FACTOR ANALYSIS TO CALCULATE THE RIVER CAPACITY

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Abstract: *A waterway is not consists of sections have constant loading gauges and - because of this - constant throughput capacity. The waterway categories themselves are suggesting to the different capacities, however the effective quantification is a significantly more complex task. The navigable section of a river consists of heterogeneous lines with space and time-varying characteristics because of its morphology and hydrology. The study examines the factors to prepare specific calculation.*

Keywords: WATERWAY PARAMETERS, SECTION THROUGHPUT, SPATIAL AND TIME AVAILABILITY, QULIFIER FACTOR

1. Introduction

Founding the unified waterway network is based on the voyage regulation of the AGN. The measure number of the track's utilization is the tonnage of the ships can be used on each line. The limits of these are formed by Table 1 in the case of each category.

Table 1: *Cargo capacity on the waterways* [1]

Waterway class (AGN)	Deadweight [t]	
	Motor cargo vessels	Pushed convoys
IV	1 000 – 1 500	1 250 – 1 450
Va	1 500 – 3 000	1 600 – 3 000
Vb	1 500 – 3 000	3 200 – 6 000
VIa	1 500 – 3 000	3 200 – 6 000
VIb	1 500 – 3 000	6 400 – 12 000
VIc	1 500 – 3 000	9 600 – 18 000
VII	1 500 – 3 000	14 500 – 27 000

The greatest challenge of river transport planning is the knowledge of the constantly changing throughput capacity of voyage. The efficient utilization of water voyage requires the transport calculation with high reliability. [2]

The permeability of water ways basically influenced by

- the track with its own parameters and
- the composition of the used vehicles

Rivers as natural water flows can be characterized by many outer parameters like:

- climatic and metrological parameters
- configuration of the ground and terrain
- utilization forms, the effects of human interference.

The other main parameters of capacity can be changing by the attributes of the fleet
- designation (human transport or weight transport, motorized or without motors etc.)
- the order of the emerging requirements (sizes, operate frequency)
- the requirements come from the territory (stability, safety tools).

Based on above, to qualify the waterways we have to examine the attributes of the area can be used for shipping. The parameters of the fairway classically used to classify to five groups [3]:

1. Hydrological parameters (attributes come from the water frequency):

- water output (the yearly, average and medium carried off water quantity)
- water level (the height of water at a certain point)
- and the regularity of the facts above and the frequency and duration reports

2. Geometrical parameters (the track sizes of the actual hydrological terms in the given river bed):

- the depth of the fairway (with shallows data)
- the width (and the shore distance of the fairway)
- free depth of section
- attributes of bend (ray, central angle)

3. Hydraulics parameters (the dynamic attributes of the carried off water quantity):

- water speed values (valued in space and time)
- special flows (occurrences deviate from the laminar direction)
- surface curves (in different water levels)

4. Meteorological parameters (weather elements which can influence shipping)

- wind (with waves)
- fog and other forms of wet
- Permanently high or low temperature (mostly icing)

5. Traffic parameters (features originating from the traffic of vehicles):

- navigation technology that is applicable on the territory (self-propellered vessels, pushed and towed convoys)

- the dimensions of the convoy that can be created on the area

- the speed that is necessary for the safe travel of great loadable vehicles, and the performance of main engine that is necessary to do this.

- the lowest admissible distance between vehicles, and its factors that influence it

(The last three parameters are assessed separately according to upstream or downstream, and different water levels)

As we have already estimated, a determination factor for the throughput of the rivers – the application of vehicles – can be originated from traffic features.

The other main component – the track – is shaped according to the four listed parameters. Hereafter, we will analyse the latter condition system, traffic factors will be the topic of another study.

2. Spatial availability

In the following, we will examine the waterway, as the components of a complex system, and the affect they have on each other, and in what kind of way do they influence the throughput capacity.

When planning artificial waterways and canals we can determine the necessary minimal water level, the depth and width of the riverbed for the expected load under a standardised waterway class.

In the case of natural water flows, the minimal navigable water level (H_{Nmin}) can be determined in an indirect way. This is the standard water level with which the navigation is 100% ensured in measure of the recommendations that belong to the classification.

The bed of a natural river shapes itself according to geological and morphological conditions, so it changes from section to section, and the water level that is needed for the insurance of travelling changes as well.

In a chosen cross-section of a waterway, the H_{Nmin} can be graphically determined in the following way:

- through standards we can determine the value of the width of the fairway (B_{Cmin}) belonging to the classification

- in the actual segment we look for the lowest level into which the necessary width can be still inserted. (This determines the margins of the fairway that belong to H_{Nmin} as well).

- to the determined level we add the expected value of the draught (t_{Cmin}) with needed underkeel clearance (C_U).

The water level in the cross-section, that ensures the passing of the load according to the class of waterway, is at our service.

The navigable range of fairway is enclosed by the maximal water level (H_{Nmax}) that still ensures boating. The two steps for determination are:

- the estimation of the lowest level of the bridge (L_{Blow}) in the cross-section that has an upper waist

- from this we deduct the recommended height of passage (f_{Cmin}) with needed safety clearance (C_B) of the waterway class.

So with this we have the water level in the cross-section, that constantly ensures to pass vehicle and cargo heights according to the class of the waterway

The navigable range and the voyage restrictor of a cross-section are shown in the first chart.

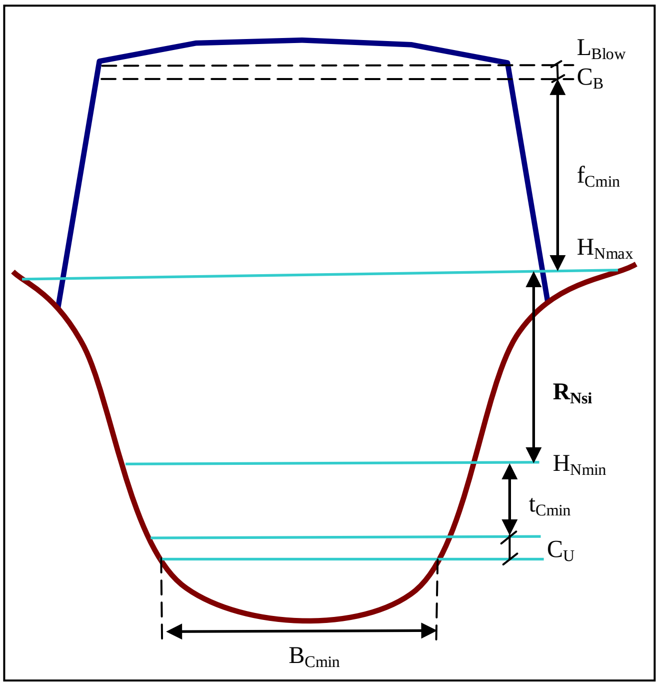

Fig. 1 *Fairway parameters*

Of course we need to know the limitations mentioned above for further sections. If a continuous (isobar-lined) river survey is available, we can expand the previous methods in space. Nowadays this can be done easier and faster by computing systems. As a result we get the spatial diagnostics of the analysed section of the river, which makes it possible to track both the vertical and horizontal changes; therefore we get the sinuosity specifics of the assumed width.

Choosing authentic sections for a possible gauge on the examined section is not possible directly by comparing the minimal water-level, because the river has a natural flow. Because of the above mentioned morphological specifics, different water output is necessary for the minimal water level (H_{Nmin}) on every section. By this to specify the restrictive river section we have to choose from the water outputs of the examined river sections which ensure minimal water levels. This gives us the minimal water output to make navigation possible (Q_{Nmin}). At a lower level on the river section, traffic is possible only by gauge-restriction.

In general the suitable fairway depth is depend on the width and the actual water output, therefore:

$$h_i = f\,(B_C;\, Q_i)$$

The minimal navigable water output (by the shown method) consists the morphological specifics of the examined river section (shape of the section, flaw of the water surface, material of the river bed, geometrical measures).

We have to choose the restrictive water output (Q_{Nmax}) belonging the navigable maximal water levels. This means the geometrical parameters of the river section's infrastructures. At a higher level, riverage on the section is possible only by draught-restrictions.

By this method we get the water output range (Q_{Nmin} - Q_{Nmax}), which makes a continuous (100%) navigation possible on the section's waterway-classification.

In an actual application we show the draught-restricting water levels on the actual river section on the following diagram. On figure No.2. you can read the lowest water level for riverage on the different river sections and the necessary water output for them.

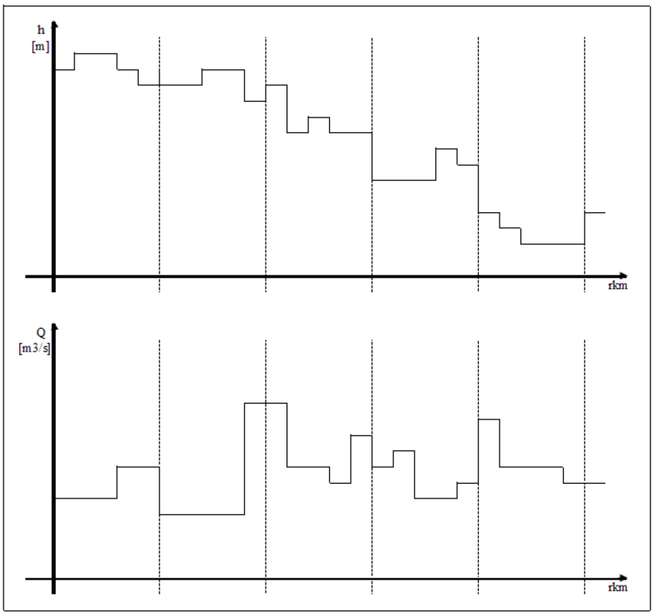

Fig. 2 *The navigation-proof water levels and water discharge on the examined river section*

The highest value of the minimal water outputs will affect the river capacity. At this chosen cross-section we can specify the water output for different - declined - draught by the method above. By preparing to restrictions it is possible to specify practically one- and two-way traffic, so full and half-width of the fairway. Its correspondences are on the figure No.3.

3. Time availability

By comparing the minimal shipping water level with the actual water level we can calculate the degree of obstruction during shipping in individual sections. The exploration of the laws of changes on water levels can give us the probability of obstructions in shipping over time. As a result of climatic effects the water level is periodically changing.

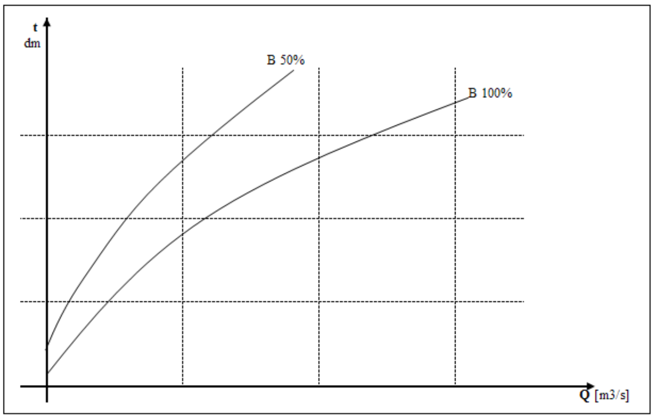

***Fig. 3** Connection between the draught and the water output on the actual river section*

We can only measure it reliably by analysing daily water level data over a long period (50 years) of time. The standard form of the function [4]:

$$Q_k^p = Q + \sum_1^n \varphi_1(t) \qquad [\%]$$

$$\varphi_1(t_1) = Q_1 \cos\frac{2i\pi}{365}t + b_1 \sin\frac{2i\pi}{365}t$$

(1)

The distribution of water output values over time is also determinable by the parameters of the also periodic distribution function [4]:

$$Q_p(t) = a_0 + \sum_1^n c_1 \cos\frac{2i\pi}{365}t + d_1 \sin\frac{2i\pi}{365}t \qquad [\%]$$

(2)

If we use this correlation with the minimal shipping water output, we get the probability of the value being on, or over the margin of shipping water output over time in a given section. We get a full picture, if we also use the correlation for the water level data under reduced draught and half-width. The results are like the curves illustrated on diagram 4.

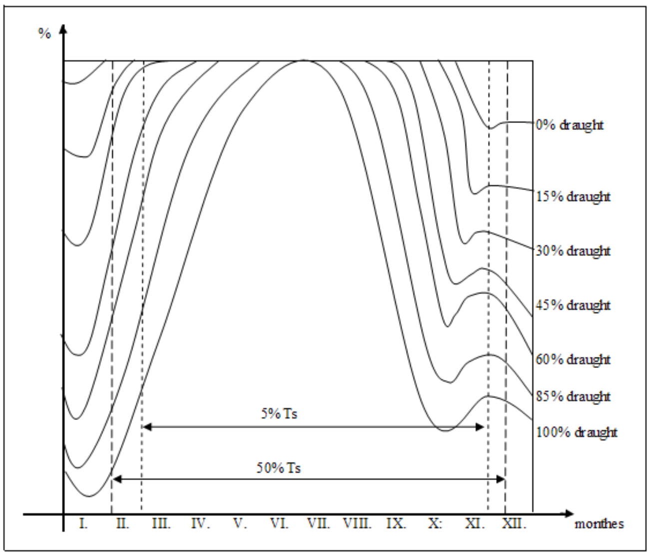

***Fig. 4** The probability of draught constricting water level in a given section*

With the time duration of shipping water outputs (T_N) the shipping season can be reduced by:

- a random event (blocking of shipping lanes because of an havaria, or another event)
- events that are occurring in a particular regularity (in the temperate zone it is mostly ice formation)

The first event is statistically insignificant, but with the second one it is mathematically calculable. To determine the laws of ice formation we should look at the following perceptual data:

- the starting of ice formation
- the time of the stabilization of the river
- the time duration of the ice covering
- the starting again of the flow
- the melting of the ice

These are used as probability variables, but because of the fact that these will give us too much variations, the duration of the ice covering (T_i) could be take into account with more probability (0, 5 and 50%). Knowing this – as a shipping necessity – we can calculate the usable duration of the shipping season (T_{eff}):

In one year the number of days that are not appropriate for shipping (T_n) can be calculated from the sum of the times of obstructions:

$$T_n = \sum_{t=1}^{365} T_{min}(t) + \sum_{t=1}^{365} T_{max}(t)$$

(3)

Or otherwise in rate:

$$T_n = \sum_{t_0}^{t_n} T_{min}(t) + \sum_{t_0}^{t_n} T_{max}(t) \qquad [\%]$$

(4)

Where:

T_n: the duration of obstruction
T_{min}: days falling out because of a water output under Q_{Nmin}
T_{max}: days falling out because of a water output over Q_{Nmax}

The time duration of shipping water outputs (T_N) in the shipping season [5]:

$$T_N = T_{365} - T_n$$

(5)

4. Qualifier factor

Multiple parameters of the fairway can be a characteristic of a given section of the river, and it will affect its quality.

The above shown water level calculation gives us an opportunity to complexly analyse the navigability of a waterway.

Next to the minimal shipping water output that has morphological parameters, with the processing of the laws of changes on water levels we can calculate the smallest occurrent water output (Q_0) in a given section. The relationship of these is representative to the secureness (S_s) of shipping of the section:

$$S_s = \frac{Q_0}{Q_{N\,min}}$$

(6)

From the proportions we can set up the quality classifications suggested under figure 5.

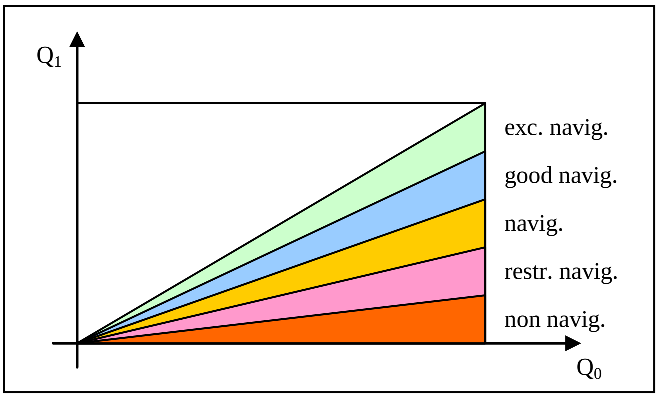

Fig.5 *Waterway quality categories based on water output relations*

Conclusion

The parameters of waterway that are varying in space and time along the river creates a complex measuring system.

With their analyses we can draw conclusions about the necessary traffic management, the possible vehicle constructions, and what waterway improvement is possible.

For these high cost procedures a high reliability waterway rating method is necessary.

By looking at the method for obstructing water outputs we can give the river sections a complex classification.

For the comprehensive expression of the rivers shipping capability at the same time we need to consider the traffic patterns, which we will do in the continuation of this study.

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