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Hydrotechnical Conditions and Inland Transportation's Costs

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Abstract

The article contains a description of the method supporting the organization of broken cargo transportation. The program, which uses the presented method allows the planning of transport including rail and inland waterways.

Description of the computer program shows how to calculate the direct costs for transport modes and external costs of inland transport and probability to achieve throughput of individual sections of the waterway.

An essential part of the description is providing a method for calculating the probability of the desired depth of the waterway, the continuous number of days needed to complete the task. The reported results were referred to data from the past.

The program is intended for use by shipowners and shippers operating the inland waterways.

1. Introduction

Division of Hydraulic Machines and Systems and Inland Vessels Modeling for several years deals with problems of inland waterways in Poland. Recently, they developed a computer program to assist estimating the cost of inland transport, taking into account the hydrotechnical conditions of the waterway.

The program allows to calculate the total cost of broken transportation of bulk commodities, transported using rail and inland waterways.

Due to the fact that PKP Cargo does not provide detailed data on the cost of their transport service, rail transport calculations are based on published freight rates.

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Calculation of direct costs generated by inland vessels is made primarily on the basis of data obtained from the biggest Polish shipowner ODRATRANS and for the fleet used on Odra River. External costs are estimated based on the results of tests conducted at the Department of Mechanical Engineering Wroclaw University of Technology.

2. Hydrotechnical Conditions

The depth of the waterway, a basic hydrotechnical parameter of waterways, for the channeled sections is constant. Hydrotechnical buildings regulate the maintained water levels. Exceptions are the only periods of drought or floods.

One of the major problems of Polish inland waterways during the navigation season are transit depth fluctuations in the unchanneled section of the river. For this reason, when taking into account transportation on unchanneled part of the Odra River (below the Brzeg Dolny), transport costs becomes not the most important problem for ship owners. Sometimes transportation is not feasible.

Presented program helps to indicate the costs of transport and the capacity for selected sections. It also gives the probability of suitable hydrotechnical conditions for the realization of specified transport.

Suitable hydrotechnical conditions are understood as the depth of a safe transit (draught of the fleet plus a safety stock imposed by the manager of the waterway, RZGW). Pushed barges operates on the depth of Oder River ranges from 0.7 m to 2.2 m, depending on load. Shipping at the lowest levels of load is not a viable for economic reasons. At a depth less than 1.5 m transit pushed sets do not operate.

The value of immersion of the vessel has an impact on the ship resistance, and consequently: fuel consumption. However, the increase of immersion shoulders also means increase in the amount of carried goods. For this reason it is best to load as much as possible on the inland vessels.

For the calculation of probability of occurrence of the transit depth, the program takes into account only periods of uninterrupted presence of the required depth of the transit. Cruise roundabout (with a starting point to destination and back) should be made within consecutive days without interruption.

After a specifying the routing of transportation and the cruise speed, the program calculates the length of the voyage. And for the resulting number of days, the probability of a transit depth required for a set number of days is calculated.

3. The Program

The program is written in Java. Most of the data needed for calculations are introduced by the author on the basis of suggestions, which means that one can change it – if it deems inappropriate for reviewed case.

However, one must specify the routing of cargo, and also for inland transportation select a ships, average speed and validation of the suggested unit costs of individual components of the cost of carriage.

Main window of the program is 'Inland Navigation' ("Transport wodny"), shown in Figure 1. It is divided into four main parts:

- Parameters of the push train,
- Statistics,
- The parameters of the voyage,
- Cost of a round voyage.

Fig. 1. The 'Inland navigation'

Parameters of the push train allows to select a type of a push tugs and barges. These data are needed to determine the capacity and length of the push train – required to meet the program calculations.

The statistics part is to provide the probability of occurrence, selected depth of the waterway on the free-flowing Odra, plus safety stock.

The program performs calculations based on data collected from the years 1981-2007 [4]. The data come from the manager of the waterway, the Regional Board for Water Management in Wroclaw (Regionalny Zarząd Gospodarki Wodnej we Wrocławiu). It refers to the section from Brzeg Dolny to Nysa Łużycka estuary. This section was chosen because it is limiting for the entire free-flowing Odra. This means that in this section are the lowest values of the transit depth.

Based on these data the probability of the desired depth (increased by 0.1 m -accepted tolerance) of the waterway is calculated, for the duration of a trip up and down the river. This time is calculated based on the length of individual section, ship's speed relative to the shore and daily working time of locks (the crew).

It is important that the calculation only takes into account the desired depth for a set number of days in a row. So that trip could take place without stopping.

The last part of the 'Inland Navigation' window are transport costs assuming a round voyage. All costs are expressed in Euro.

The program includes:

- The external costs [EUR/tkm],
- The crew salary costs [EUR/h],
- The running costs [EUR/h],
- The depreciation costs [EUR/h],
- The costs of reloading and port costs [EUR/t],
- The lock fee [EUR/śluza],
- The channel fee [EUR/km kanału],
- The fuel costs [EUR/l],
- Other costs if any.

Under the 'Edit unit costs' button, there are given the transport costs and unit labor costs of carriage. They are calculated as the sum of all costs included in the calculations.

4. Method for Calculating the Capacity of River Sections

Capacity calculated by the program for canalized sections assume full utilization of locks in their work time. The calculations in the model uses equation (1) [5]:

$$P = \frac{60 \cdot B \cdot b \cdot W \cdot a}{t \cdot 1000} \left[\text{thousand} \quad \text{ton/year} \right] \tag{1}$$

where:

- P capacity,
- B the number of days of navigation in the year [-],
- b locks daily working time [h],
- W the payload of the push train [ton],
- a factor of the average vessel utilization and irregular motion (a=0,85) [-],
- t the longest duration t (in the section) of going through the lock [min].

For free-flowing river sections it was calculated according to (2) [5]:

$$P = \frac{W \cdot V \cdot B \cdot t_d \cdot K_1 \cdot K_2 \cdot K_3}{l_b + l_s} \left[\text{thousand} \quad \text{ton/year} \right] \tag{2}$$

where:

- P capacity,
- W the payload of the push train [ton],
- V the average speed of the vessel relative to the shore [km/h],
- B the number of days of navigation in the year [-],
- t_d crew daily working time (here adopted the daily working time of locks) [h],
- K1 coefficient of ship traffic uniformity (K1=0,7) [-],
- K2 coefficient of the working ports irregularity (K2=0,8) [-],

- K3 coefficient of intensive two-way traffic (K3=0,9) [-],
- lb safe distance between vessels in kilometers (lb=1 km) [km],
- ls the length of the push train [km].

Note that the free-flowing Odra capacity was calculated for illustration only, since similar to the total use of locks for canalized sections, formula (2) assumes full use of the section, which in practice means sailing one push train after another.

5. Method for Calculating the Probability of Occurrence of the Water by Designated Number of Days

To calculate the probability of sufficient depth of the transit by the desired number of days, the depth of the waterway and its persistence length have been taken as independent random variables.

Using a computer program Weibull + +, the first random variable (transit depth), has been matched to the normal distribution. A course of the normal distribution is shown in Figure 2.

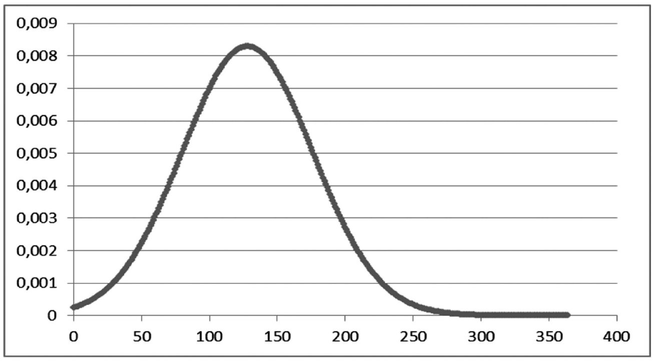

Fig. 2. Graph of the normal distribution

The average of this distribution was μ = 128.2955 cm and standard deviation σ = 48.1399 cm. According to this distribution, the expected value of the depth of the waterway fluctuated in the range of 1,28-0,48 = 0.8 m to 1.28 m 0.48 = 1.76. For the depth of 0,00-3,64 m (theoretical values assumed by a normal distribution) the distribution function were determined, ie the probability that the water level will be lower than indicated. Subtracting this value from one, the expected probability of desired deep or more were achieved.

Similarly, the distribution of length occurrence of deep fitted to logarithm-normal distribution. A course of the logarithm-normal distribution is shown in Figure 3.

The average of this distribution was μ = 0.7489 of day, and standard deviation σ = 0.6594. Counting the cumulative distribution function for a given number of

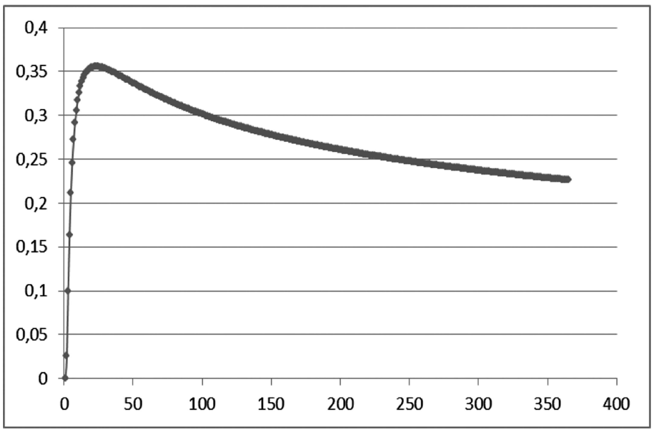

Fig. 3. Figure logarithm-normal distribution

days, the range of 1-365 days (the value adopted for the calculation of the logarithm-normal distribution), the probability of a transit depth of a set number of days was calculated.

Sample data obtained for the distributions was described in Table 1.

Table 1

Examples of the probability of a certain depth and the probability of a transit depth for a specified number of days

The water level [cm]	The probability that the level would be ≥ the given	Number of days	The probability that the number of days will be ≥ than the desired
80	0,842125591	1	1
120	0,568407284	3	0,839670139
150	0,326044144	6	0,599205805
180	0,141400879	9	0,476844231

Probability that the transit depth will last for set number of days is the product of two indicated probabilities. Examples of calculated probabilities are shown in Table 2.

Table 2

Examples of the probability of occurrence of the transit depth for 3 days

The water level [cm]	Number of days	The probability of a given depth for 3 days
80	3	0,707107712
120	3	0,477274623
150	3	0,273769532
180	3	0,118730096

The results obtained on the basis of described distributions were compared with values obtained using the program OptDep. This program is based on the same data from years 1981-2007. It indicates the percentage of times in the past there were conditions for the implementation of specified carriage.

Comparison of data for selected parameters is illustrated in Table 3 and Figure 4.

Table 3

Comparison of data from the OptDep and described method

The water level [cm]	Number of days	The probability of a given depth for given number of days	
		Described program	OptDep program
90	1	0,786840	0,6692
	3	0,660686	0,5889
130	1	0,485878	0,5090
	3	0,407977	0,4311
150	1	0,326044	0,3952
	3	0,273770	0,3166
170	1	0,193158	0,3038
	3	0,162189	0,2352

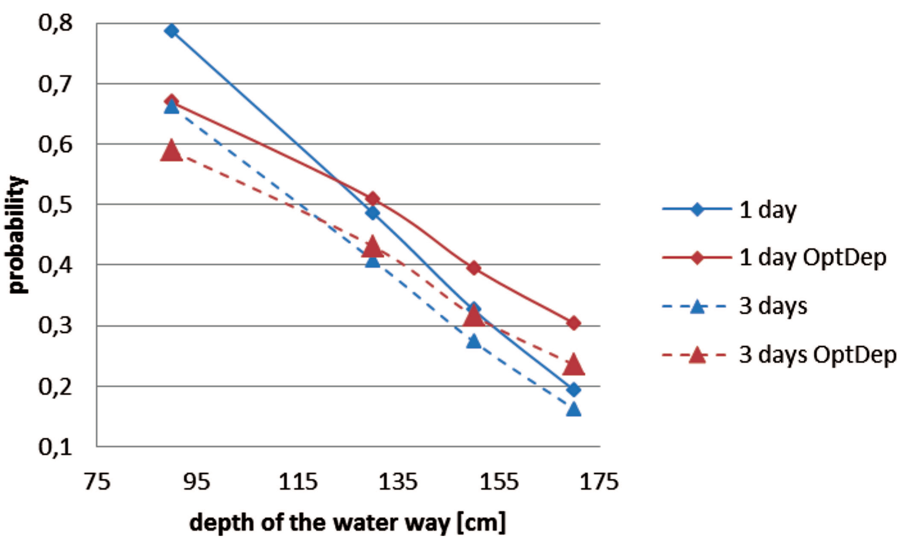

Fig. 4. Comparison of data from the OptDep and described method

The presented data show the differences between the obtained results, but the nature of the course of comparing the curves is similar, hence the results of probability distributions can be regarded as correct.

OptDep program is based on the closed period, the measurement of depth, which occurred in the past. The calculation of the probability is forward-looking. For this reason, compared results should not be identical.

The presented graph on Figure 4. illustrates that there is a greater probability that in the future occur depth of 95cm and less likely to experience greater depth.

Based on presented calculations of probability, while planning of future transport, one can possibly underestimate size of loads possible to carry. However the impossible to get an assumption that would be impossible to achieve.

6. Summary

The method of calculating the cost of bulk transport on the example of the Odra Waterway, is presented by a description of this program. Based on its calculations, one can make comparisons of the cost of inland navigation and rail (calculating rail costs is also possible in the program).

Capacity of ODW sections calculated by the program and the probability of needed depth on the trail, are the basis for long term planning of the maximum transport capacity of individual sections.

Program can be used by companies and businesses that use inland waterways in Poland. Polish waterways, unfortunately, do not guarantee a specific statute transit depth throughout the navigation season. Because the calculation was based on individual programs, it can greatly facilitate the prediction of transport supply.

References

1. www.pkp-cargo.pl 2011.
2. Kulczyk J., Winter J.: Śródlądowy transport wodny, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2003.
3. Kulczyk J., Sradomski W., Tabaczek T.: Optimization of inland vessel multipropeller propulsion system operating parameters. In: Computer Systems Aided Science. Industry and Transport, Zakopane TRANSCOMP 2006.
4. Dane uzyskane na podstawie pomiarów RZGW we Wrocławiu 2007.
5. Lisiewicz T., Kulczyk J.: Przepustowość Odrzańskiej Drogi Wodnej od Gliwic do Szczecina, Dokumentacja robocza, Politechnika Wrocławska Instytut Konstrukcji i Eksploatacji Maszyn, Wrocław 2008.