Data Collection, hydraulic and morphological modelling of the Danube River and the Sava River in the Republic of Serbia
Lot 1: Hydraulic and morphological modelling of the SRB-HRV common stretch of the Danube River

404-02-00086/2022-06

REPORT ON MCA DEFINITION

Version: **Final**
Date: 17 December 2024
Author: Nikola ROSIC
Approval: Marko JABLANOVIC

Content

Tables

Figures

Abbreviations

Abbr.	Meaning
1D	One dimensional (model, modeling)
2D	Two dimensional (model, modeling)
AD	*Akcionarsko društvo* (Joint-Stock Company)
AGN	European Agreement on Main Inland Waterways of International Importance
CA	Contracting Authority
CEF	Connecting Europe Facility
EIA	Environmental Impact Assessment
EIB	European Investment Bank
ENR	Etiage navigable et de régularisation
EU	European Union
EUSDR	European Union Strategy for the Danube Region
GNS	Good Navigation Status
HNWL	High Navigation Water Levels
HRV	Croatia
JS	Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin
LNWL	Low Navigation Water Levels
MCA	Multi-Criteria Analysis
MoCTI	Ministry of Construction, Transport and Infrastructure
NAIADES	Action plan for boosting future-proof European inland waterway transport
PIANC	World Association for Waterborne Transport Infrastructure
PLATINA	PLATform for Implementation of NAiades
ref.	Reference (State or Value)
SEA	Strategic Environmental Assessment
SHDI	Shannon Diversity Index
SRB	Serbia
TBR MDD	The Transboundary Biosphere Reserve Mura-Drava-Danube
TEN-T	Trans European Transport Network
UN	United Nations
UNFCCC	UN Framework Convention on Climate Change
WFD	Water Framework Directive

Introduction

The Contract "**Data Collection, hydraulic and morphological modelling of the Danube River and the Sava River in the Republic of Serbia, Lot 1: Hydraulic and morphological modelling of the SRB-CRO common stretch of the Danube River**" is financed by the European Union under the Connecting Europe Facility (CEF) Programme and the European Investment Bank (EIB), under the Finance Contract Serbian Inland Waterway Infrastructure between the European Investment Bank and the Republic of Serbia. The Contracting Authority (CA) is the Ministry of Construction, Transport and Infrastructure (MoCTI) of the Republic of Serbia. The service contract was concluded between the MoCTI and the Hidrozavod DTD AD Novi Sad (hereinafter referred to as the Consultant).

The overall objective of the project is to contribute to the creation of a competitive transport system by improving infrastructure alongside the Danube River, in accordance with the national policy and strategy provisions, and EU transport system development plans. The project aims to ensure **fast, safe, reliable and environmentally friendly transportation**, facilitating the smooth flow of freight and mobility of people. An integrated planning approach and inter-sectoral cooperation through the Stakeholders' Forum platform support the entire process.

A key goal of the project is to support the **achievement of Good Navigation Status (GNS)** as required under the **EU's NAIADES Action Plan** and related national commitments. GNS ensures that the Danube River and its infrastructure are maintained at levels that guarantee efficient and reliable navigation. The project contributes to these goals by identifying and addressing **navigation challenges (bottlenecks)** in the common Croatian - Serbian stretch of the Danube River (river-km 1433.1 to 1295.5). These challenges, primarily caused by dynamic water level alteration, if not addressed properly, can negatively affect the overall navigation.

The project activities focus on developing **hydrological and morphological models**, reassessing **Low and High Navigation Water Levels (LNWL/HNWL)**, analyzing critical **navigational bottlenecks**, preparing potential **sustainable solutions** to address the navigational challenges in prioritized bottlenecks, and promoting stakeholder collaboration. These actions align with the overarching transport-related objectives of improving connectivity, efficiency, and safety across the EU's inland waterway network, thus contributing to a seamless integration of the Danube Corridor into the broader Trans-European Transport Network (TEN-T).

Environmental Objectives

Environmental objectives and considerations in the project are defined through the compliance with the EU Environmental Legislation (Habitats[1] and Birds[2] Directive) and Water Framework Directive[3], in particular, with the requirements of Article 4(7).

Furthermore, the project adheres to principles outlined in the **Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin**, ensuring a balanced approach between navigation improvement and environmental sustainability. By harmonizing navigational improvements with environmental objectives, the project supports **integrated river basin management** and contributes to broader goals of **sustainable development**.

---

[1] Habitats Directive (Council Directive 92/ 43/ EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora)

[2] Birds Directive (Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds)

[3] Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy)

Multi-Criteria Analysis and Integrated Study

The Activity 3 of the Contract involved defining the Multi-Criteria Analysis (MCA) framework, which will be applied to evaluate proposed alternative solutions for improving navigation conditions during low water periods at identified prioritized bottlenecks in the project area—SRB-HRV common stretch of the Danube River. The MCA ensures that technical, economic, social, and environmental factors are systematically assessed, balancing the need for efficient navigation with broader sustainability goals.

The final output of the Contract is an **Integrated study on alternative solutions**.

How to read

Chapter 1 of this report provides basic international strategic and legal framework of the project. The subject of the Chapter 2 is basic process leading to the definition of the Multi-Criteria Analysis (MCA), while the principles in definition of alternative options are given in the Chapter 3. MCA methodology is elaborated in the Chapter 4, with provision of examples and further considerations in the Chapter 5.

1. International strategic and legal framework

The complex international strategic and legal framework of the project consists of a number of documents and initiatives of strategic importance, including international and interstate agreements, strategies, action plans, EU Directives and Regulations, management plans, guidelines (Figure 1).

Figure 1: International Strategic and Legal Framework

The most important components of the international framework include, but are not limited to, the following: European Agreement on Main Inland Waterways of International Importance – AGN, Blue Book – Inventory of Main Standards and Parameters of the E Waterway Network, Convention Regarding the Regime of Navigation on the Danube, DC Recommendation on Minimum Requirements related to Fairway Parameters, Convention on Cooperation for the Protection and Sustainable Use of the Danube River, Water Framework Directive (2000/60/EC) – WFD, Danube River Basin Management Plan, Joint Statement on Guiding Principles for the Development of Inland Navigation and Environmental Protection in the Danube River Basin (the Joint Statement, JS), Regulation (EU) No 1315/2013, update No 758-2016 (TEN-T Regulation), Guidelines Towards Achieving a Good Navigation Status – GNS, European Green Deal, EU's Sustainable and Smart Mobility Strategy, EU's White Paper on Transport - Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system, Rhine Danube Corridor Work Plans of the European Coordinator, Action plan for boosting future-proof European inland waterway transport (NAIADES III), The European Union Strategy for the Danube Region (EUSDR), Luxemburg Declaration – Declaration on commitment towards the implementation of effective waterway maintenance measures, EU's SEA (Strategic Environmental Assessment) Directive, EU's EIA (Environmental Impact Assessment) Directive, EU's Birds Directive, EU's Habitats Directive, NATURA 2000, EU's Biodiversity Strategy for 2030, EU strategy on adaptation to climate change - Forging a climate-resilient Europe, The

ESPOO Convention (Convention on Environmental Impact Assessment in a Transboundary Context), The environmental goals of the UNESCO 5 country Transboundary Biosphere Reserve Mura-Drava-Danube and its common workplan ((Republic of Croatia and Hungary: "Mura-Drava-Danube Transboundary Biosphere Reserve" and Republic of Serbia: "Bačko Podunavlje Biosphere Reserve"), Manual on Good Practices in Sustainable Waterway Planning - PLATINA Manual, PIANC's Working with Nature, Aarhus Convention, Agreement between the Government of the Republic of Serbia and the Government of the Republic of Croatia on Navigation on Inland Waterways and their Technical Maintenance, Finance Contract SERBIAN INLAND WATERWAY INFRASTRUCTURE between the Republic of Serbia and the European Investment Bank, EIB Environment Framework & EIB Environmental and Social Standards, EIB Climate Adaptation Plan, UN Framework Convention on Climate Change – UNFCCC.

2. Basic process towards application of the MCA

Based on the results of the 1D modeling report, including the Hydrological Study, the Consultant calculated new reference water levels—*Etiage navigable et de régularisation* (ENR) or *Low Navigation Water Levels* (LNWL)—for the entire project area (SRB-HRV common stretch of the Danube River).

In the next step, the Consultant identified navigational bottlenecks, defined as river stretches which do not meet the fairway parameters required for the safe navigation. A total of 13 navigation bottlenecks were identified. This list was then compared to the list of bottlenecks previously identified and agreed between two countries more than a decade ago, which contained a total of 17 identified bottlenecks. Further on, the Consultant developed a methodology for prioritizing the identified navigation bottlenecks. This methodology aligns with the decision-making process outlined in the PLATINA II project, taking into account the selection of measures and their impact on fairway availability[4]. As a result of this prioritization, the initial list of 13 navigational bottlenecks was refined, by excluding sectors that can be addressed by **operational measures** (realignment of the fairway, narrowing of the fairway) and/or **maintenance measures** (maintenance dredging). Ultimately, four (4) "prioritised" sectors were identified for detailed investigation.

The "prioritized" sectors—Apatin, Čivutski Rukavac, the Drava Confluence, Staklar, and Aljmaš (the latter included as a non-critical site to broaden the analysis)—will be examined in detail. This will involve exploring potential solutions, with multiple options considered for each bottleneck, to address the navigational shortcomings in these areas. Additionally, a Multi-Criteria Analysis (MCA) framework will be applied to evaluate the proposed solutions.

3. Basic principles in definition of alternative options

For each of the 4 prioritized navigation bottlenecks and additional one between critical sectors Drava confluence and Staklar (named Aljmaš), 3 different alternative options will be defined and analyzed. One of those options shall be the "Do-nothing" scenario, meaning the scenario **without any interventions**—neither non-structural interventions, such as operational (e.g. fairway shifting, narrowing) or maintanance measures (e.g. dredging), nor structural interventions—engineering measures (e.g. chevrons, bottom sills)[4]. Being one of four options, the "Do-nothing" scenario will, at the same time, be the baseline scenario to which the other three alternative options containing structural and/or non-structural interventions in the

[4] Source: Good Practice Manual on Inland Waterway Maintenance, MOVE/FP7/321498/PLATINA II, 2016, p. 86; based on NEWADA duo (2014): Feasibility Study for a Waterway Maintenance Management System (WMMS) for the Danube, Network of Danube Waterway Administrations – data and user orientation, Final Report, NEWADA duo project deliverable O.6.4.9

waterway will be compared. As a result of the applied MCA, alternative options will be ranked, indicating preferable scenario for navigational bottlenecks. Special attention is given to application of latest scientific insights regarding the assessment of the effects of river engineering measures on the ecological integrity of the river systems.

Flowchart of the modeling process and position of the MCA is given at the Figure 2.

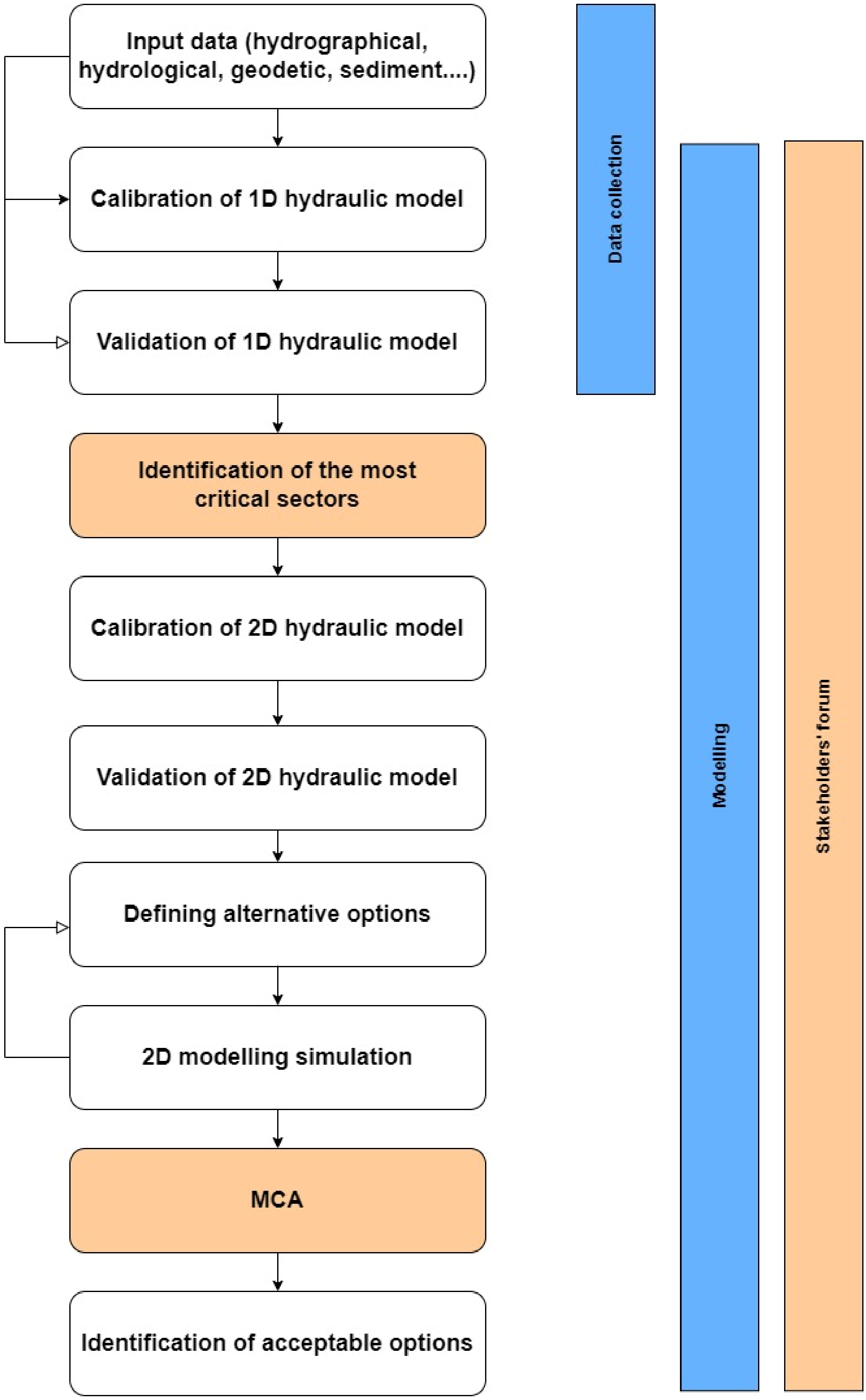

Figure 2: Flowchart of the modeling process

4. MCA definition

The primary goal of the project on Monitoring and Modelling of the Croatian-Serbian common Danube section is to define the most suitable alternative option to improve navigation conditions on the shared stretch of the Danube between Serbia and Croatia. The final result of the project is a Study of Alternative Solutions and Recommendations for Future Investments. All proposed and analyzed alternative scenarios will be designed to ensure safe navigation on this common section of the river. The multi-criteria analysis will assess the impacts of the proposed measures on ecological parameters in the joint sector of the Danube, as well as the economic indicators of the proposed measures (scenarios). That is a reason why the criteria used in this project are categorized into three groups: Navigation, Environment, and Feasibility. The selected criteria stem from important goals related to improving ecological parameters, as well as the economic sustainability of the solutions.

The multi-criteria analysis for selection of the optimal scenario for each sector shall be defined and agreed in order to rank alternative scenarios for improving navigation conditions along the common Serbian-Croatian sector of the Danube and "Do-nothing" scenario that represent scenario without interventions (structural or non-structural, operational or maintanance). This scenario will serve as a basis for evaluating alternative solutions. In this process, for some criteria from the first two groups of criteria, improvements in navigation parameters and selected ecological parameters will be required compared to the 'Do-nothing' scenario, which means that lower limits will be introduced in terms of scoring. Thus, alternative solutions will need to meet minimum navigation conditions, but they will also need to ensure improvements in certain ecological parameters throughout their project lifespan (based on specific ecological goals).

All alternative scenarios will comply with the EU legislation and recommendations related to water and river basin management including the EU Water Framework Directive (WFD), Birds and Habitat Directive (BHD), EU Taxonomy, Danube commission, ICDPR documents, as well as relevant national legislation.

5. MCA methodology

The criteria defined in the MCA for this project are categorized into three groups: navigation, environment, and feasibility. Alternative scenarios will be ranked using the **Weighted product model** of Multi Criteria Analysis. For each sub-criterion, the indicator values for alternative scenarios and the "Do-nothing" scenario will be compared. These indicator values pertain to the estimated condition after implementing measures (either under alternative scenarios or "Do-nothing" scenario), using numerical simulations of 2D sediment transport.

"Do-nothing" scenario serves as the reference with a score of 1 in the multi-criteria analysis. If an alternative scenario receives a final score (obtained by multiplying scores across all criteria) less than 1, it indicates that this scenario is "worse" than the "Do-nothing" scenario. Conversely, if a measure under alternative scenarios receives a score greater than 1, it can be recommended for implementation. Naturally, the scenario with the highest score represents the "best" scenario.

The expression for the overall evaluation of an alternative solution will have the following form:

$$Total\ score = N_1^{0.30} \cdot N_2^{0.05} \cdot N_3^{0.05} \cdot E_1^{0.15} \cdot E_2^{0.05} \cdot E_3^{0.05} \cdot E_4^{0.05} \cdot E_5^{0.05} \cdot E_6^{0.05} \cdot F_1^{0.05} \cdot F_2^{0.10} \cdot C^{0.05}$$

where the terms denoted with *N, E, F* and *C* represent the scores for navigational (3 criteria), ecological (6 criteria), economic (2 criteria) and climate change aspects (1 criterion), respectively. The exponents in the expression are the weight coefficients assigned to each sub-criterion. All components of the product are adopted in the analysis based on expert judgment combined with quantitative data where available, which is explained through calculated values for quantitative indicators or assigned values for qualitative indicators related to the corresponding criteria. Summarized scores are given for criteria that encompass multiple indicators. The scores for criteria are provided based on expert consideration, as the indicators may overlap to a certain extent. Therefore, indicators within the same group do not have to be independent. The same applies to different criteria, for example, there is a relationship between the diversity of morphological forms and biodiversity (hydro-morphological indicators and indicators for living organisms are dependent).

Discrete values can be adopted for all variables: 0 – an unacceptable value that causes the entire solution to be rejected, so these solutions will not be ranked; 0.25 - a value indicating the least acceptable solution 0.5 – a value indicating moderate but acceptable deterioration compared to the "Do-nothing" scenario; 1 – a value indicating an unchanged state compared to the "Do-nothing" scenario; 1.5 – indicating moderate improvement; and 2 – significant improvement. Considering the specific navigational and ecological goals, for certain criteria, minimum acceptable values of 1 or higher are introduced (this will be explained in more detail in the description of the criteria).

6. Criteria

To explain why the weighting coefficients were selected as indicated, we can consider the priorities and objectives of the project. The coefficients reflect the relative importance of each criterion group, informed by past experience, expert input, and communication with decision-makers. Here is the reasoning for each category:

40% for navigation related criteria

- Reasoning: Improvement of navigational conditions is the primary focus in this activity, ensuring the safety, efficiency, and reliability of transportation. The criteria within this category (depth requirements, maneuverability, and safety) directly impact the usability of the waterway for vessels and are based on the recommendations of the Danube Commission (DC), European legislation and international treaties.
- Why 40%? This relatively high weight indicates the importance placed on improving and maintaining navigation standards, reflecting the countries' obligation to ensure Good Navigation Status. Projects in similar contexts likely prioritized navigation heavily due to its role in economic and logistic terms, and the whole EU transport policies, where the inland waterway transport is considered as environmentally friendly mode of transport. The high weighting for DC recommendations (0.30) reflects the critical role of physical waterway parameters for navigation. Lower weights for maneuverability (0.05) and safety (0.05) acknowledge their importance but subordinate them to channel dimensions.

40% for environment related criteria

- Reasoning: Environmental sustainability is a critical component of modern waterway projects, aligning with EU directives and global efforts to mitigate ecological impacts. The criteria include hydro-morphology, naturalness, sediment quality, and impacts on fauna and flora.
- Why 40%? Equal weight with navigation suggests a balanced approach where environmental considerations are as significant as navigation needs. This ensures that interventions are not only functional but also ecologically responsible. The higher weight for hydro-morphology (0.15) stems from its broad influence on ecosystem health and waterway stability. Equal weights (0.05) for naturalness, sediment quality, and biological aspects indicate a more balanced but less dominant consideration compared to hydro-morphology.

15% for feasibility criteria

- Reasoning: Feasibility, encompassing technical and financial aspects, is crucial for determining whether a proposed solution can be realistically implemented. Cost-effectiveness and execution capability are key to successful project delivery.
- Why 15%? While important, feasibility is secondary to the core objectives of navigation and environmental protection. However, it still carries substantial weight, as impractical solutions would undermine the project's viability. The higher weight for financial aspects (0.10) emphasizes cost considerations in decision-making. Technical aspects (0.05) are vital but often constrained by financial and environmental considerations.

•

5% for climate change vulnerability

- Reasoning: Climate change vulnerability addresses the adaptability and resilience of proposed measures in response to future climatic conditions. This is relatively new but growing focus in waterway management.
- Why 5%? Although essential, this criterion carries less weight than the others due to its more specific scope. Decision-makers may have prioritized immediate navigation and environmental needs over long-term climate adaptivity in this instance.

In Table 1, Table 2, Table 3 and Table 4 proposed criteria, indicators, acceptable scores and weighting coefficients are provided. The coefficients were proposed based on values previously applied in similar projects and communication with decision-makers.

Table 1: Criteria related to navigation

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
N_1	Maximal DC recommendations	Quantitative - Water depth ratio (width of 200 m used as reference value), Width ratio (water depth of 2.5 m used as reference value), Curve radius ratio	1.5 - 2	0.30
N_2	Maneuverability	Quantitative - Velocity ratio Qualitative - Hindrance	0.25 - 2	0.05
N_3	Safety	Qualitative - Visibility of the structures	0.25 - 1	0.05

Table 2: Criteria related to environment

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
E_1	Hydro-morphology	Quantitative - Riverbed volume ratio, SHDi ratio, Length of low flow channels ratio, Bankfull discharge water level difference, Near bank velocity ratio, bank erosion length ratio	0.25 - 2	0.15
E_2	Physical naturalness of solution	Quantitative - Number of structures difference and level of nature protection	0.25 - 2	0.05
E_3	Sediment and water quality	Quantitative - Dredging volume Qualitative - Effects on physical, chemical and biological parameters of water quality	0.25 - 2	0.05
E_4	Bird population	Qualitative - Aspects of nesting, wintering and foraging	1 - 2	0.05
E_5	Fish population	Qualitative - Aspects of spawning, migration, wintering habitats, growing and living	1 - 2	0.05
E_6	Flora	Qualitative - Creation of new areas for distribution	1 - 2	0.05

Table 3: Criteria related to feasibility

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
F_1	Technical aspects	Quantitative - Execution of works and Response time	0.25 - 1	0.05

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
F_2	Financial aspects	Quantitative - Investment and maintenance costs/avoided users costs as benefit	0.25 - 2	0.10

Table 4. Climate change related criterion

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
C	Climate change vulnerability	Qualitative - Aspects of exposure, sensitivity and resilience	0.25 - 2	0.05

In the following text, the presented criteria will be described in more detail, and examples of scores for scenarios involving structural and non-structural measures will be provided. It is important to note that the examples offer only indicative expected scores, which evaluate the impact of a certain type of structure on the analyzed indicators. These scores should not be generalized, as the impact of a solution depends not only on the type of structure but also on its dimensions and spatial position.

6.1. Navigation criteria

Alternative solutions presented in the study should enable safe and secure navigation, formally demonstrated by meeting navigability conditions within the adopted fairway limits of each sector, according to the criteria of the Danube Commission. However, some aspects of navigation cannot be formally evaluated through these conditions, so additional criteria are introduced into the MCA (Multi-Criteria Analysis) that directly or indirectly relate to additional recommendations concerning safe and unobstructed navigation.

The criteria used to demonstrate the achievement of navigation-related objectives are divided into three groups based on the possible range of acceptable values in the MCA (Multi-Criteria Analysis).

Maximal DC recommendations (N1): The first group includes criteria related to the recommendations of the Danube Commission in terms of navigation conditions. The ratings for this criterion N1 can should be greater than 1.0. Namely, considering that the primary goal of the project is to propose and analyze alternative solutions to improve navigation conditions, the score for this sub-criterion should be higher than 1. However, the project will also analyze the effects of measures aimed at enhancing naturalness, i.e., renaturalization measures, which will not necessarily address navigation conditions. In this sense, the MCA analysis, tailored to fit the project's modeling framework, will take on a broader significance.

Maneuverability (N2): The second group relates to hydrodynamic parameters that may make vessel maneuvering more difficult or easier. Ratings for this criterion (N2) may be less or greater than 1, depending on the occurrence of certain flow patterns. For example, changes in maximum velocities (higher or lower) compared to the reference state ('Do-nothing') or the occurrence (presence or absence) of sudden changes in flow pattern can influence navigability, thus being considered key obstacles or enablers for navigation.

Safety (N3): Finally, the third sub-criterion, for which a score N3 is given, concerns the expert evaluation of the risk of vessels colliding with structures (if they are part of the solution), and in the best-case scenario, this score can be 1 (meaning that additional risks are absent or negligible). A score of 0.5 for this criterion would indicate minimal risks and value of 0.25 the least acceptable risks.

6.1.1. Maximal DC Recommendations

Water depth ratio

The primary indicator of navigability is the water depth at the low water navigation level (defined for the Q94% discharge) within the fairway. To assess navigability, water depths within the fairway limits preadopted for each sector at the low navigation level after the implementation of measures are compared to the corresponding depths in the 'Do-nothing' scenario. The water depth ratio will be the ratio of the average minimum depths along the fairway for the alternative and the 'Do-nothing' scenarios. The minimum depths will be averaged based on the longitudinal profile of minimum depths in cross-sections.

Width ratio

Satisfying the minimum navigable depth at the low water navigation level (which is 2.5 m for the joint sector) can also be achieved outside the limits of the existing fairway. To evaluate this 'reserve,' a width ratio is introduced, which represents the ratio of the width where this depth requirement is continuously met for the alternative solution (at the low water navigation level) to the correspondingly defined width for the 'Do-nothing' scenario. As with depths, the average widths from the longitudinal profile will be compared.

Curve radius ratio

The curvature of the fairway is a parameter analyzed in scenarios where changes to the axis of the existing fairway are planned. The curve radius ratio will represent the ratio of the minimum designed radius to the existing radius in the sector.

6.1.2. Maneuverability

Velocity ratio

The flow velocity affects the maneuverability of the vessel, and consequently, the safety of navigation. The velocity ratio represents the relationship between the maximum calculated water velocity for the condition after implementing measures and the do-nothing condition. Maximum velocities will be checked within the range of the low, average and high-water navigation levels.

Hindrance

Within this criterion, the flow patterns that may facilitate or hinder navigation will be considered. The presence of changes in flow pattern will be examined, and an expert assessment based on results of numerical simulations will be made regarding how these flow patterns can affect the maneuverability of the vessel.

6.1.3. Safety

Visibility of the structures

This criterion takes into account the reduction of navigation safety due to the construction of river training structures. This risk, although minimal, is inevitably introduced by the construction of structures, even if they must be properly marked and registered in the river information system. Depending on the level of risk assessed by expert judgment, it may have a greater or lesser impact on navigation safety.

6.2. Environmental criteria

The proposed Multi-Criteria Analysis (MCA) builds on prior work in the navigation projects in Serbia (Consortium Witteveen Bos, 2013), in which criteria were divided into three groups (navigation, environment and feasibility) with more weight given to the first two groups (navigation and environment – 40% each). The suggested criteria, indicators, and weighting coefficients are based on values applied in similar projects and communication with experts, including those from Stakeholder Forum, and decision-makers.

An integrated planning approach and multi-criteria analysis of hydro-morphological alterations of a critical sector of the Danube and their impact on biota (fish, birds, flora) will give the most adequate and appropriate solution. Existing environmental documentation is collected and used. Regarding ecological status of this common sector of the Danube is estimated based on abiotic and biotic quality parameters as moderate according to WFD (Liška, Wagner, & Sengl, 2019).

The impact of the proposed solutions on the environment is assessed by evaluating the considered scenarios using the criteria related to:

- Hydromorphology;
- Naturalness of solutions
- Sediment and water quality;
- Fish population;
- Bird population;
- Flora;

In this group of criteria, there are also indicators for which alternative scenarios must not receive scores lower than those for the "Do-nothing" scenario. For the group of indicators that directly relate to wildlife (fish, birds, and flora), a score lower than the reference score (1.0) is not acceptable. For all other groups of indicators, scores ranging from 0.25 to 2.0 are possible.

6.1.4. Hydro-morphology indicators

Riverbed volume ratio

Using a coupled 2D model of free surface flow and sediment transport, the change in the geometry of the Danube riverbed will be simulated for the selected sectors. As a result of the numerical simulations, the change in riverbed volume (defined as volume bounded by provisional horizontal plane beneath the riverbed and the riverbed itself) will be obtained and compared for each alternative solution with the riverbed volume change in the "Do-nothing" scenario. Based on this comparison, the impact of the proposed measures on morphological changes will be assessed. Previous studies (including study conducted by Hidroing and Danube sediment study) indicate a trend of erosion in the joint sector; however, without an integrated assessment of the water and sediment regime, it is difficult to conclude to what extent this is the result of river training structures along the common sector, controlled (or even uncontrolled) sediment extraction or water regime changes influenced by management decision or climate changes.

River training structures aimed at deepening the riverbed improve navigational conditions through bed erosion but have negative ecological impacts by removing sediment from the riverbed, which is vital for aquatic life. This clearly creates a conflict between navigation needs and ecological concerns. However, sediment transport must also be viewed integrally from an ecological perspective, as sediment nourishes downstream areas. For instance, on the Danube section downstream of the joint Serbian-Croatian sector (Serbian free-flow sectors), erosion is even more pronounced. If measures to retain sediment were implemented solely within the joint sector, it would increase sediment deficits downstream. Considering the local nature of this project, it is recommended to positively evaluate measures that minimize changes in the riverbed volume and their impact on sediment regime alterations. This approach addresses not only ecological concerns but also the broader conflict of interest between navigation and ecology (Ausili et al., 2022). According to this approach, solutions that result in low values of riverbed volume changes compared to the "Do-nothing" scenario will be considered as favorable solutions since it will not have a significant impact on the sediment regime.

SHDi ratio

The Shannon diversity index is a measure of spatial unevenness of a certain attribute. When considering the riverbed in a horizontal plane, and assessing the presence of specific river forms, this index will reflect morphological diversity (Kidová, Radecki-Pawlik, Rusnák, & Plesiński, 2021), which is important for biodiversity. The SHDi index will be determined for low-flow conditions in each analyzed scenario, for the state after riverbed adjustment as a result of modelling. At low-flow levels, the following characteristic areas will be identified in the horizontal plane: areas under active flow, areas of stagnant water, river bars, and areas potentially covered by vegetation (areas that are not submerged during higher water levels). An example of the identification of these areas for two fictitious scenarios is given in Figure 3 and Figure 4.

The Shannon index will be calculated as follows:

$$SHDi = -\sum_{i=1}^{4} p_i \ln p_i$$

where pi is proportion of each area class in river main channel planform (as shown in figures, 4 area classes are used). pi is the proportion of each area class relative to the total area. The sum is taken over all 4 classes.

Higher values of this index indicate greater diversity of the analyzed forms and represent a more desirable outcome from the ecological perspective.

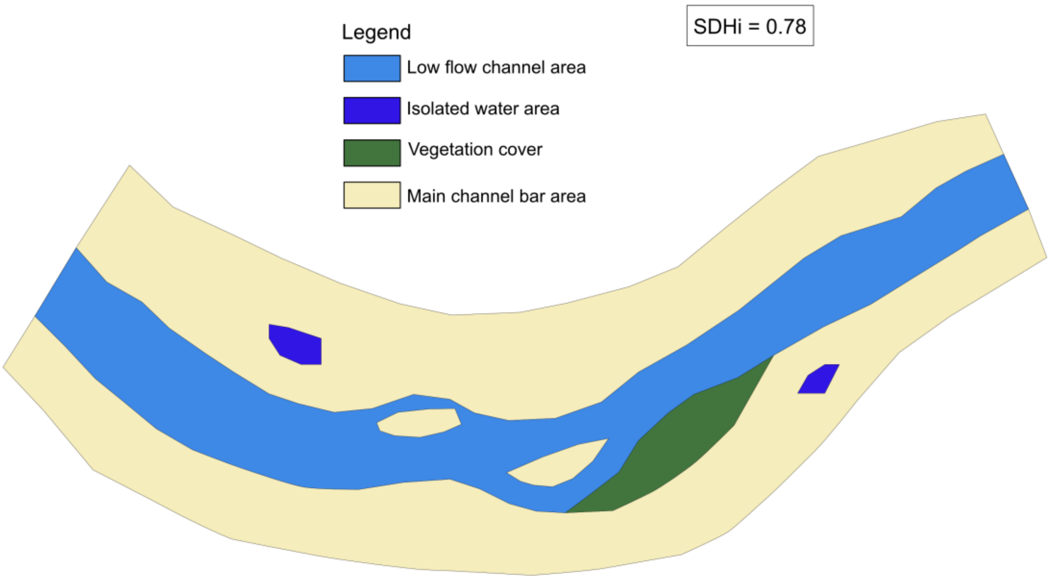

Figure 3: Characteristic areas after 2D sediment transport simulation for channel forming discharge (fictitious "Do-nothing" scenario)

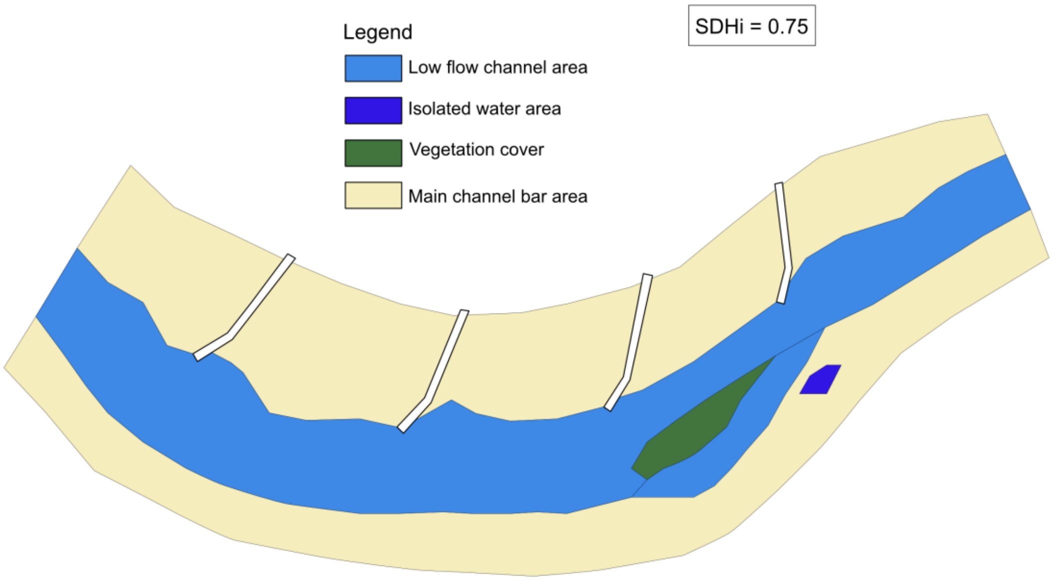

Figure 4: Characteristic areas after 2D sediment transport simulation for channel forming discharge (fictitious alternative solution with groynes)

In the example from the figures, a visual inspection suggests that the morphological diversity is greater for the "Do-nothing" scenario, which is also reflected in a higher SHDi value. Thus, in this case, due to the SHDi ratio, the assessment indicates a moderate negative change for the alternative scenario from a morphological perspective. Considering the importance of this indicator, the overall criterion for the alternative solution must receive a score of less than 1.0.

Length of low flow channels ratio

Given the ecological significance of low-flow conditions, an additional indicator is introduced to specifically evaluate the effect of the proposed solutions on the change in channel length under environmental flow, which can be determined based on input data used in hydrological study (e.g. GEP method can be used as obligatory method in Serbia). The value of the indicator is calculated as the ratio of the channel axis length for the alternative solution compared to the reference solution.

Water stage elevation difference for bankfull discharge

Due to the lack of input data for simulating river flow during flood events (as these analyses would exceed the scope of the project), the impact of the proposed measures on the high-water domain is assessed indirectly by comparing the calculated water surface elevations at bankfull discharge for the alternative and "Do-nothing" scenarios (at the upstream end of the critical sector modelled).

For a predefined discharge that approximately fills the main channel of the Danube (to be determined later as a result of numerical flow simulations), water levels for the "Do-nothing" scenario and alternative scenarios will be compared. Although the measures are not expected to have a significant effect within this discharge domain, an increase in water levels will be positively evaluated—considering the ecological importance of periodic flooding—as an indicator of a slight increase in the frequency of flooding.

Near bank velocity ratio

The previous indicator indirectly relates to sediment input into floodplains through advection. To also account for sediment transport via dispersion, albeit indirectly, a new indicator is introduced.

Generally, the lateral sediment inflow is proportional to the transverse gradient of velocities (and depths) in the channel during high water (Figure 5). This means that the inflow of sediment from the main channel to the floodplains will be greater if the differences in velocities in the main channel and floodplains are larger (same is valid for depth ratio). If these velocity differences decrease—e.g., by constructing groynes that reduce the depth in vicinity of the banks— then the velocity gradients will also decrease, leading to an expected reduction in sediment inflow and, consequently, lower sedimentation in the floodplains (Instead of sediment being transported into the floodplains, it may settle in groyne fields, reducing the sediment that reaches the floodplain). Given that the project does not have complete data on the geometry of the floodplain, the impact of alternative solutions on lateral sediment exchange can only be assessed indirectly. Therefore, based on the results of hydraulic analyses, flow velocities (and depths) along the banks will be compared for conditions after the implementation of alternative solutions and for the reference state ("Do-nothing") at bankfull discharge (the flow corresponding to the state just before water overflows from the main channel).

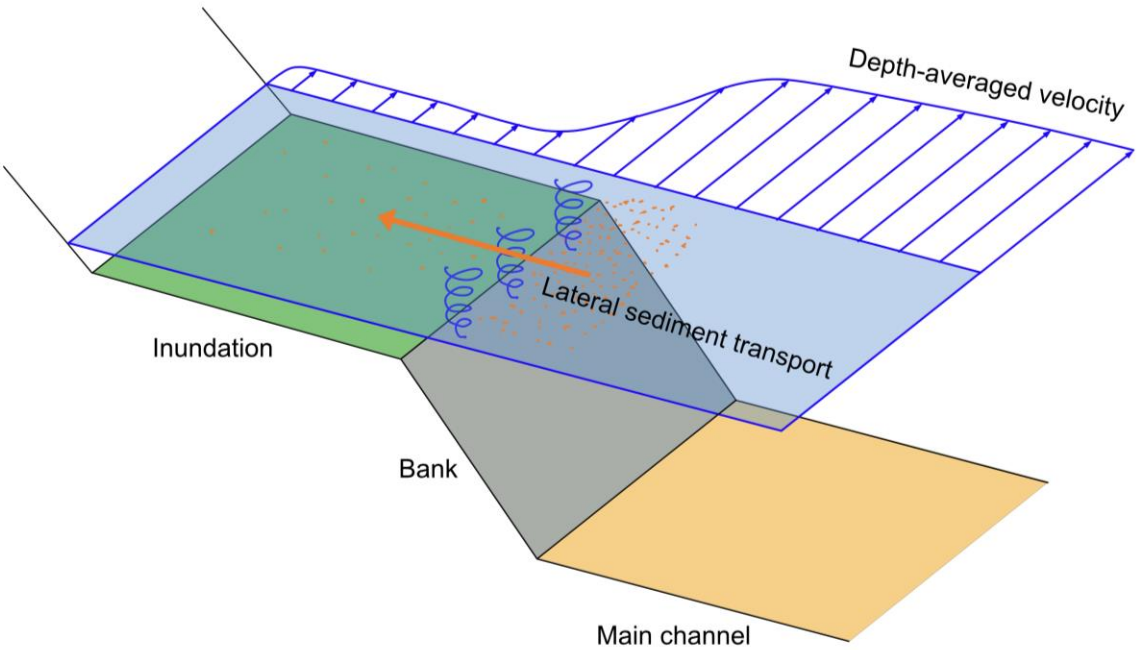

Figure 5: Lateral sediment exchange between main channel and floodplain

The length of the erodible bank ratio

An important aspect of lateral connectivity is the link between the main channel and the floodplains, which is expressed through river meandering. Since meandering can be modeled in the sediment transport simulation model to be used in the project, it will be assessed based on the length of the riverbank where meandering occurs in the numerical simulation. An increase in this length compared to the baseline scenario will be positively evaluated.

6.1.1. Physical naturalness of solution

Number of structures difference

As a specific indicator of the natural appearance of the riverbed, an additional indicator is introduced to evaluate the presence of river training structures. A reduction in the number of structures compared to the baseline scenario is positively assessed.

This indicator can also be linked to another aspect of the connectivity between floodplains and the main channel, manifested through aquatic-terrestrial fluxes that are not directly a result of flooding. River training structures may have a negative ecological impact by disrupting these fluxes (Figure 6).

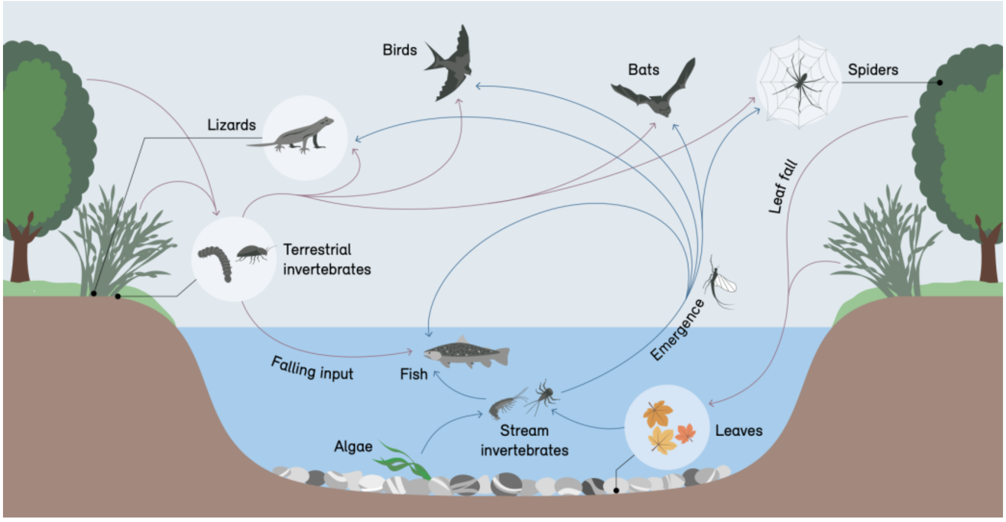

Figure 6: Illustration for aquatic-terrestrial fluxes (Baxter, Fausch and Saunders 2005)

Level of nature protection

This indicator complements the previous one as it considers the specificity of the area where interventions are proposed, i.e., it accounts for the change in the number of structures from the perspective of ecosystem protection. This means that the change in the number of structures will have a greater impact on the evaluation (positive or negative, depending on whether the number decreases or increases) if the area where the measures are proposed is designated as a zone of special significance from the perspective of nature protection.

6.1.2. Sediment and water quality indicators

Dredging volume

Dredging is a measure that is standardly applied as part of the maintenance of fairways. However, although this measure ensures the required dimensions of the fairway, it introduces certain ecological risks due to direct destruction of fish habitat areas or the mobilization of pollutants. Additionally, since the geometry of the flow is altered, the degree of implementation of this measure can have a greater or lesser (additional) impact on the sediment regime. In the MCA (Multi-Criteria Analysis), the necessity of including this measure in the solution (scenario) is negatively evaluated and removal from river system will be considered as unacceptable. The negative contribution to the score for the category “Sediment and water quality” will be assessed based on expert evaluation, considering the volume of material to be dredged.

Water quality parameters

The project does not include mathematical modeling of the impact of solutions on water quality parameters, but all aspects of water quality will be considered, and a qualitative assessment of this impact will be provided based on expert evaluation. In the assessment, other indicators used in the MCA (primarily hydro morphological) will be taken into account, as well as the characteristics of river training structures if they are part of the solution.

6.1.3. Bird population indicators

Considering both ecological indicators in bird population (nesting, wintering and foraging), negative effect of some hydro-morphological alterations can be manifested through the lack of connection of habitat with the surrounding environment. Some changes in river morphology can be characterized as positive, by establishment of shelters for certain bird species.

The scores for the impact of the solutions on the bird's population will be:

- the "do-nothing" scenario has the value 1;
- with improvement (expert judgment combined with quantitative data where available) the value increases from 1 to 2;
- significant deterioration disqualifies the solution (the solution needs modification).

Nesting

During nesting, all bird species related to the Danube banks and floodplains, all representatives of the orders Anseriformes, Charadriformes, Ciciniformes, and from birds of prey the white-tailed eagle will be taken into account (Table 5).

Table 5: Selected bird species for MCA in terms of nesting

	Nesting
Waterfowls	Anseriformes (Aythya ferina, Aythya fuligula, Anas crecca, Tadorna tadorna, Branta leucopsis, Cygnus cygnus)
Cormorants	Suliformes fam. Phalacrocoracidae (Phalacrocorax carbo, Microcarbo pygmaeus)
Herons, storks and ibises	Ciconiformes fam. Ardeidae (Ardea cinere, Ardea alba, Arde purpurea, Ardeola ralloides, Nicticorax nicticorax, Ixobiychus minutus, Egretta garzetta, Botaurus stellaris), Ciconiidae (Ciconia nigra)
Wader	Charadriformes fam. Charadriidae
Rails	Gruiformes fam. Rallidae
Roller, bee-eater, kingfisher and and sand martin	Coraciformes (Alcedo athis,Merops apiaster), Passeriformes (Riparia riparia)
Birds of prey	Falconiformes Accipitriformes (Haliaeetus albicilla, Milvus migrans)

Wintering

For the winter period, the impacts on the Anseriformes that live on the Danube and the white-tailed eagle will be analyzed (Table 6).

Table 6: Selected bird species for MCA in terms of wintering

	Wintering
Waterfowls	Anseriformes
Herons, storks and ibises	Ciconiformes fam. Ardeidae
Cormorants	Suliformes fam. Phalacrocoracidae
Rails	Gruiformes fam. Rallidae
Birds of prey	Accipitriformes (Haliaeetus albicilla)

Foraging

In addition to the nesting and wintering season, the Danube and surounding floodplain areas represents an important feeding area for a large number of birds (up to 20,000), primarily woterfowls, during spring and autumn migration. This aspect will also be taken into account.

	Foraging
Waterfowls	Anseriformes
Herons, storks and ibises	Ciconiformes fam. Ardeidae, Ciconiidae, Threskiornithidae
Wader, gulls and sandpiper	Charadriformes fam. Charadriidae, Laridae, Scolopacidae,
Rails	Gruiformes fam. Rallidae
Birds of prey	Accipitriformes (Haliaeetus albicilla, Milvus migrans, Circus spp.)

6.1.4. Fish population indicators

The fish population was selected as a reliable environmental criterion for MCA and the conservation status was the criterion for selection and analyses. Regarding the fish population which is present in the investigated sector of the Danube the numbered ecological indicators in MCA analysis takes in account fish species with high categories in threat status (IUCN, 2023), (EU Habitat directive, Croatian and Serbian legislations) recorded in critical sector of the Danube (OIKON, Hidroing, VPB, 2024).

Recorded fish species in critical sector of the Danube are classified according to ecological characteristics (habitat preference, feeding habits, and living) into 3 groups: Rheophils, Litophils and Limnophils & phytophils (Table 7).

Rheophils – fish species best adapted for living in flowing water, in current of water;

Litophils – fish species adopted for living on a hard river bottom (ruffe, balon`s ruffe, sander, schrätzer, gobies;

Limnophils & phytophils – fish species best adopted for living in slow and stagnant water.

T The most sensitive ecological indicators are spawning, migration and wintering. Any hydrological alteration or construction will impact fish population. Some can be positive, having in mind the possibilities that solutions will make suitable and good environment for certain fish species, mostly rheophils (physical diversity, compensation). On the other hand, some construction may have negative impact, by destruction or disappearance of habitats that are suitable for spawning, wintering or migration.

The scores for the impact of the solutions on the fish population will be given in the same way as for birds:

- the "do-nothing" scenario has the value 1;
- with improvement (expert judgment) the value increases from 1 to 2;
- significant deterioration disqualifies the solution (the solution needs modification).

Table 7: Selected fish species for MCA
(Legend: (R) – rheophils; (Li) – lithophils; (L&Ph) - Limnophils & phytophils)

Species name	Latin name	Status (IUCN)	Status (SRB)	Status (HR)	EU Habitat Directive
Asp (R)	*Aspius aspius*	LC	P	LC	Annex II, V
Common barbel (R)	*Barbus barbus*	LC	P	LC	Annex V
Balkan loach (L&Ph)	*Cobitis elongata*	LC	SP	VU	Annex II
Loach (L&Ph)	*Cobitis elongatoides*	LC	SP	VU	Annex II
Danube bleak (R)	*Alburnus sava*	LC	SP	LC	
Balon's ruffe (L)	*Gymnocephalus baloni*	LC	SP	VU	Annex II, IV
Schreaetzer (L)	*Gymnocephalus schraetser*	LC	P	CR	Annex II, V
Ide (L&Ph)	*Leuciscus idus*	LC	P	VU	
Common chub (R)	*Squalius cephalus*	LC	P	VU	
Cactus roach (R)	*Rutilus virgo*	LC	P	NT	Annex II, V

6.1.5. Flora indicators

The evaluation of the solution in terms of its impact on flora will be conducted primarily by assessing morphological changes in the riverbed, which will be estimated based on the results of 2D flow and sediment transport simulations. An expert assessment will be provided regarding the potential for creating new areas for distribution.

Registered species of the flora that will be analyzed along critical sectors are:

- 91E0* Alluvial forests - Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) - Populus alba, Populus nigra, Salix alba, Rubus caesius, Carex elata, Carex remota, Carex riparia, Galium palust, Polygonum hydropiper, Rumex sanguineus;
- 3130 Oligotrophic to mesotrophic standing waters with vegetation - Lindernia dubia, Eleocharis acicularis, Cyperus michelianus, Lythrum portula;
- 3150 Natural eutrophic lakes with Hydrocharition or Magnopotamion type vegetation - Lemna spp., Spirodela polyrhiza, Utricularia vulgaris, Azolla filiculoides, Salvinia natans (emerged plants);
- 3270 Rivers with muddy banks - Bidens frondosa, Bidens tripartitus, Polygonum hydropiper, Potentilla supina.

The scores for the impact of the solutions on the flora will be given in the same manner as for fish and birds:

- the "do-nothing" scenario has the value 1;
- with improvement (creating new areas for distribution) the value increases from 1 to 2;
- significant deterioration disqualifies the solution (the solution needs modification).

Listed habitat types NATURA 2000, with regard to its ecological characteristics, is a list of typical and indicator species that were recorded along the critical sections of the Danube. NATURA 2000 floodplains are sensitive to changes in the water level and the natural river hydromorphological dynamics. The flora of the Natura 2000 habitat types was included in this analyses.

6.3. Feasibility criteria

The project considers the technical and economic feasibility of the solutions. In terms of technical aspects, the time needed for a solution to show its effects and the difficulty of implementing the measures are evaluated. For the economic feasibility of the project, the ratio of economic benefits to costs is considered. As with other criteria, the assessments are based on indicators through which alternative solutions are compared with the "Do-nothing" scenario.

6.1.6. Technical aspects

Construction of works

Within the technical aspects, the score will be further reduced for structural measures whose execution is complex (precise positioning of the structure, underwater construction, use of different types of materials (Consortium Witteveen Bos, 2013). If any structural solutions are complex in this regard, the score for that solution will be further reduced, meaning the scenario being considered will receive a score of 0.25 for the technical aspects.

Response time

The evaluation of measures cannot be based solely on their effects, as the time required for these effects to manifest (or be proven) can vary significantly and influence many indicators of project success. Therefore, in this project, measures are assessed according to this time factor. The highest score of 1.0 is given to the zero alternative and those non-structural measures that do not require complicated implementation procedures (e.g., fairway realignment). Structural measures require a series of steps, including the development of technical documentation and the construction of structures. An additional issue is the inability to predict the time after which river structures will show their effects (with uncertainty in estimating the effects themselves). Since this time is significantly longer for structural measures in any case, all scenarios involving such measures will receive a score no higher than 0.5 for the Technical aspects criterion group.

6.1.7. Financial aspects

Investment and maintenance costs/avoided users costs as benefit

The financial aspects of the alternative solutions will be compared with the financial indicators of the "Do-nothing" scenario. Through analysis of all alternative solutions, the difference between the benefits and the costs of the measures will be assessed. Benefits will be calculated as the avoided costs for fairway users due to the extended navigation period (if it is estimated to be extended) compared to the "Do-nothing" scenario. In this way, positive values of the benefit-cost difference will indicate solutions that are financially better than "Do-nothing," and such scenarios will be evaluated with a score of 1.5 or even 2. Conversely, scores between 0.25 and 1.0 may be given.

6.4. Climate change vulnerability

The impact of climate change on changes in the water and sediment regime is beyond the scope of the project, but the vulnerability of navigation and ecosystems to climate change will be qualitatively addressed, taking into account aspects of exposure (through the identification of affected categories), sensitivity and resilience across all scenarios, considering the vulnerability assessment of the "Do-nothing" scenario as the reference state. The sensitivity of the solutions to climate change will be evaluated based on the analysis of the sensitivity of the effects of the solutions to changes in hydrological inputs, while resilience will be assessed based on the potential for modifications to the solutions over time.

7. Numerical Example of MCA

The scenarios mentioned—"Do nothing," "Groyne system," and "Fairway realignment"—are **not preselected or definitive choices for the project**. Instead, they represent an initial framework or examples of potential scenarios to be assessed during the project's evaluation phase.

The project aims to comprehensively explore a range of options to address the objectives and challenges. These scenarios serve as examples to improve understanding of how MCA works. It is the starting point to frame the discussion and analysis, while ensuring that a variety of strategies are considered, including innovative or hybrid solutions. In this context, the **mentioned scenarios are merely illustrative**.

Scores for the criteria - Navigation

Scenario / Indicators - Subcriteria	"Do-nothing" (Reference values/state)	Groyne system (Indicators -> **Score**)	Fairway realignement (Explanation -> **Score**)
Water depth	ref. value: $\overline{H}$ = 2.45 m *Comment: DC recommendation is not met*	*ratio* = 1.08 ($\overline{H}$ = 2.65 m)	*ratio* = 1.04 ($\overline{H}$ = 2.55 m)
Width	ref. value: $\overline{B}$ = 170 m *Comment: DC recommendation is not met*	*ratio* = 1.10 ($\overline{B}$ = 187 m)	*ratio* = 1.07 ($\overline{B}$ = 182 m)
Curve radius	ref. value: $\overline{R}$ = 1300 m	*ratio* = 1.00 ($\overline{R}$ = 1300 m)	*ratio* = 0.95 ($\overline{R}$ = 1240 m)
N_1 - Maximal DC Recommendations	**1.0**	**2.0**	**1.5**
Velocity	ref. value: $\overline{V_{max}}$ = 1.70 m/s	*ratio* = 1.03 ($\overline{V_{max}}$ = 1.75 m/s)	*ratio* = 1.00 ($\overline{V_{max}}$ = 1.70 m/s)
Hindrance	ref. state: No sudden change in flow pattern	proj. state: No sudden change in flow pattern	proj. state: Moderate changes in flow pattern
N_2 - Maneuverability	**1.0**	**1.0**	**0.5**
Visibility of the structures	ref. state: There are four groynes on the sector with same crest level = DLNL + 1m	proj. state: Additional four groynes with crest level = DLNL + 1m (slightly increased risk of accidents)	New marking works will be conducted
N_3 - Safety	**1.0**	**0.5**	**1.5**

Environment

Scenario / Indicators - Subcriteria	"Do-nothing" (Reference values/state)	Groyne system on convex side of the bend (Indicators -> **Score**)	Fairway realignement (Explanation -> **Score**)
River bed volume	ref. value: $V = -88500$ m^3	*diff.* = -7000 m^3 ($V = -95500$ m^3)	*diff.* = 0 ($V = -88500$ m^3)
SHDi	ref. value: $SHDi$ = 0.78	*ratio* = 0.96 ($SHDi$ = 0.75) Negative mpact on biodiversity (living organisms negativelly affected including macroinvertebrate)	*ratio* = 1.0 ($SHDi$ = 0.78)
Length of LF channels ref. value/ratio	ref. value: L_{lf} = 250 m	*ratio* = 0.84 (L_{lf} = 210 m)	*ratio* = 1.0 (L_{lf} = 250 m)
$Z(Q_{bankfull})$	ref. value: Z = 90.00 m.a.s.l.	*diff.* = 1 cm (Z = 90.01 m.a.s.l.)	diff. = 0 m (Z = 90.00 m.a.s.l.)
Near bank velocity ratio	ref. value: V_b = 1.4 m/s	*ratio* = 0.64 (V_b = 0.9 m/s)	*ratio* = 1.0 (V_b = 1.4 m/s)
Bank erosion length ratio	ref. value: L_{be} = 2050 m	*ratio* = 0.95	*ratio* = 1.0 (L_{be} = 2050 m)
E$_1$ - Hydro-morphology	**1.0**	**0.25**	**1.0**
Number of structures difference	ref. value: 10	difference = +4 (aquatic-terrestrial fluxes can be disturbed with all 4 structures)	difference = 0
Level of protection	ref. state	5-Country biosphere reserve	*no changes*
E$_2$ - Naturalness of solution	**1.0**	**0.25**	**1.0**
Dredging volume	n.a.	n.a.	n.a.
Water quality parameters	n.a.	slightly negative effects since local stagnant water introduced	*n.a.*
E$_3$ - Sediment and Water quality	**1.0**	**0.5**	**1.0**
Nesting	ref. state	no changes if groyne system is proposed along shallow banks/ negative effect for steep banks	*no changes*
Wintering	ref. state	n.a.	*no changes*
Foraging	ref. state	n.a.	*no changes*
E$_4$ - Birds	1	**1 / 0**	**1**

Scenario / Indicators - Subcriteria	"Do-nothing" (Reference values/state)	Groyne system on convex side of the bend (Indicators -> **Score**)	Fairway realignement (Explanation -> **Score**)
Spawning	ref. state	n.a.	*no changes*
Migration	ref. state	n.a.	*no changes*
Growing	ref. state	sheltered	*no changes*
Living	ref. state	negative due to siltation	*no changes*
Wintering habitats	ref. state	n.a.	*no changes*
E_5 - Fish	**1.0**	**0.5**	**1.0**
Creation of new areas for distribution	ref. state	no significant change	*no changes*
E_6 - Flora	**1.0**	**1.0**	**1.0**

Feasibility

Scenario / Indicators - Subcriteria	"Do-nothing" (Reference values/state)	Groyne system (Indicators -> **Score**)	Fairway realignement (Explanation -> **Score**)
Response time ref. value/ratio	*no response time*	*long period*	*short period*
Execution of works	without executon works	moderate difficulty	improving marking system (simple implementation)
F_1 - Technical aspects	**1.0**	**0.25**	**1.0**
CBA ref. value/ratio	<0	*significantly higher B-C*	*higher B-C*
F_2 - Financal aspects	**1.0**	**2.0**	**1.5**

Climate change

Scenario / Indicators - Subcriteria	"Do-nothing" (Reference values/state)	Groyne system (Indicators -> **Score**)	Fairway realignement (Explanation -> **Score**)
Aspect of sensitivity	ref. state	*moderate sensitivity*	*no changes regarding reference state*
Aspect of resilience	ref. state	*moderate adaptivity*	*no changes regarding reference state*
C - Climate change vulnerability	**1.0**	**0.5**	**1.0**

Total score

	Group score for navigation	Group score for environment	Group score for feasibility	Group score for climate change	**Total Score**
"Do-nothing"	1.00	1.00	1.00	1.00	**1.00**
Groyne system	1.19	0.71	1.00	0.97	**0.81**
Fairway realignement	1.11	1.00	1.04	1.00	**1.16**

The solutions ranked by total score:

1. Fairway realignment
2. "Do-nothing"
3. Groyne system

8. References

Ausili et al. (2022). *Integrated sediment management. Guidelines and good practices in the context of the Water Framework Directive.* COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC).

Baxter, C. V., Fausch, K. D., & Saunders, W. C. (2005). Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. *Freshwater Biology*, 201-220.

Consortium Witteveen Bos. (2013). *Preparation of Documentation for River Training and Dredging Works on Selected Locations along the Danube River: Multi Criteria Analysis, BoQ and conceptual designs.* Feasibility study, Belgrade.

IUCN. (2023). *The IUCN Red List of Threatened Species. Version 2023-1.*

Kidová, A., Radecki-Pawlik, A., Rusnák, M., & Plesiński, K. (2021). Hydromorphological evaluation of the river training impact on a multi-thread river system (Belá River, Carpathians, Slovakia). *Scientific Report*.

Liška, I., Wagner, F., & Sengl, M. (2019). *Scientific Report: A Shared Analysis of the Danube River. Joint Danube Survey 4.* ICDPR.

OIKON, Hidroing, VPB. (2024). *Monitoring of the hydrological, hydraulic and morphological characteristics of the Danube River and inventory of biodiversity components on the joint Croatian-Serbian sector of the Danube River.*