Co-funded by the European Union

CRISTAL

CLIMATE RESILIENT AND ENVIRONMENTALLY SUSTAINABLE TRANSPORT INFRASTRUCTURE, WITH A FOCUS ON INLAND WATERWAYS

[D 1.2 Stakeholders Evaluation and Key Innovative Technology Assessment]

CRISTAL - Climate resilient and environmentally sustainable transport infrastructure, with a focus on inland waterways

Document summary information

Grant Agreement No	101069838	**Acronym**	CRISTAL
Full Title	Climate resilient and environmentally sustainable transport infrastructure, with a focus on inland waterways		
Start Date	01/09/2022	**Duration**	36 months
Project URL	http://www.cristal-project.eu/		
Deliverable	Stakeholders Evaluation and Key Innovative Technology Assessment		
Work Package	WP1		
Contractual due date	31/11/2022	**Actual submission date**	21/12/2021
Type	R	**Dissemination Level**	PU
Lead Participant	Fraunhofer		

Revision history (including peer reviewing & quality control)

Version	Issue Date	Complete %	Changes	Contributor(s)
V0.1	19.01.2023	10%	First structure	Ralf Fiedler, Fraunhofer
V0.2	01.02.2023	25%	Key technology clusters	Sonia Giovinazzi; ENEA
V0.2	03.02.2023	30%	SWOT French pilot site	Stéphane Gastarriet; VNF
V0.3	09.02.2023	35%	SWOT Italian pilot Site, IV	Andrea Ballarin, IV
V0.3	10.02.2023	40%	SWOT Polish pilot site, UniGda	Ernest Czermański, UniGda
0.4	10.02.2023	50%	PESTEL Analysis for Political and Environmental	Ralf Fiedler, Fraunhofer
0.5	20.02.2023	60%	PESTEL Analysis for Economic and Legal	Tsolakis Orestis, Certh
0.6	22.02.2023	80%	Consolidation of all input, conclusions, and summary	Ralf Fiedler, Fraunhofer
0.7	23.02.2023	90%	Input to PESTEL re. Social and Technological	Ola Qasseer, KTI, Sonia Giovinazzi; ENEA
0.9	24.02.2023	97%	Review	Elvina Nowak, ETP-Alice
1.0	24.02.2023	100%	Incorporation of review suggestions	Ralf Fiedler, Fraunhofer

List of abbreviations

Abbreviation/Term	Description
AE	Acoustic Emission
AGN	Agreement on Main Inland Waterways of International importance
Aipo	Agenzia Interregionale per il fiume Po
CEP	Courier Express Parcel
EPRS	Directorate-General for European Parliamentary Research Service
EU	European Union
FOS	Fiber Optic Sensors
GA	Grant Agreement
IV	Infrastrutture Venete S.r.l
IWT	Inland waterway transport
KET	Key enabling technologies
KPI	Key performance indicator
LNG	Liquid Natural Gas
NST	Standard goods classification for transport statistics
PESTEL	Political, Economic, Social, Technological, Environmental and Legal
PLC	Programmable Logic Controller
SB	Smart Buoys
SCADA	Supervisory Control and Data acquisition
SDG	Sustainable Development Goals
SHM	Structural Health Monitoring
SIR	Subsurface Inspection Radar
STOA	Scientific Foresight Unit

tkm	Tonne-kilometres
TRL	Technology Readiness Level
UN	United Nations
VNF	Voies navigables de France

Disclaimer

Copyright message

Table of contents

1. Executive Summary

The main goal of this deliverable is to provide the result of the research undertaken in the tasks 1.3 and 1.4.

This entails

- an assessment of possible risks and opportunities of the stakeholders involved. The analysis is carried out through a SWOT analysis. Following a proposal made in other WPs in Cristal, the group of stakeholders is restricted to the core group of infrastructure operators. In that respect Cristal follows a pragmatic stepwise approach not to enlarge the group of stakeholders to more users of IWT in this early stage of the project.
- Definition of technology clusters of the technologies to be deployed assessed through a PESTEL-Analysis.

The SWOT Analysis of the different pilot sites reveals that all infrastructure operators have assessed their strengths in the areas of the available budgets and recognition of the importance of the inland waterway mode of transport by the respective responsible ministry.

The weaknesses include the ageing infrastructure and the dimensioning of individual segments of the waterway or the locks. The external opportunities and risks most mentioned are the expectations of funds for infrastructure development and technological services, and the scepticism that these funds will be sufficient to maintain or repair the ageing infrastructure.

The external factors that represent opportunities for the stakeholders include new technologies, that are expected to make inland navigation more resilient and thus more reliable. Infrastructure resilience is expected to be increased by better modelling of hydrological conditions and the establishment of new services for users.

The threads include however climate change, which is mentioned above all, even if there is not much evidence that currently climate change effects the infrastructure operators already acutely.

The Cristal technologies have been grouped into the following technology clusters:

- Fiber Optic Sensors (FOS) Technology
- Smart Buoys (SB) System
- Subsurface Inspection Radar (SIR) Technology
- Acoustic Emission (AE) Technology

The Pestel Analysis shows that many factors must be considered for the deployment of the technology clusters. The use of fiber optic sensors, smart buoys, the Subsurface Inspection Radar system and the Acoustic Emission system in inland waterway transport is impacted by a variety of macro-environmental factors. These include political, economic, sociocultural, technological, environmental, and legal factors, all of which must be taken into account when assessing the potential success and growth of the industry. Investment and incentives from the European Union, as well as technological advancements, can help promote the use of new technologies to improve efficiency, safety, and sustainability of IWT. Additionally, legal considerations must be taken into account, such as standards[1], regulations, and legal principles in different countries, in order to ensure that the technology clusters are used ethically and responsibly.

1.1. Introduction

The CRISTAL project aims to increase the availability and attractiveness of inland waterway transport by implementing new technologies and processes. Pilot sites will be set up in three regions of Europe, which are not among the most developed for inland navigation. The project's goal is to shift the modal split in these regions by at least 20% in favour of inland navigation. This will be achieved through better data acquisition, improved plannability during extreme weather events, and better monitoring of the status of existing infrastructure.

Climate change has significant impacts on inland ports and IWT infrastructure, including water level fluctuations, more frequent and intense storms, and increased erosion. To address these challenges, infrastructure authorities can invest in more resilient infrastructure, regularly maintain, and repair existing infrastructure, and implement technologies to adapt to climate change impacts.

In summary, the CRISTAL project aims to enhance the resilience of inland waterway infrastructure to minimize downtimes and to provide synchromodal solutions to bridge unavoidable downtimes.

1.2. Mapping CRISTAL outputs

Table 1 Alignment of D1.2 contents to the corresponding GA deliverable & task(s) descriptions

CRISTAL GA Component Title	CRISTAL GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D1.2 Stakeholders Evaluation and Key Innovative Technology Assessment	*Stakeholders Evaluation and Key Innovative Technology Assessment*		*This deliverable combines the findings from the tasks 1.3 and 1.4. Del 1.2 carries out a SWOT analysis among the stakeholders. Additionally it lists technology clusters and evaluates them through a PESTEL Analysis.*
TASKS			

[1] EUR-Lex - 52021DC0324 - EN - EUR-Lex (europa.eu) / Flagship 2.

Task 1.3 Users and Stakeholders Evaluation	*Integration of relevant stakeholders inherent requirements*	*Chapter 2*	See above
Task 1.4 Key Innovative Technology Assessment	*Stakeholder-risk-analysis including operational and economic risks and benefits of stakeholders. Identification of key business players involved in the selected pilots; Priorities and expected "value-in-use" for stakeholders.* *Identification of the key technologies' clusters needed to achieve the vision* *PESTEL analysis per technology (cluster)*	*Chapter 3 and 4*	

1.3. Deliverable Overview and Report Structure

The purpose of WP1 is to develop an action plan by identifying relevant domains, processes, and stakeholders. The analysis conducted will contribute to defining research and development priorities for subsequent work packages, thereby minimizing both internal and external risk exposure.

The goal of the tasks 1.3 and 1.4 is to integrate the requirements of all stakeholders in relation to the project's strategic assumption, which is to develop resilient inland waterway infrastructure for transport. The main activity is to conduct a stakeholder risk analysis, particularly with regard to operational and economic dimensions.

The deliverable first provides the stakeholder risks and benefits, using a SWOT-analysis. The assessment of technologies then follows, according to their impact on different levels of society and the economy in the form of a PESTEL-analysis. These methods are used to evaluate the risks and opportunities that come with the CRISTAL project's engagement in the IWT sector.

2. Stakeholder risks and benefits - SWOT-analysis

A SWOT analysis is a well-established methodology mostly used for the analysis of companies to identify their internal Strengths and Weaknesses and external Opportunities and Threats. The acronym SWOT stands for:

- Strengths: characteristics of the business or project that give it an advantage over others
- Weaknesses: characteristics that place the business or project at a disadvantage relative to others
- Opportunities: external conditions that the business or project could exploit to its advantage
- Threats: external elements in the environment that could cause trouble for the business or project.

Table 2: SWOT methodology

	Helpful to achieving the objective	Harmful to achieving the objective
Internal origin attributes of the organization	Strengths	Weaknesses
External origin attributes of the organization	Opportunities	Threats

Here however the SWOT is not used to analyse a company or a governmental department, but the current situation of strengths and weaknesses - the internal factors - that decide how the infrastructure operators can cope with the overall CRISTAL project goal of a more resilient infrastructure and the opportunities and threats to identify the external factors which support, or which hinder them from progressing in that direction.

It includes operational and economic risks and benefits of stakeholders. Identification of key business players involved in the selected pilots; priorities and expected “value-in-use” for stakeholders. For better readability, the external opportunities and threats are divided into the categories political, economic, social, technological, environmental, and legal.

2.1.SWOT Analysis of the French infrastructure operator VNF

Strengths	Weaknesses
Responsiveness for crisis management through VNF as a state administration divided into different territorial units, bringing proximity to local stakeholders. France inland waterway logistics is increasing: +6.3 % in tkm compared to 2019 (in spite of recent crisis) High competitiveness, as a safe, inexpensive, available, and interconnected mode of transport Compared to other modes of transport, the price of large-scale inland waterway transport is the cheapest according to tkm. Compared to road transport, inland waterway transport produces five times less CO_2 emissions according to transported tons. French network availability is about 98 %, which is far superior to any other transport mode. Very limited risk of congestion. Inland waterway transport coupled with a floating stock, it is the best transport mode to face demand surges, it is the perfect mode for “just-in-time” supply chains. Safe mode of transport, as few thefts or accidents occur Increasing the length of the wide-gauge network to 2,200 km through several ongoing operations Expansion the length of the wide-gauge network to reach everywhere carrying capacities per trip ranging from 2,500 tons to 5,000 tons through several ongoing operations	IWT is often considered as too complicated. (Actors like forwarders are often not well informed about inland waterway transport.) The network is currently too limited to low waterclasses. IWT development would mean large gauge canals. It is ongoing but not ready for now (only 2000 km for now) Infrastructures are often in bad conditions (dating from the 60’s for large gauge and from the 19th century for small gauge) Maintenance is not optimized currently as it is controlled nationally. Often, VNF is not the owner but only the manager of the infrastructure. It limits the possibilities to comply with environmental issues.

Connection of the Seine (under construction Seine-North Canal Europe with the network of northern European rivers and canals (Expected 65 % increase in national transport volumes) New services are developed by VNF to make the network more user friendly and more efficient (EURIS, NAVI or CEDRE) Developing the resilience of its network for resilience to the increasing intensity and frequency of droughts through the management of 50 reservoir dams with a reserve of 150 million m^3	
Opportunities	**Threats**
Political	
Political decisions like the development of the infrastructure in Le Havre or Fos, or the modification of the prices in Dunkerque, with CMA CGM that erased part of the handling cost difference to equalize costs between all transport modes. A large number of ports in France are reaching the end of the concession period, enabling the possibility to enhance competitiveness.	With no financial autonomy and no multi annual programming, VNF's actions management is difficult.
Economic	
To enhance motorization and modernization, VNF has a budget of 100 m€ until 2030. Container transport growth, specifically on Seine basin is a potential source of development. Supply chain is improving enabling new clients to enter in the market.	French industry production is declining and under strong international competence, with the context of energy crisis and economic, social and environmental dumping of non-European countries. Road transport competitiveness increased since 1970. Part of the current fleet on inland waterway network is old and need to be modernized. To do so, 1000 m€ to 1500 m€ are necessary by 2030. VNF can finance 75 % of this cost, but 150 m. € to 300 m€ need to be found still.

	The latest crisis has impacted the supply chains, and might continue in the future. Energy price rises make pumping water for locks and canals much more expensive.
Social	
By a strong effort of pedagogy with the development of River-Learning training, and the support of important feeders and organizations like AUTF and TLF (sector organizations), new transport agents got into inland waterway transport, along with new shippers.	Limited recruiting and training resources.
Technological	
Development of various projects about alternative fuels, about green energies production, about energy consumption optimization, about autonomous vessels, about new logistics models in urban areas, etc.	Cybersecurity: outdated IT infrastructure of the VNF network that is not secure in terms of cybersecurity. In addition, an increase in cyber-attacks. Pumping water is required for some manmade canals, increasing the risk of supply failure
Environmental	
New politics of GHS emissions and climate change adaptation have been made by the government, VNF is modernizing its network in accordance with them, and water manager, many opportunities are available.	In the far future, 2070, some experts anticipate a general decrease of water flow, which would diminish the recharge between 10 % and 25 %. VNF needs to manage water flow. Flooding episodes are more and more violent, which increase risks on hydraulic structures. Environmental requirements complicate the realization of the VNF mission and can affect competitiveness. VNF noticed a rise in the invasive alien species, endangering small gauge canals.
Legal	

A new agreement has been made between VNF and SNCF réseau, the main railway operator in France, enabling multimodal transportation.	

2.2.SWOT of the Italian infrastructure operators IV and AiPo

Infrastrutture Venete Srl

Strengths	Weaknesses
Remote management of navigation locks and hydraulic barriers through video surveillance via SCADA (Supervisory Control and Data acquisition) as well as HMI (Human Machine Interface) systems Acquisition of data through water level sensors connected to a company server/similar sensors connected with PLC (Programmable Logic Controller) for process control/every minute. High level of accessibility of the infrastructure due to the free access. Periodic maintenance of infrastructure ensured by public funds, thus allowing fully functional infrastructure Constant water level maintained allowing favourable navigation conditions Interesting funding opportunities available for the development of cold ironing facilities Dynamic use of energy produced and available at cold ironing facilities (i.e. leisure, re-charging EV, maintaining temperatures…) Interventions to solve "bottlenecks" in progress to adapt the waterway to CEMT V class	(Limited) periods of restriction of navigability of the inland waterway due to either the high level of water or defective locks (average of 15 days/year). Still some bottlenecks to be solved hampering fully operative conditions (e.g. under bridge clearance). Physical accessibility to the waterway limited to vessels of maximum size about 110 m x 11 m x 3.5 m draft

Opportunities	Threats
Political	
	Temporary lack of the RIS (River Information Services) system, which is ready but not yet operational as the RIS directive must be implemented by the Ministry. Potential obstacles in realizing cold ironing facilities due to different requests Difficulties in establishing contracts/dialogue with territories to locally produced renewable energy to fuel cold ironing facilities.
Economic	
Presence of established interfaces (i.e. Port of Mantua and RRT of Rovigo) with other modes of transport (road, rail).	
Technological	
Development of a hydrological-hydraulic numerical model for the Fissero-Tartaro-Canalbianco basin by the Soil and Coast Defense Directorate of the Veneto Region. Cold ironing facilities connected with territorial potentialities would improve the attractivity of the infrastructure for different purposes. Plan of cold ironing facilities would be beneficial for any other similar areas to develop accordingly.	
Environmental	
	Impact of climate change on water levels based on extreme weather events, thus impacting the navigability of the canal, especially of the last stretch which is in direct contact with the sea.

	Presence of water discharges from the reclamation consortia into the inland waterway.

AiPo Interregional Agency for the Po River

Strengths	Weaknesses
Set up of monitoring tools to improve information on navigability. Creation of a shallow water forecasting model as a decision support system within the supply chain. Identification of alternative modes of transport in relation to the hydrometric conditions of the waterway. Availability of a hydrological-hydraulic numerical model for the Po River. Interventions to solve "bottlenecks" in progress to adapt the waterway to CEMT V class	Periods of restriction of navigability of the inland waterway due to either the high level of water or defective locks (average of 80 days/year). Still some bottlenecks to be solved hampering fully operative conditions (e.g., under bridge clearance) thus leaving a space for future increase of traffic. Physical accessibility to the waterway limited to vessels of maximum size about 110 m x 11 m x 3.5 m draft
Opportunities	**Threats**
Political	
	Temporary lack of the RIS system, which is ready but not yet operational as the RIS directive must be implemented by the Ministry
Economic	
Presence of established interfaces (i.e. Port of Mantua and Cremona, RRT of Rovigo) with other modes of transport (road, rail). Increase stakeholder interest in river freight transport.	
Social	
Improve and increase tourist navigation within a class Va waterway.	
Technological	
Development of a hydrological-hydraulic numerical moving-bed model for the Po River.	

Environmental	
	Impact of climate change on water levels based on extreme weather events, thus impacting the navigability of the Po, especially of the last stretch which is in direct contact with the sea. Presence of water discharges from the reclamation consortia into the inland waterway

2.3. SWOT of the Polish infrastructure operator Wody Polskie by Lukasiewicz and University of Gdansk

Strengths	Weaknesses
One entity performing the role of infrastructure authority Individual field units of State Water Holding Polish Waters have suitable housing and resources meeting legal and safety requirements, enabling statutory activities and facilitating project cooperation. Division into regional units Wody Polskie's division dealing with water user matters, including permits, fees, and cooperation in areas such as navigation, energy, industry, tourism, and recreation, supports the pilot project's objectives.	Infrastructure operator did not always manage to provide sufficient human resources for implementing tasks in the Water Law Act of 2017[2], which may cause delays or difficulties. Insufficient control of water management in the protection against floods may lead to delays in statutory activities. Infrastructure operator did not always manage to fully ensure proper maintenance and operation of State Treasury water facilities. Infrastructure operator reportingly has sometimes some difficulties regarding a timely handling of tasks related to water law consents and notifications, potentially causing difficulties and delays. Supervision over determining and enforcing fees for water services was not effective.
Opportunities	**Threats**
Political	
Adoption by the Council of Ministers of the Sustainable Transport Strategy 2030 Support for the development of inland waterway transport at the European level White Paper Plan to create a single European transport area	Lack of activity of local government and government authorities aimed at rebuilding and increasing the capacity of waterways in Poland Ineffectiveness of actions for the development of inland waterways in Poland, according to the report of the Supreme Audit Office
Economic	

[2] NIK, (2020b), Działania na rzecz rozwoju śródlądowych dróg wodnych, Departament Infrastruktury, Najwyższa Izba Kontroli: Warszawa

Ensuring the continuity of the network of connections in countries neighbouring the Polish transport network Availability of EU funds for the development of infrastructure River transport becoming an element of sustainable zero-emission transport Focus on reducing the intensity of road transport Advantages of inland waterway transport Trends in the use of river transport in container transport Development of seaports	Asymmetry of demand for transport directed mainly to road transport Obsolete means of water transport Conditions of profitability of inland waterway transport Regression of inland waterway transport of cargo
Social	
Development of opinions at the level of society Implementation of tasks within the third component of the Strategic Project until 2030 (socio-economic activation of the areas adjacent to the waterway and local development based on the new values of the river)	Protests by environmental circles
Technological	
Development of modern technologies and digitization of waterways Development of sustainable intermodal transport system Development of inland multimodal logistics centres Development of the CRISTAL Corridor Management System	Lack of implementation of programs for the development of inland waterway transport Segmental fulfilment of European standards for navigation on Polish rivers Limitations in bridge clearances Failure to adapt to new technologies of river ports of international importance in Poland
Environmental	
Quite favourable geographical conditions - the two main rivers, the Vistula and the Odra, connect the main economic areas of the country with seaports, which may contribute to the development of inland water transport. Availability of EU funds for investments in environmentally friendly forms of transport	Vistula River is not navigable along its entire length. Only the section of the lower Vistula up to the area of Włocławek and the section of the canalised Vistula in the vicinity of Kraków create conditions for the development of inland water transport.

2.4.Conclusion of the SWOT Analysis

It should be borne in mind, that the strengths and weaknesses identified here are self-assessments of the infrastructure operators. Therefore, the focus differs; while the operator of the French test site is also concerned with the general advantages of a supply chain via inland waterways and the perception in the logistics sector that does not correspond to this, their Italian colleagues focus primarily on their technological solutions and the improvement of these. In Poland, on the other hand, the evaluation was carried out externally because the infrastructure manager is not a project partner. Therefore, aspects are included there that mainly attribute the lack of development of the inland navigation sector in Poland, viewed from the outside.

The SWOT analysis shows that the 3 different pilot sites differ in the way they are equipped and regarding their possibilities. This difference is comparable to the ranking that we observe in the IWT volumes. Thus, the commitment of the French transport policy in favour of inland waterways seems the highest in our example, as the new canal between the Seine and the North Range ports illustrates.

In the case of the strengths, mentioned are, above all others, the aspects of the available budgets and the recognition of the importance of the inland waterway mode of transport by the respective responsible ministry. The Italian sites rely above all on their existing technological developments and their improvements, which facilitate the business of inland waterway users and reduce their costs. Examples include the plan to better predict water levels and sedimentation in the fairway and the plans to offer shore power stations for inland navigation.

Among the weaknesses, concerns about the outdated infrastructure dominate. This is exactly why CRISTAL wants to contribute with some of its solutions for preventive or predictive maintenance. Other weaknesses that are frequently mentioned include the dimensioning of individual segments of the waterway or the locks.

For the operators, the political opportunities and threats are the recognition by policymakers of inland navigation as a mean to achieve political goals such as emission reduction, decarbonisation or generally the cost-effective handling of supply chains. The Italian operators complain that the River Information Systems, although available, are not in use due to the lack of regulations by the government.

Economically we observe on the one hand the promise of funds for infrastructure development or the provision of funds for technological services, and on the other hand, the scepticism that these funds will not be sufficient to maintain or repair the ageing infrastructure. It is also welcomed that legislation on CO_2 taxes would favour inland navigation. The declining industrial production in Europe is seen by the French operator as a risk to achieve a good utilisation of the infrastructure.

Regarding social opportunities and risks, the operators' expectation is limited to better conditions for tourism on some inland waterways.

Regarding technological external factors, the positive expectations for the implementation of new technologies that make inland navigation more reliable for its customers predominate. Infrastructure resilience as such is, however, only one important topic among several. Resilience will also be increased by the availability of better modelling of hydrological conditions in the respective areas. It is also about applications for better information about current conditions on inland waterways, monitoring of inland waterways in terms of navigability and the establishment of new services for users who will, for example, operate electrically powered barges. As risks with technology, a possible vulnerability to cyber-attacks is mentioned. As already summarised under political, it is also a question of regulation whether available technology systems such as River Information Systems can be used. Energy-saving technologies are mentioned indirectly because the increase in energy prices means that operators of energy-intensive pumps for the locks will face considerable additional costs.

In the group of environmentally relevant factors, the expectations of climate change are mentioned above all, even if they remain very vague. For example, there are forecasts that announce a change in precipitation with a time horizon of almost 50 years, but as already laid down in Deliverable 1.1, we have no evidence that currently climate change effects the infrastructure operators already acutely. An exception to this, however, is the last very dry summer in Italy and elsewhere, where water had to be taken from canals for irrigation of agricultural areas, so that inland navigation was given lower priority in this conflict of use.

Under the aspect of legal opportunities and risks, agreements are mentioned with other operators from other modes of transport to cooperate more closely in the infrastructure development.

3. Identification of the Key Technology Clusters to achieve the CRISTAL vision

The CRISTAL project aims to achieve its vision by developing two key technologies:

- Resilient infrastructures: This involves the creation of comprehensive, real-time, and intelligent structural health monitoring and modeling systems for different segments or parts of infrastructures. The purpose of these systems is to support preventive and predictive maintenance, also known as knowledge-based maintenance. By optimizing maintenance and enhancing investment plans, the goal is to extend the asset life. The vision is to have smart and intelligent infrastructure equipped with self-diagnostic systems that can detect deteriorating conditions, expected failures, and intervention needs.
- Resilient navigability: This involves the development of comprehensive, real-time monitoring and modeling systems for the prediction of water levels and hydrological conditions. The aim is to create a more resilient inland waterway transport system by providing accurate and timely information on navigability conditions.

3.1. CRISTAL system architecture and technologies

Both the CRISTAL resilient navigability and resilient infrastructure key technology clusters will include:

1. The acquisition of both static and dynamic data, which will reside in a cloud-based infrastructure, such as a cloud-based communication middleware. This will be accomplished through the use of webservices or the development of ad-hoc connectors. Innovative sensors will be created as part of the CRISTAL project to acquire dynamic data.
2. Data analytics and artificial intelligence will be used to extract valuable insights from the data. These insights will be summarized as Key Performance Indicators (KPIs) related to resilient navigation and/or resilient infrastructure. The KPIs will be customized to meet the specific needs of different stakeholders and end-users and are designed to support various decision-making processes.
3. The KPIs for resilient navigation and/or resilient infrastructure will be presented in an accessible format, including GIS-based dashboards and apps, digital twins, and Building Information Modelling (BIM). These representations are intended to be easily usable for the stakeholders and end-users.
4. Integrated decision support services will be designed, integrating resilient navigability and/or resilient infrastructure KPIs within the synchro-modal platform (SCMS). These services will be co-created with CRISTAL River Pilots and made accessible via the similar means listed in point 3 above (e.g., dashboards, apps, BIM, DT).

Figure 1 represents the draft CRISTAL system architecture that was envisaged and included in CRISTAL Grant, where the aforementioned steps are referred to respectively as: 1) persistence layer; 2) middleware layer; 3) presentation layer and 4) service layer.

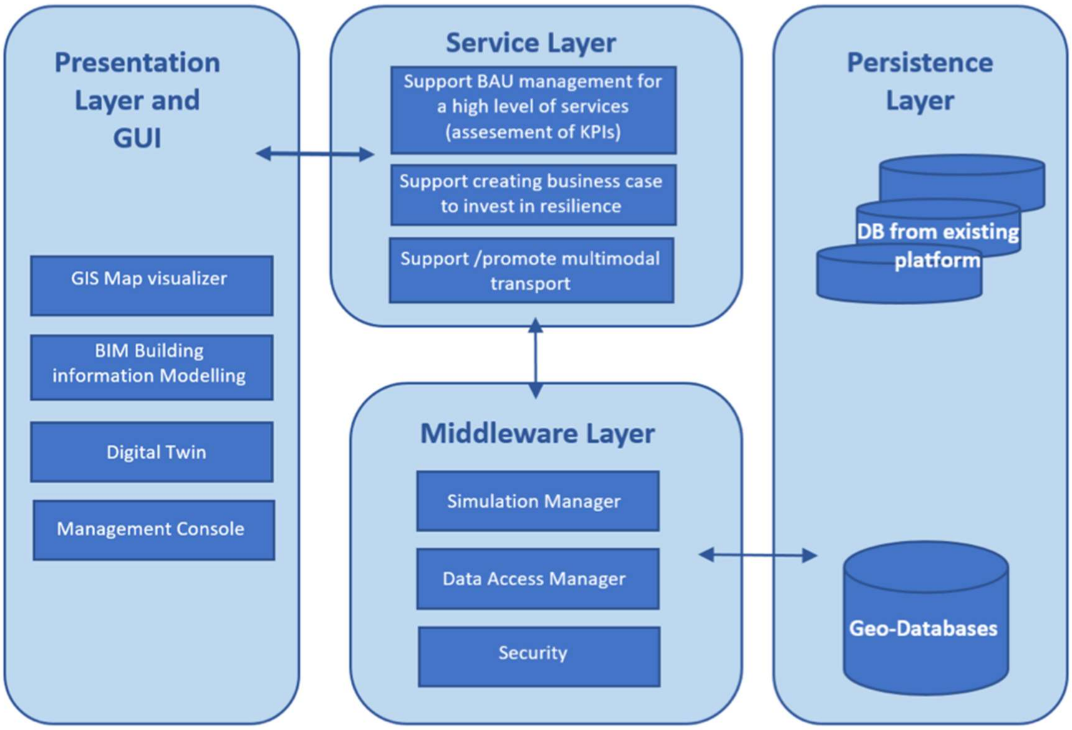


Figure 1: Draft CRISTAL system architecture

The draft CRISTAL system architecture originally envisaged in the Grant is under further elaboration as showcased in the figures reported in Annex 1. However, in this deliverable, reference is made to the simple and effective representation in Figure 1.

Table 3, extracted from D2.1, provides a concise overview of CRISTAL sensors and their envisaged use and proposed test pilots, either in terms of Resilient navigability or Resilient infrastructures.

Table 3: CRISTAL sensors: envisaged use and proposed test pilots

CRISTAL data generators	USE (Resilient navigability or Resilient infrastructures)	Test Pilots
Fiber Optic Sensors (FOS) Technology	Navigability of free-flowing waterways • real time and continuous monitoring of critical section lines	Po (Italy) and Vistula (Poland) partially free-floating
Intelligent Buoy System (IBS)	Navigability of controlled waterways • real time and continuous monitoring of controlled water-levels • localization of buoys	Poland

	• counting passing ships • environmental parameters like water depth, wind speed, current speed, water and air temperature and wind direction • Wireless communication with the buoys, ships and the	
Subsurface Inspection Radar (SIR) Technology	Preventive Maintenance - Inspection of engineered structures within scheduled maintenance procedures (i.e., structure of locks)	France
Acoustic Emission (AE) Technology	Monitoring, and Predictive[1] Maintenance on port's land assets (structures)	France

Table 4 identifies, extracted from D2.1, for the above-mentioned CRISTAL sensors, which kind of end-users might need them and their user needs.

Table 4: CRISTAL sensors: envisaged use and proposed test pilots

CRISTAL sensors	User needs	Possible End-users of resilient navigability and resilient infrastructures KPIs
Fiber Optic Sensors (FOS) Technology	Real time section profiling of critical sections within free-flowing waterways. Real time weight measurements of the sediments on the FOS equipped area. Profiling of critical sections based on the weight of sediments will be responsibility of the pilot.	Barge Operators Logistic Server Providers Infrastructure operators Calamity Abatement Operators
Intelligent Buoy System (IBS)	Real time and continuous monitoring of water-levels IWT traffic monitoring Environmental parameters monitoring Wireless (LPWSN) communication	Infrastructure operators Transport and environmental government agencies
Subsurface Inspection Radar (SIR) Technology	Inspection of dams (obligation), Inspection of locks. Visualisation of possible failings, assessment, and classification of the severity of failings to plan maintenance measures is a subsequent step that requires data processing.	Infrastructure operators

Acoustic Emission (AE) Technology	Automatic and low-cost monitoring of inland metallic port-based infrastructure or superstructure such as cranes, locks, pumps, large combustion machines, pistons, and many more. NDT Non Destructive Testing, SHM Structural Health Monitoring to support predictive maintenance of large land-based port structure. Assessment and monitoring only, grading of the defect severity and/or of the priority of interventions to avoid/mitigate the impacts is a follow up step requiring data processing	Infrastructure operators

Table 5 identifies for the same CRISTAL sensors, likely.

2)middleware layer;

3) presentation layer and;

4) service layer (numbering and working follows what represented in Figure 1 and listed above).

Table 5: CRISTAL Key technology clusters - from sensors to integrated services

CRISTAL sensors	*2) Middleware layer* Modelling for resilient navigability and resilient infrastructures KPIs	Representation of KPIs	Integrated Services (KPIs embedded in Syncro-modal platform for decision support
Fiber Optic Sensors (FOS) Technology	1st level Modelling – **data analytic modelling** – to go from weights measured by FOS to the drawing of the critical section profile 2nd level Modelling – **digital analytic modelling** and/or Artificial Intelligence modelling to obtain long-term prediction of navigability by integrating numerical simulation + real time data from existing sensors + real time data on weather nowcasting	Integration of navigability KPIs in RIS - Italy GIS dashboards and App Digital Twin	Interoperability with SCMS platform to minimize the disruption of the logistic process and normal operations in extreme weather and human caused events
Intelligent Buoy System (IBS)	Self-contained	Data provided source for Digital Twin	Interoperability with SCMS platform to minimize the disruption of the

			logistic process and normal operations in extreme weather and human-caused events. The data source of the requested information for S.C. management and decision processes
Subsurface Inspection Radar (SIR) Technology	Self-contained	BIM Building Information Modelling Integration in RIS - France GIS dashboards and Apps	Not expected
Acoustic Emission (AE) Technology	Self-contained	Digital Twin	Interoperability with SCMS to minimize the disruption to the logistic process and normal operations caused by: 1) damages and/or failures of engineering infrastructures; 2) regular maintenance processes

3.2.Supporting framework for CRISTAL key technology clusters

The Waterway Data Platform is integrating data from public and private sources across sectors to be used by everyone. This enables AI-enabled services to be developed and improves outcomes for waterways. To maximize the effectiveness of this platform, it is important to take an open and interoperable approach from the start by making sure the data from different sources is compatible. This bottom-up approach across the EU and beyond allows waterways to share technical solutions and creates a large market for small and medium-sized enterprises and start-ups. Security, trust, collaboration, and the involvement of stakeholders in the design are also essential components for this platform's success.

Building on the Minimum Interoperability Mechanisms (MIMs), commonly agreed standards should be used to achieve interoperability of data, systems, and platforms between cities, communities, and suppliers. If necessary, new standards, such as Fair AI, should be implemented.

To ensure successful digital solutions, it is important to develop the skills and capacity of local administration, facilitate knowledge sharing, and embed a citizen-centric approach to policymaking. Additionally, a framework should be developed and implemented to measure and monitor the benefits of digitalization for citizens, public authorities, businesses, and other stakeholders at the local level. Furthermore, legislative measures should be assessed to provide a common framework for cross-sector and cross-border digital solutions to cities and communities.

In terms of funding, the Digital Europe Programme (DEP), the Connecting Europe Facility (CEF), the Recovery and Resilience Facility (RRF), Regional Development Funds, and Horizon Europe should be explored. Additionally, shared public procurement practices should be used to define specifications and reduce the cost of investing in digital platforms and related technologies. Building on the Minimum Interoperability Mechanisms (MIMs) and the SynchroniCity project[3], commonly agreed standards should be used to achieve interoperability of data, systems, and platforms between cities, communities, and suppliers around the world.

If necessary, new standards such as Fair AI should be developed. It is also important to develop the skills and capacity of local administration, facilitate knowledge sharing, and embed a citizen-centric approach to policymaking. Additionally, a framework should be developed and implemented to measure and monitor the benefits of digitalization for citizens, public authorities, businesses, and other stakeholders at the local level. Furthermore, legislative measures should be assessed to provide a common EU framework for cross-sector and cross-border digital solutions to cities and communities.

To ensure a successful digital platform, it is important to explore EU funding opportunities for cities, including the Digital Europe Programme (DEP), the Connecting Europe Facility (CEF), the Recovery and Resilience Facility (RRF), Regional Development Funds, and Horizon Europe.

3.3. Timeline for checking acceptability and impact of the proposed technology cluster

A stepwise and gradual process is suggested in line with the CRISTAL project milestones.

During the Laboratory Testing phase (TRL 4-5), the innovation is analysed based on the design criteria identified during the Desk Study. Laboratory testing of the technical product is performed and, if necessary, simple semi-quantitative or more detailed qualitative evaluations of impacts (e.g., pollutant analysis) are conducted. A preliminary social acceptance check should also be completed which may be based on interactions with representative stakeholder groups.

During the Operational Testing phase (TRL 6-8), the innovation is analysed using the boundary conditions associated with the (intended) operational and market environment. This phase consists of analysing the PI under operational boundary conditions and demonstrating the performance of the innovation when

3

placed in a simulated operational environment and/or during real events. A more detailed impact assessment may be conducted using the existing conditions at the location. Additionally, social acceptance testing may be performed with stakeholders or end-users from the environment where the innovation is intended to be implemented. These tests represent a significant step in demonstrating the technical effectiveness and social readiness of the innovation. Financial, technical, educational and capacity building, monitoring and measuring, and legal measures should also be taken into account.

4. PESTEL analysis of technology clusters

A PESTEL analysis is a framework used to analyse macro-environmental factors that may affect a business or an organization. The acronym stands for Political, Economic, Social, Technological, Environmental, and Legal factors. The method is mostly used to identify potential opportunities and risks that may impact a company's operations and performance. It is often used in strategic planning and decision-making. Within this chapter, a PESTEL analysis is provided for the technology clusters deployed in CRISTAL.

To carry out a PESTEL analysis for the technology clusters, one researches and gathers information on each of these factors and assess their potential impact on the stakeholders – here, the infrastructure operators. This contributes to enhance the transparency regarding market conditions, trends, and potential risks and opportunities that come with the potential introduction of different technologies. The information gathered can be used to inform strategic planning and decision-making for the stakeholders.

Initially, an attempt was made to conduct a separate Pestel analysis for each of the individual technology clusters. However, it soon became apparent that a large number of the factors identified related to both the technology elements such as the fibre optic sensors or the smart buoys and other technology clusters are identical, because a Pestel analysis is also always a mirror of the framework conditions under which a technological development can take place. These framework conditions are often the same, so it was decided not to conduct individual analyses for individual elements.

A PESTEL analysis in the field of transport and logistics resp. technology clusters would involve evaluating the following factors.

4.1. Political

Important aspects in the introduction and diffusion of new technologies are the corresponding political framework conditions. Government policies and regulations are often related to transportation through measures such as tariffs, trade agreements, and safety standards. Furthermore, subsidies, public investment targets and other incentives can have a significant influence on the development of new technologies. In the case of technology elements such as sensors, for example, this could mean subsidising or taxing but mostly setting the standards for development of such technologies and later deployment. Incentives via publicly funded research and development projects are an essential factor in the innovation and introduction of new technologies.

It can be assumed that research funding and pre-competitive development will lead to new demonstrators. The extent and scope of funding will remain more or less at today's level. Incentives can also be of a non-monetary nature, e.g., campaigns or creating awareness to these kind of devices in IWT. Many of the applications for sensors might soon reach a technically mature level, where less to none state support is necessary.

However, political boundary conditions can also be set quite decisively at different levels.

Political factors for these technology clusters include:

- Governmental support for inland waterway transport in general. The government's level of support for the development and implementation of technologies such as fiber optic sensors or smart buoys can impact the growth and success of the whole industry.
- Trade agreements and regulations: The presence or absence of trade agreements and regulations between countries can affect the ease of transport of goods via IWT.
- Political stability and security are important factors that can impact the use of the four technology clusters, as they affect the overall reliability and safety of inland waterway transport.
- Encouragement for the use of smart technology in the transport sector.
- Publicly funded research and development projects are important for promoting innovation in new technologies like sensors and systems. As technologies mature, they may require less state support and become more self-sustaining.
- Government regulations on the single clusters to be used in IWT, e.g., permitted frequency bands, data protection regulations.
- Security and safety concerns for critical infrastructure such as IWT links
- Encouragement for technologies like fiber optic sensors or smart buoys deployment in rivers as IWT links to assure a real-time overview about sediments and changing shipping channel dimensions regarding depth and exact location.

4.2.Economic

EU economy has been recently hit by Ukraine war and sanctions towards Russia. Inflation and slow GDP growth may hamper transport investments, including for CRISTAL technology clusters. But EU's Green Deal[4] and Smart Mobility Strategy[5] set to increase funding for IWW development. EU aims to become climate neutral economy by 2050 and reduce transport emissions by 90% by then. Shifting freight from road to inland shipping and rail is a key element of this.

- The impacts of the Ukraine war on the EU economy are ongoing and the duration is uncertain.[6]
- The EU managed to avoid recession, but the energy shock and record high inflation are slowing down EU GDP growth, potentially hindering investment in transportation solutions. Economic growth and development can impact the demand for goods that are transported via waterways, which in turn affects the need for new technologies.
- Better usability of IWT to enhance and improve IWT as an environmentally friendly and economic mode of transport that saves costs for the users.
- The four technology clusters of CRISTAL may require funding for development and implementation. The availability of funding for research, development and implementation of new technology clusters can be a limiting factor.
- The cost of implementing technologies can be a significant factor in their adoption and usage in the industry.

[4] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[5] https://transport.ec.europa.eu/transport-themes/mobility-strategy_en
[6] https://economy-finance.ec.europa.eu/economic-forecast-and-surveys/economic-forecasts/winter-2023-economic-forecast-eu-economy-set-avoid-recession-headwinds-persist_en

4.3. Social

As new technologies emerge and continue to rapidly evolve, they inevitably affect various aspects of daily lives and businesses. Beyond the technical advancements, new technologies can have significant impacts on the social factors that shape our society. Technological advancements can alter our social behaviours and norms, leading to both positive and negative consequences. It is crucial to consider these social factors when developing and implementing new technologies to ensure that their impacts are both beneficial and equitable. General trends with the focus on IWT transports include:

- The proportion of older people (over age 65) is increasing in the European population from 2020 to 2050, resulting in a higher number of dependent and inactive people, which may impact logistics activities. Demographic changes, such as population growth and aging, as well as consumer preferences and behaviour can affect the demand for goods transported via waterways and thus the demand for new technologies.[7]
- The decline of multigenerational family models is leading to social isolation, and the active generation is under pressure to balance caring for older relatives and children while working, resulting in reduced job performance and limited willingness to take on high-pressure job positions or positions that require a large absence from the family.
- The labour-intensive nature of certain jobs in water transport makes it challenging to replace professionals, as vocational training is sporadic, and the career model is unattractive.[8]
- Jobs in transportation require long commutes, atypical working hours, and intermittent working locations, leading to higher labour costs, decreased productivity, shirking behaviour, and sickness absenteeism. However, earlier studies show high job satisfaction in the water transport sector compared to other transportation sectors.[9]
- EU population is well-educated, with a significant proportion having higher education. This is expected to make them more receptive to new technologies.
- E-commerce and smaller households are posing challenges for CEP logistics, with waterborne city logistics being a potential solution[10], which is however only a niche within a niche, since waterways are only useable in a very limited number of EU cities.
- Sustainability expectations are increasing, putting pressure on logistics companies to operate in an environmentally conscious way.
- People are increasingly committed to less polluting means of transport, making inland water transport a favourable option with appropriate service levels and technology.
- The attitudes of different communities and stakeholders towards technology can impact the acceptance and adoption of the four technology clusters in inland waterway transport.
- Awareness of the benefits of the four technological clusters in inland waterway transport

[7] https://www.eea.europa.eu/data-and-maps/figures/population-pyramids-for-europe-africa
[8] EC (2014) Employment, skills and working conditions in transport. JRC Scientific and Policy Reports
[9] José Ignacio Giménez-Nadal, José Alberto Molina, Jorge Velilla (2022) Trends in commuting time of European workers: A cross-country analysis, Transport Policy, Vol. 116, pp. 327-342.
[10] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Household_composition_statistics#Relative_differences_in_households_for_men_and_women.2C_young_people_and_older_people

4.4. Technological

Technological advancements have enabled the development of more reliable, scalable, and efficient systems, which can have a profound impact on businesses, governments, and individuals alike. Improvements in areas such as artificial intelligence, cloud computing, and the Internet of Things (IoT) have resulted in faster and more accurate data processing, increased security, and enhanced connectivity.

Key enabling technologies (KETs) are a set of critical technologies, which include advanced manufacturing, advanced materials, life-science technologies, micro/nano-electronics and photonics, artificial intelligence, and security and connectivity technologies. These technologies are essential for building an interconnected, digitalized, resilient, and healthier European society, as well as for enhancing the EU's competitiveness and position in the global economy.

To assess how the EU is performing in developing and protecting ownership and know-how in these crucial technologies, the Scientific Foresight Unit (STOA) of the Directorate-General for European Parliamentary Research Service (EPRS) conducted an analysis. The analysis compared the EU's efforts with those of strong global players like China and the United States of America.

Based on the challenges identified in the analysis, STOA proposed policy options to strengthen the EU's technological sovereignty in KETs.

Key enabling technologies (KETs), including: 1) advanced manufacturing; 2) advanced materials; 3) life-science technologies; 4) micro/nano-electronics and photonics; 5) artificial intelligence; 6) security and connectivity technologies (See Figure Below) are crucial for an interconnected, digitalised, resilient and healthier European society, as well as being important for the EU's competitiveness and position in the global economy. The Scientific Foresight Unit (STOA) of the Directorate-General for European Parliamentary Research Service (EPRS) analysed how the EU is performing in developing and protecting ownership and know-how in these critical technologies, especially in comparison with strong global players such as China and the United States of America. Based on the challenges identified in the analysis, STOA identified policy options for strengthening the EU's technological sovereignty in KETs.

Whilst European R&D is generally strong in new KET technologies, the transition from ideas arising from basic research to competitive KETs production is the weakest link in European KET enabled value chains. This situation, namely the gap between basic knowledge generation and the subsequent commercialisation of this knowledge in marketable products, has been commonly identified across the KETs and is known in broad terms as the "valley of death" issue

STOA identified important challenges for the development and commercialization of the 6 above-identified and mentioned KETs:

- Lack of resources/raw materials: Europe is dependent on third countries for access to many of the critical raw materials or resources needed in the context of KETs. Quality datasets, which as a fundamental enabler for artificial intelligence (AI) can also be considered a resource, and unfortunately, they are not available to the vast majority of European companies.

- Dependence on non-European suppliers: In several KETs (i.e. micro/nano electronics and life-science technologies), many of the supply and value chains depend on non-European companies and know-how that put Europe in a position of dependency in the global geo-political context.
- Digital skills: A lack of and drain on technological expertise can be observed, which compromises European industry and academia. In a more digitalised and connected society, the acquisition of specialised digital and technical skills for both workers and end users are essential to realise the full potential of KETs.
- Commercialisation of research results: Europe struggles to turn the outputs of scientific research results into commercial products and retain them in Europe. Most currently successful business models and products originate in non- European companies.

STOA identified important actions to overcome the above-mentioned limitations thus allowing for the development and protection of the European ownership and know-how on critical and innovative technologies:

- Develop R&D (Research and Development) competencies and knowledge thanks to the support of public and private sectors, thanks to R&D and innovation (R&D&I) funding;
- Provide: the capacity to turn R&D into market products and a reduction in dependence on third countries, by building the right industrial ecosystem through the creation of start-ups and the leadership in critical technologies.
- Protect: the capacity to achieve and preserve technological leadership, by favouring the delivery of innovation through patenting and co-inventions.
- Retain: the capacity to maintain competencies and knowledge through adapted education and skills to ensure the availability of the necessary qualified people in research and production of critical technologies.

Adapted onto the CRISTAL project this means

- Development within the four technological clusters with improved performance and accuracy measuring e.g. sediments and acoustic deviations
- Integration the four technological clusters with IoT technology to guarantee a seamless data stream of information
- Integration the four technological clusters with other technologies such as IoT and AI
- Emergence of new technologies and innovations in the field of IWT
- The quality of the water in the waterways can impact the safety and reliability of inland waterway transport, and the effectiveness of the technologies such as smart buoys.

4.5. Environmental

In general, new technologies can support the goal towards a more sustainable transport sector. However, their production and deployment come with some new risks to the environment which have to be assessed in order to evaluate their true net contribution to environmental gaols such as reduction of carbon emissions. The environmental aspects of the deployment of the technology clusters are considered to be the following.

- Climate change but also regular weather events can impact the frequency and severity of low or high water events, which can in turn affect the safety and reliability of inland waterway transport. The more information is provided by technology clusters, the more and the better the responsible parties can react towards such conditions.
- The EU has set CO_2 emissions goals aligned with the Paris Agreement through strategies such as the European Green Deal and the Sustainable and Smart Mobility Strategy.[11]
- These strategies are expected to significantly increase funding for the development of Inland Waterways Transportation (IWW), which is relevant to the four technological clusters of CRISTAL.
- Inland waterways transportation is a green mode of transport that consumes only a fraction of the energy required by road vehicles and approximately half that of rail transport. To become a climate-neutral economy by 2050, the EU has a 2030 target of 55% CO2 emission reduction and the transport sector must reduce emissions by 90% by 2050. To achieve these goals, a substantial part of the inland freight carried by road today should shift to inland shipping and rail.
- Environmental regulations can impact the technology clusters and the transport of goods via IWT.
- Such technology clusters can also contribute to a better environmental monitoring of the inland waterways.
- The quality of the water in the waterways can impact the effectiveness the technology clusters.
- Issues of eco-friendliness of such technology clusters versus other technologies and processes to control the inland waterways
- Environmental impact of deploying and maintaining the technology clusters
- Use of any rare earth minerals in the production of the technology clusters
- End-of-life disposal of the technology clusters
- Carbon footprint reduction using such technology clusters through strengthening the usability of the IWT sector.

4.6. Legal

Legal considerations must be taken into account when developing new technologies. Laws, regulations, court decisions, and even the legal principles of particular countries must be taken into account in order to ensure that technology is developed and used in an ethical and responsible manner. The list hereunder explores the respective legal impacts of technology developments.

- The NAIADES III action plan aims to promote the development of the European inland waterway transport (IWW) and its legislative initiatives could impact the development and implementation of all four technology clusters of CRISTAL.
- The Commission plans to propose a dedicated cooperation framework for inland waterway transport within the revision of the TEN-T Regulation, enabling Member States to accelerate completion and upgrade of the inland waterways and to better coordinate cross-border actions and projects. This will have a positive impact on the implementation of the CRISTAL technology clusters, especially along river corridors that run through different EU countries.

[11] European Parliamentary Research Service: Briefing. Karin Jacobs, (2022). Inland waterway transport in the EU.

- The Commission aims to support the deployment of cross-disciplinary digital information and operation systems for water and waterway management through the Connecting Europe Facility (CEF), which will have a positive impact on the development of technological clusters such as the ones identified in CRISTAL.
- The revision of the Combined Transport Directive will fully integrate inland waterways as an essential component of intermodal transport, making increased resilience and reliability of IWWs a key priority. Technological clusters that aim at ensuring these attributes will receive support.[12]
- The revision of the River Information Services (RIS) Directive will further promote the implementation of smart traffic and transport management solutions in inland waterway transport, with a specific focus on harmonised corridor management based on RIS. This is fully aligned with the objectives of the CRISTAL technological clusters, promoting their development.
- The four technological clusters and their services will need to abide by certain technical standards set by the RIS Directive on harmonised river information services.[13]
- The four technological clusters should also abide by all EU-issued environmental protection rules and directives, including those that address the prevention of air and water pollution and the conservation of species and ecosystems for any installations of these clusters in the sensitive ecosystems of rivers.
- Health and safety regulations: Health and safety regulations can impact the use of the technology clusters in the industry, as they affect the safety of transport and the workers involved.
- Liability and insurance regulations can impact the use of smart buoys in the industry, as they affect the responsibility for damages and losses during transport.
- Intellectual property rights within the four technological clusters
- Competition laws related to the four technological clusters
- Import/Export regulations for the four technological clusters

[12] EC. (2021). Communication from the Commissions: NAIADES III: Boosting future-proof European inland waterway transport, COM(2021) 324 final
[13] https://ris.cesni.eu/30-en.html

4.7.Conclusion of Pestel Analysis

The use of fiber optic sensors, smart buoys, the radar inspection system and the Acoustic Emission system in inland waterway transport is impacted by a variety of macro-environmental factors, including political, economic, sociocultural, technological, environmental, and legal factors. It is important to consider these factors when assessing the potential success and growth of the industry.

In its various dimensions, the Pestel analysis provides indications of the framework in which technological developments take place. Taking into account the spot analysis already summarised above, these are the following points in the area of politics:

Policies and regulations impact the development and deployment of new technologies in transportation,while subsidies, public investment targets, and incentives can promote the development of new technologies. Tariffs, trade agreements, and safety standards can affect the adoption of new technologies. Publicly funded research and development projects are important for promoting innovation in new technologies. This includes possible roles of local authorities, public logistics cluster which have to increase this awareness. Such incentives can also be non-monetary, such as awareness campaigns, to promote the use of new technologies in IWT. At a higher TRL level the technologies may require less state support and become more self-sustaining. The right incentives and support can drive innovation and promote the use of new technologies to improve efficiency, safety, and sustainability of transportation systems. The implementation and development of the four technology clusters of CRISTAL may require funding, which availability however is uncertain.

Economic conditions impact the stakeholders, such as GDP development, fuel prices, interest rates, consumer spending, access to capital, and fares and tariffs for infrastructure users. The European Union's Green Deal and Smart Mobility Strategy come in handy, since it supports investment into the development of inland waterways transportation. The EU economy development remains largely unpredictable, yet the EU has managed to stay clear of recession. Economic growth and development have a substantial effect on the demand for goods transported via waterways, which consequently impacts the necessity for new technologies.

Socially, demographic and cultural factors impact the demand for technology enhanced IWT products and services. Such trends include demographic changes such as an increasing proportion of older people in the European population and challenges in replacing professionals due to a lack of vocational training and an unattractive career model in logistics and transport in general, but even more in IWT. The well-educated EU population may be more receptive to new technologies than previous generations. Inland water transport is seen as a favourable option for some (limited) city logistic solutions. The attitudes of different communities and stakeholders towards technology can widely impact the acceptance and adoption of new technologies in IWT. Demographic change, population growth, urbanization, and changes in consumer preferences will impact social behaviours and norms, that is also truer for trends in the field of inland water transport (IWT).

Technological advancements will impact the stakeholders, such as automation, electrification, artificial intelligence and the development of new logistics software and platform. The four technology clusters are such technological advancements. They however must achieve the integration with existing tools and standards, notably RIS and existing tools for navigability, and in general with IoT technology to guarantee a seamless data stream of information. This challenge is quite typical in issues identified by STOA. Regarding the strengthening of Europe's technological sovereignty in Key enabling technologies.

Environmentally, new technologies can contribute to a more sustainable transport industry. However, it is necessary to assess the environmental risks associated with their production and deployment to evaluate their actual contribution to environmental objectives, such as reducing carbon emissions. Technology clusters can contribute to better environmental monitoring of the inland waterways, but water quality may affect their effectiveness. Environmental impacts include the deployment and maintenance of technology clusters, the use of rare earth minerals in their production, and their end-of-life disposal. Using technology clusters can help reduce the carbon footprint by strengthening the usability of the IWT sector.

Legal considerations include to ensure that the technology clusters are used ethically and responsibly. This includes laws, regulations, and legal principles in different countries. The legal framework entails revision of laws such as the Combined Transport Directive and River Information Services Directive. The technological clusters must abide by technical standards, environmental protection rules, health and safety regulations, liability and insurance regulations, and intellectual property rights. There are also competition laws and import/export regulations to be considered.

5. References

Bednarowska, Z. (2015), Desk research—Wykorzystanie potencjału danych zastanych w prowadzeniu badań marketingowych i społecznych, Marketing I Rynek, 7, 18–26

Biała Księga Plan utworzenia jednolitego europejskiego obszaru transportu – dążenie do osiągnięcia konkurencyjnego i zasobooszczędnego systemu transportu, Komisja Europejska, KOM(2011) 144 wersja ostateczna, Bruksela 2011.

Brzeziński Ł., Świekatowski R., (2020), Strategiczne możliwości rozwoju przedsiębiorstw z branży TSL, Zeszyty Naukowe Politechniki Poznańskiej, Organizacja i Zarządzanie, 82.

CESNI, https://ris.cesni.eu/30-en.html (20.02.23)

European Commission, Green Deal, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (15.02.2023)

European Commission (2021). Communication from the Commissions: NAIADES III: Boosting future-proof European inland waterway transport, COM(2021) 324 final

European Commission, Mobility strategy https://transport.ec.europa.eu/transport-themes/mobility-strategy_en (15.02.2023)

European Commission; COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS NAIADES III: Boosting future-proof European inland waterway transport, COM/2021/324 final

European Commission (2014) Employment, skills and working conditions in transport. JRC Scientific and Policy Reports

European Commission, , Economic Forecast_https://economy-finance.ec.europa.eu/economic-forecast-and-surveys/economic-forecasts/winter-2023-economic-forecast-eu-economy-set-avoid-recession-headwinds-persist_en (20.02.2023)

European Parliamentary Research Service: Briefing. Karin Jacobs, (2022). Inland waterway transport in the EU.

Eurostat, https://www.eea.europa.eu/data-and-maps/figures/population-pyramids-for-europe-africa

Eurostat, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Household_composition_statistics#Relative_differences_in_households_for_men_and_women.2C_young_people_and_older_people

Gierszewska G., Romanowska M., (1994), Analiza strategiczna przedsiębiorstwa, Państwowe Wydawnictwo Ekonomiczne: Warszawa.

José Ignacio Giménez-Nadal, José Alberto Molina, Jorge Velilla (2022) Trends in commuting time of European workers: A cross-country analysis, Transport Policy, Vol. 116, pp. 327-342.

Kisielnicki J., (2011), Zarządzanie projektami, Wydawnictwo Wolters Kluwer: Warszawa.

Kulczyk J., Skupień E., (2016), Śródlądowy transport wodny w Polsce – stan obecny i perspektywy rozwoju, Problemy Transportu i Logistyki, 2016.

Makowska, M. (2013), Analiza Danych Zastanych. Przewodnik dla Studentów; Wydawnictwo Naukowe Scholar: Warszawa.

NIK, (2020a), Utworzenie i funkcjonowanie Państwowego Gospodarstwa Wodnego Wody Polskie, Informacja o wynikach kontroli, Departament Środowiska, Najwyższa Izba Kontroli: Warszawa.

NIK, (2020b), Działania na rzecz rozwoju śródlądowych dróg wodnych, Departament Infrastruktury, Najwyższa Izba Kontroli: Warszawa.

NIK, (2020b), Działania na rzecz rozwoju śródlądowych dróg wodnych, Departament Intrastruktury, Najwyższa Izba Kontroli: Warszawa.

Pietras E., (2017), Macierzy ryzyka jako narzędzie oceny zagrożeń bezpieczeńśtwa informacji, Systemy Wspomagania w Inżynierii Produkcji, vol. 6, issue 9.

Platonoff A., Gadomska-Lila A. (2018), Zarządzanie strategiczne, Wydawnictwo naukowe Uniwersytetu Szczecińskiego: Szczecin.

Strategia na rzecz zrównoważonej i inteligentnej mobilności – europejski transport na drodze ku przyszłości, Komisja Europejska, COM(2020) 789 final, Bruksela 2020.

Strategia zrównoważonego transportu 2030, przyjęta uchwałą nr 105/2009 Rady Ministrów z dnia 24 września 2019 r.

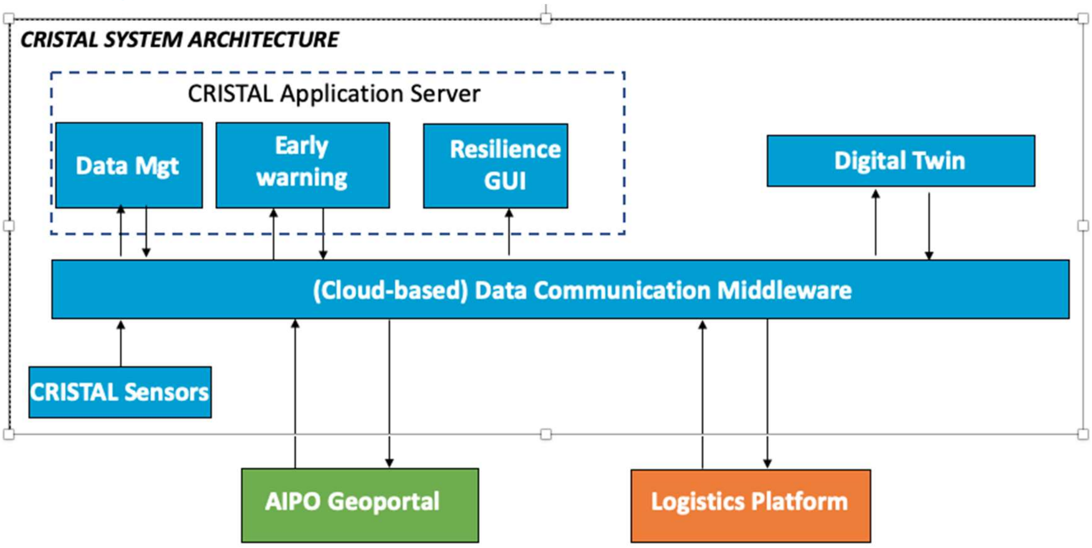
Trzaskowski P., (2021), Utworzenie i funkcjonowanie Państwowego Gospodarstwa Wodnego Wody Polskie : Konieczna reforma gospodarki wodnej, Kontrola Państwowa, 3, 398.

Wdódy Polski https://www.wody.gov.pl/o-wodach-polskich/zadania-wod-polskich (07.02.2023).

WYG International, (2019), Location Study for the Investment Project Entitled: Multimodal platform based on water, rail, road and air transport with a logistics-storage centre and a river port located in the indicated area of the left bank of the Vistula river (km 766-771), considering the area of the city of Bydgoszcz and commune of Solec Kujawski", WYG International Sp. z o.o.: Warszawa.

Annex 1:

Preliminary CRISTAL system architecture exemplifying the connection with existing system such pilot geoportals and SCMS platform (reported in the picture in orange) envisaged in D2.1



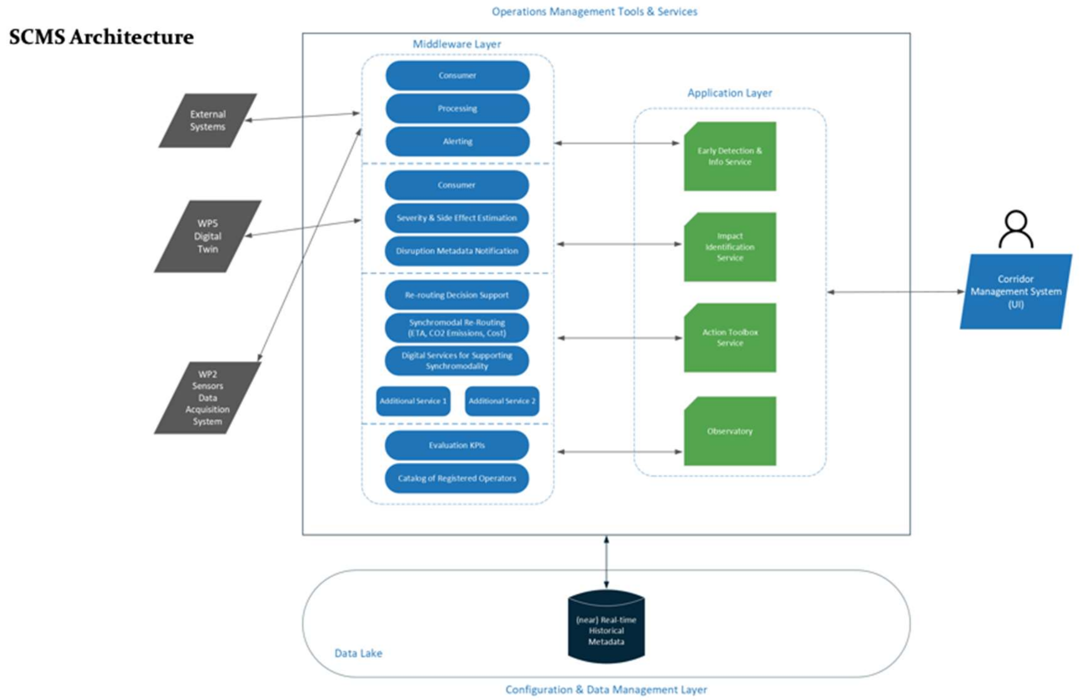


Figure 1 preliminary envisaged architecture for SCMS platform

6. List of tables

7. List of figures