Opportunity Study of the Danube Region – the Adriatic Traffic Corridor

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Abstract: Croatia has a very advantageous traffic location in the centre of Europe. It is located on the main European traffic corridors, among others, on the VII Danube and the X Sava corridor. They can be connected with the Adriatic through the corridors Vb and Vc. Existing traffic system in Croatia is inappropriate to meet most recent technological demands, as well as economy needs for synchronization of the European traffic network and philosophy. The future of Croatian inland navigation is to include Danube into a "combined river-railway traffic corridor Danube region-The Adriatic". It starts in the Danube port of Vukovar and ends in the Adriatic port of Rijeka. The Combined river-railway traffic corridor Danube Region-The Adriatic will consist of the future multipurpose Danube-Sava canal between Vukovar and Šamac, improved Sava waterway from Šamac to Sisak, followed by Sisak-Zagreb-Rijeka railway which exists already. Three possible development scenarios for the riverine part of the corridor have been observed. The first scenario includes river training of the Sava River toward the IV navigation class, the second scenario includes training of the Sava River as a IV class waterway with the multipurpose Danube-Sava canal (Vb class) and the third scenario includes the canalized Sava River as a Vb class waterway with the multipurpose Danube-Sava canal. The considered economic aspect includes navigation, use of water power, agricultural aspect, forestry, water management and environmental aspect for each scenario individually. On the basis of the scenarios, corresponding cost and benefit scheme has been determined as well as investment analysis which includes profit and other financial criteria. Performed multi-criterion analyses state precise propositions for realization of each scenario respectively.

Keywords: traffic, corridors, river-railway, waterway, multipurpose canal
1. Introduction

Croatia has an extremely advantageous traffic and geographical location by being situated on the main European traffic corridors which, accordingly, includes the VII European (Danube) corridor which is linked with via the Adriatic with the corridor Vb, Vc and X (Sava). Existent traffic system in Croatian does not comply with modern technical demands, nor does it meet the needs of the economy sector. It has not taken advantage of meeting positive preconditions in order to be incorporated into and technically coordinated with the European network.

The future of Croatian navigation lies on the Danube River and in the sphere of international traffic via the combined river-railway traffic corridor Danube Region-The Adriatic from Vukovar to Rijeka.

The combined river-railway traffic corridor Danube Region-The Adriatic would include the following:

- 61.4 km long future multipurpose Danube-Sava canal between Vukovar and Šamac
- 306 km of the Sava River from Šamac to Sisak
- 280 km of the railway track Sisak-Zagreb-Rijeka.

Economic surrounding of the traffic corridor – navigation, water power system, and aspects of the corridor in the field ecology, agriculture, forestry and water management – were observed. Analysis of investments, costs and benefits evaluation, and economic and financial evaluation was performed on the basis of the costs and benefits per scenario. Scenarios were proposed following a multi-criteria analysis.

2. Development scenarios

Three possible scenarios for the development of the riverine part of the traffic corridor were analysed and they are the following:

- Scenario 1 regulated Sava with the IV navigation class from Jamena to Sisak
- Scenario 2 regulated Sava with the IV navigation class from Šamac to Sisak via the Dunav-Sava canal with Vb navigation class
- Scenario 3 canalised Sava with Vb class from Šamac to Sisak via the Dunav-Sava canal with Vb navigation class.

Scenarios are mutually independent which means that subsequent scenarios do not incorporate preceding one(s) as a specific earlier stage. Though some segments of technical solutions are overlapping in different scenarios, the three possible scenarios presented herein contain different technical and traffic solutions each of which has a different level of costs and benefits.
Figure 1  European inland waterways and the indicated corridor
2.1 1st Development scenario
TECHNICAL SOLUTION OUTLINE
This scenario simulates the state which excludes construction of the multipurpose Dunav-Sava canal. Connection to the European inland waterway would be established via Serbia and Montenegro, as done so far.

Elements for tracing the Sava waterway are: the IV class waterway, two-way navigation secured where possible, a minimum waterway radius of $R_{\text{min}}=360\text{m}$ (on locations where river morphology prevents it, a smaller waterway radius and one-way traffic will remain), a minimum waterway gabarit of $2.2\times70\text{ m}$ is secured on the water table 95% of days annually.

ECONOMIC AND WATER MANAGEMENT SOLUTION OUTLINE
Following arrangements pursuant to this scenario, the whole Sava River from Jamena to Sisak would become a IV class waterway without limitations in terms of radius of curvature (one-way traffic). Ecologically speaking, works do not impose any changes to existent habitat nor do they jeopardize it. Furthermore, there will be no changes of the existent drainage system. There is also no possibility for securing sufficient amount of irrigation water from Sava due to minimum summer flows of natural water regime. Technical solution pursuant to this scenario does not effect forestry production. This scenario presumes that protection against floods of the Sava River will be solved by combined regulation of the water bed and water regime which is currently being used. Existent and planned development of this type of flood management system of the Sava River will not change following regulation of the Sava waterway pursuant to Scenario 1. Basic protection measures are relief canals, gates, retentions and dikes. This stage does not enable securing additional amount of water to compensate water deficit during drought periods. Regulation of the waterway on this level does not guarantee a secured water intake from Save for technological waste water, so conditions for existent intakes remain the same.

2.2 2nd Development scenario
TECHNICAL SOLUTION OUTLINE
This scenario simulates connecting the Sava waterway with the international inland waterway net through the Republic of Croatia via the future multipurpose Dunav-Sava canal along Šamac-Sisak track.

Elements for tracing the Sava waterway are: the IV class waterway, two-way navigation secured where possible, a minimum waterway radius of $R_{\text{min}}=360\text{m}$ (on locations where the river morphology prevents it, a smaller waterway radius and one-way traffic will remain), a minimum waterway gabarit of $2.2\times70\text{ m}$ is secured on the water table 95% of days annually.

Elements for tracing the Dunav-Sava canal are: the Vb class waterway, two-way navigation, a minimum waterway radius of $R_{\text{min}}=750\text{ m}$, a minimum waterway gabarit in the direction of $4\times34\text{ m}$ dimensions will be secured by the net present value (NPV).
ECONOMIC AND WATER MANAGEMENT SOLUTION OUTLINE

The part of the waterway on the Sava River (from Šamac to Sisak) is described in Scenario 1. The multipurpose Dunav-Sava canal in the length of 61.4 km will be constructed for a standard international Vb class waterway. Navigation from Sava towards Western Europe will be performed via the Dunav-Sava canal the length of which would be 417 km and towards Eastern Europe the length of which would be 85 km.

An essential ecological contribution of the canal to the existent system is the following: during low water level periods in the canal basin, the water intake from Sava will include releasing of 30 m$^3$/s water into the canal in addition to the quantity necessary for irrigating agricultural grounds. Hydro-technological facilities, i.e. gates will be used to release 5 m$^3$/s water into Bosut, and 4.5 m$^3$/s water into Vuka. Furthermore, it is possible to perform controlled recharging of forest basins in view of simulating natural habitat of the dominant and most valuable common oak. The forestry study has shown that regulating water regime in common oak forests along the canal can increase timber mass three times in comparison with the current status which represents a measurable ecological contribution. On the Bid-Bosut segment of the basin of the Dunav-Sava canal, construction of the Dunav-Sava canal enables connecting that basin with inland waterways as well as supplying it with water from Sava by means of gravitation or pressure in case of small water bodies, or from Danube by pressure alone. On the segment of the basin of the Dunav-Sava canal where the Vuka River flows, there will be no changes: the canal does not enable irrigation, and drainage will go directly into Danube as was the case before construction of the Dunav-Sava canal. The Dunav-Sava canal can contribute significantly to forestry production because it can enable forest irrigation by controlled increasing of the level of groundwater in the forests of the Bid-Bosut plateau. The forestry study has indicated that regulating water regime in common oak, ash and hornbeam forests can increase timber mass for 10% and general forest function for 20% (during production cycle of 120 years which implies a cycle from cutting to a full grown oak forest). Construction of the canal will enable occasional controlled releasing of water from the Sava River into the Dunav-Sava canal via a gate on the part of the canal on Sava, and, subsequently, into the water release system in the riparian part of the canal. These waters will make up for major summer water deficits on the lowlands of the Bid-Bosut basin which threaten the existent ecosystems located therein.

PROTECTION AGAINST FLOOD

In future, digging the multipurpose Dunav-Sava canal via a watershed (from 10$^{th}$ to 18$^{th}$ canal km, Figure 2) will connect the basins of Bid-Bosut and Vuka thus creating a canal basin the surface of which will be 4000 km$^2$. Connection of the basins of Bid-Bosut and Vuka will be controlled by a shiplock [20] and a gate [21] of the Danube hydro-technical junction, and connection of the canal and Sava by a shiplock [17] and a gate [18] of the Sava hydro-technical junction (60$^{th}$ canal km). Accordingly, of the total canal length of 61.5 km, 10 km will be in the Danube regime, 1.5 km in the Sava water level regime, and the major part in the length of 50 km in the regime of the canal with a continuous water level of +80 m over the sea
level for the most part of the year. Vuka and the Bobot canal will be drained directly into Danube (as prior to construction of the canal), and following its construction, one part of Biđ-Bosut floods as well.

![Diagram](image)

**Slika 2** Basin drainage scheme – future state

Floods of Biđ, Jošava, Kaluder and Bosut flowing in the direction of Vinkovci will be distributed via the Bosut gate located downstream [15] into the downstream Bosut river channel towards Sava and via the canal towards Danube. In this manner Vinkovci will be protected from floods. Major part of floods will be directed towards Bosut and released by means of gravitation into Sava via the gate [2] located at the river mouth of Bosut into Sava. If, due to a high water level of Sava, it is not possible to enable gravitational runoff of Bosut via that gate, Bosut will be pumped into Sava with a pumping station. If the Bosut inflow surpasses the capacity of the pumping station, a specific amount of Bosut will be released into the retention of the Spačva-Studva basin. It is anticipated that gravitational runoff of the remaining amount of floods via the canal into Danube is performed on the Danube hydro-technical juncture via the gate [21] (Figure 3b). From there, water is released in a controlled manner downstream into the river channel of the canal belonging to the Danube regime. This scheme is applied for Danube water level from +80 m over the sea level to +82 m over the sea level. The drainage scheme “everything into Danube” is possible when the water level of Danube is equal to or below the water level in the canal (+80 m over the sea level)(Figure 3a).
In case of a high water level of Danube, over +82 m over the sea level, complete drainage from the Spačva-Studva basin region is directed into Sava via the gate and the pumping station located on the rivermouth of Bosut into Sava, as the case before construction of the Dunav-Sava canal (Figure 3c). Pursuant to hydrological analyses, this case reoccurs once every five years or once every other year when VES N. Sad (hydroelectric power station) is constructed. Since according to the proposed future hydro-technological solution for basin drainage of the Dunav-Sava canal, water from Vuka will be separated from water of Bid-Bosut by means of a gate [21] and a shiplock [20] in the Danube hydro-technical junction, the possibility of flooding of the Bid-Bosut basin with waters from Vuka is removed owing to deceleration of the high waters of Danube.

2.3 3rd Development scenario
TECHNICAL SOLUTION OUTLINE
This scenario of the traffic corridor Danube - Region-The Adriatic, as well as Scenario 2, simulates connecting the Sava waterway with the international inland waterway net, i.e. Danube, through the Republic of Croatia.

Hence, this scenario focuses on the Sava River in the length of 290 km from Sisak to Šamac (the rivermouth of the multipurpose Danube-Sava canal into Sava) and the future multipurpose Danube-Sava canal between Šamac and Vukovar in the length of 61.4 km. Sava waterway will be shortened for ca 40 km from its used length of 290 km because certain number of tunnels will be dug on meanders having too small radiuses. In this manner this scenario incorporates the total of ca 311.4 km of waterway in Croatia. It includes regulating
Sava to Vb navigation class and a complete construction of the Dunav-Sava navigation canal of Vb class. Observed scenario is in accordance with navigation regulations stated in the UN Study from 1972. However, technical parameters concerning waterway have been updated. Sava will be canalized with two water steps: Šamac and Košutarica (Jasenovac).

Elements for tracing the Sava waterway are Vb class waterway, two-way navigation secured along the whole length of the route, a minimum waterway radius of $R_{\text{min}} = 450$ m, a minimum waterway gabarit of 3.7x89 m will be secured on the water table 85% of days annually, with a radius of curvature $R \geq 700$ m (i.e. in less curved segments of Sava, the width of the waterway can be narrower).

**ECONOMIC AND WATER MANAGEMENT SOLUTION OUTLINE**

Technical solution for Sava according to this scenario has several purposes. By canalising the river with two water steps, Šamac and Jasenovac, the following will be improved: quality of waterway, protection against flood and irrigation when compared to the same functions pursuant to Scenario 1 and 2 which incorporate only regulation of the river channel. Furthermore, this scenario incorporates the function of water power management of Sava. Construction of water steps changes water regime of Sava, in case of low and medium water level, whereas during high water level there will be no major changes to the water regime. This is caused owing to the feature of water steps which in case of low and medium water level, keep deceleration only in the current river channel of Sava, i.e. below the level of existent surrounding ground. Water appears in inundations only in case of managing floods as is the current state of affairs. In this manner the existent flood protection system for the central part of Posavlje does not change. Solution to the multipurpose Danube-Sava canal corresponds completely to the one described in Scenario 2.

### 3. Project costs and benefits

Pursuant to the needs of the above stated technical features, the following estimation of costs has been made:

<table>
<thead>
<tr>
<th>Construction scenario</th>
<th>Project description</th>
<th>LAND REDEMPTION [€]</th>
<th>EQUIPMENT REPLACEMENT COSTS within 100 ys. [€]</th>
<th>ANNUAL COSTS [€]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario 1</strong></td>
<td>Regulation of the Sava waterway to 4th class</td>
<td>0</td>
<td>14.093.781</td>
<td>422.813</td>
</tr>
<tr>
<td><strong>Scenario 2</strong></td>
<td>Regulation of the Sava waterway to 4th class with the multipurpose Danube-Sava canal</td>
<td>13.393.333</td>
<td>744.259.247</td>
<td>8.292.457</td>
</tr>
<tr>
<td><strong>Scenario 3</strong></td>
<td>Regulation of the Sava waterway to 5b class with the multipurpose Danube-Sava canal</td>
<td>13.875.613</td>
<td>1.242.257.610</td>
<td>23.010.524</td>
</tr>
</tbody>
</table>
Basic benefits achieved by realisation of this project are the following:

- establishing a new traffic route and new means of transportation which represents a major step forward for economy, connects Croatia with the global market and creates conditions for the development of local economies along the entire length of the corridor;
- regulating the water regime of Sava and its tributaries along the major part of the riverbank, complete control of floods with a 100-year payback period, establishing safe development conditions, increasing land and assets value;
- developing power supply system;
- securing safe water sources for irrigation, technological needs and improving small watercourses;
- improving water supply owing to a continuous bioremediation of groundwater;
- increasing agricultural profits, increasing production assortment, guaranteed yield;
- increasing water regime of the forest ecosystems, increasing timber mass yield;
- maintaining and improving natural conditions of wetlands by securing water during summer periods, developing special branches of tourism, hunting, fishing, sports and recreation activities;
- increasing employment rate in numerous spheres analysed herein, as well as additional activities during construction works and when put into operation.

4. **Economic and financial evaluation of the project**

Since evaluation of the project is primarily performed by banks interested in monitoring financing of the project, the evaluation of economic and financial analyses includes the following:

- Economic flow and payback period;
- Net present value (NPV)
- Internal rate of return (IRR)
- Possible credit arrangements
- Financial flow.

Financing model is concluded by three important interested parties, i.e. the Republic of Croatia, strategic partners and financial institutions prepared to participate in the realisation of the project.

In view of controlling and evaluation the validity of the project, additional criteria have been included. Since this is an infrastructural project of a strategic importance for the Republic of Croatia interconnecting 7 counties, beside the stated evaluation criteria, investment criteria was also included in the economic and financial evaluation of the project because it directly triggers increase in gross national product (GNP) of the region. More precisely, according to this criterion, the threshold for minimal acceptable value of
Investments for Croatia has been estimated to 4 billions HRK (e.g. Scenario 1 does not comply with this condition).

Interests of strategic partners are presented through the internal rate of return (IRR), and minimal acceptable amount of the rate is estimated to 5%. According to this criterion, all three Scenarios meet the condition. However for this type of project it is desirable to find an acceptable interest (< 4%) on the money market. Interests of financial institutions are present through the value of the debt-service coverage ratio (DSCR) of 1.15. In this case, all Scenarios meet this criterion.

Investment period for Scenario 1 is 15 years, with annual investments from 4 to 14 billions HRK. With this minimal investment, the expected traffic should also give minimal profit which means that the payback period is rather long, 20.24 years. This also testifies to the claim that the corridor should interconnect Sava and Danube in Croatia, shorten freight routes towards Europe which would make this inland waterway more attractive.

Investment period for Scenario 2 is 12 years, with annual investments from 250 to 740 billions HRK. Since this Scenario incorporates construction of the multipurpose Danube-Sava canal, major investment connotes numerous benefits – project profits. Though the payback period is 23.81 years, it should be borne in mind that this is an infrastructural project which will bring about other invaluable benefits beside valorised and identified ones.

Investment period for Scenario 3 is 15 years, with annual investments from 500 to 900 billions HRK. This maximal scenario brings about versatile direct and indirect benefits. Accordingly, the payback period of 24.5 years can be regarded acceptable since this is an infrastructural project of national importance.

5. Conclusion

Pursuant to the above stated the Republic of Croatia should choose between Scenario 2 and 3. Owing to major investments, both Scenarios have a potential to become the basis for economic development of the region along the length of the corridor. To that effect, it is important to protect interests of the local industry and secure its partial or significant recovery by its direct participation in realisation of the project.

The first step in decision making process is to reach strategic decision on the Scenario in order to launch negotiations for realisation of the project. By accepting the selected Scenario it is no longer possible to change allocation of benefits established by that specific Scenario; however pending negotiation period it is possible to gain additional benefits. The next step is a tactical decision on the variant of the selected Scenario owing to changeable parameters of each Scenario: ownership share, credit grace period, interest rate and manner of payment, duration of credit payback period, issuing guarantee and total duration of concession.

Incentives with which the Republic of Croatia is trying to revive economic activity today are necessary but not enough for this kind of development. The State should have a
strong ally in commercial banks. If this is not the case, the State should achieve its macroeconomic goals in the sphere of production, employment, stability of prices and net export through the mechanisms of monetary, fiscal, income and foreign trade policies.

References
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