulting from improvements in the efficiency and effectiveness of ice-breaking actions carried out to ensure flood protection, as well as related to the reduced risk of flooding and ensuring the guaranteed length of the barge navigation season;
- indirect and induced effects appearing in the surroundings, resulting from increased efficiency of trade exchange using inland waterway transport and development of the inland waterway sector.

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