



Portable Innovation Open Network for
Efficiency and Emissions Reduction Solutions

PIONEERS Legacy

Demonstrators Factsheets: Inland Automated Vessels Technology

WP7

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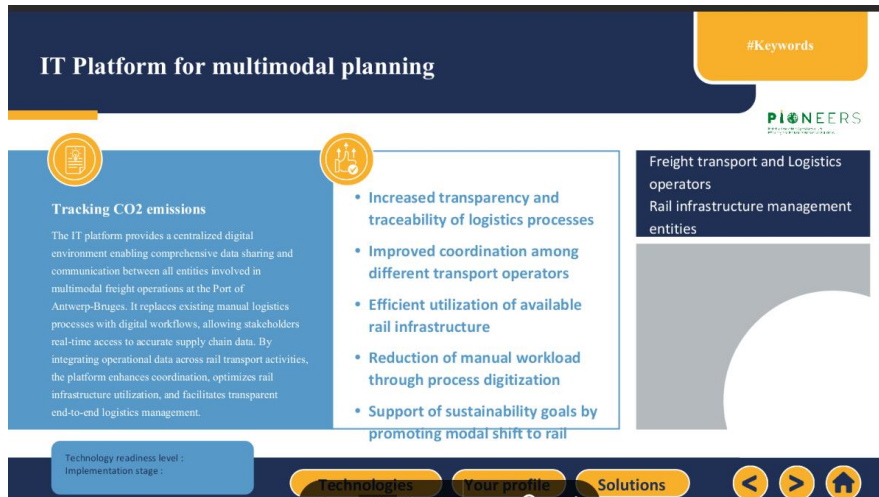
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1. Demonstrator CARD



The **semi-automated** vessel demonstration showcased the remote operation of an inland barge navigating between the Port of Antwerp and Willebroek. Led by Seafar and imec under the PIONEERS project, the demonstration integrated real-time remote control, AI-powered object detection, and advanced situational awareness tools. Using a centralized Remote Operation Center, operators controlled the vessel with support from onboard sensors, cameras, and a standardized control system. The project also featured a digital twin environment for simulation and training, highlighting the system's potential to reduce crew requirements, enhance safety, and support sustainable, scalable inland waterway transport.

2. Value Proposition

1.1. What problem does the innovation solve?

1.2. Key benefits (e.g. sustainability, grid optimization, cost-efficiency)

By shifting freight from road to water, barges cut CO₂ emissions and promote greener logistics. The automation of inland vessels delivers a positive business case supporting this shift, and helps to address several critical challenges facing the sector:

- **Crew Shortages** - Remote operation reduces reliance on onboard crew, addressing labor shortages and enabling more flexible, shore-based roles.
- **Operational Inefficiency** - Automation minimizes idle time by allowing operators to manage multiple vessels, boosting productivity and vessel utilization.
- **Safety Risks** - AI-powered object detection and sensor fusion enhance situational awareness, reducing human error and improving navigation safety

- Scalability - Simulation tools enable rapid testing and adaptation, making the system scalable across ports and vessel types
- Green vessel propulsion – The positive business case from automation may also enable vessel retrofit for green powering of vessels

2. Demonstrated Results & Impact

- 2.1. Key performance indicators (energy savings, emissions reduction, cost-benefit)

Strategic

CO2 reduction: 300-1,000 tons/yr, based on typical emissions of ??????tons/yr

TRL level: 6 – 7 'Technology demonstrated in relevant environment' / 'System prototype demonstration in operational environment'

Time to deployment: 24 – 36 months

Demo-specific

Crew cost reduction: 40-60%

Multi-vessel management: 3-5 vessels per operator

Autonomous operation: 12-16 hours/day (reducing idle time)

Navigation accuracy: 99.5%

3. Key Stakeholders

- 3.1. Who needs to be involved (port authority, energy provider, technology provider)

Who will lead the implementation of automated inland vessels:

- Barge owners and operators
- Inland waterway freight companies
- Technology providers such as Seafar

Who needs to be involved from a regulatory and utilities perspective:

- National transport ministries
- Inland waterways authorities and transnational coordination bodies
- Port authorities and vessel traffic control centres

- Mobile telecommunications network providers

4. Technology Description & Operational Requirements

4.1. System overview

The Seafar system enables remote operation of inland vessels through a centralized **Remote Operation Center (ROC)**. It integrates a standardized **Vessel Control System (VCS)**, real-time sensor data from the **Global Navigation Satellite System (GNSS)**, **radar**, **Automatic Identification System (AIS)**, and onboard **cameras**, along with **artificial intelligence (AI)**-powered navigation tools. A **digital twin** environment provides for development and testing, as well as safe and scalable deployment.

The Seafar system supports a progressive automation trajectory, ranging from crew-supported navigation to fully unmanned operations. The demonstrated inland vessel operates at a high level of automation, combining remote control with AI-enhanced situational awareness. While a licensed operator remains in control from a Shore Control Center, the system automates key functions such as path planning, object detection, and distance estimation. This corresponds to a **semi-autonomous** level of automation, consistent with **Conditional to High Automation**, as defined by the Central Commission for the Navigation of the Rhine (CCNR). According to the CCNR's 2022 classification¹:

- **Level 3 (Conditional Automation)** involves the system performing all dynamic navigation tasks, including collision avoidance, with the expectation that a human operator can intervene if needed.
- **Level 4 (High Automation)** extends this by enabling the system to perform all tasks without expecting human intervention, though fallback performance is still ensured by the system.

Seafar's roadmap includes full automation on fixed trajectories, where vessels operate without onboard crew and are monitored centrally.

4.2. Unique features and functions

¹ [DefinitionAutomatisation_en.pdf](#)

- **Remote Operation Center (ROC):** Allows shore-based captains to control multiple vessels simultaneously.
- **AI-Enhanced Navigation:** Real-time object detection, segmentation, and distance estimation using fast performing YOLO (You Only Look Once) models and radar-camera fusion.
- **Digital Twin & Simulation:** Built on Unreal Engine and AirSim, enabling virtual testing and training.
- **Standardized VCS:** Ensures compatibility across vessel types, simplifying integration.
- **Situational Awareness Tools:** Live video feeds, obstacle mapping, and distance warnings enhance safety and decision-making.

4.3. Required staff training

Operators require training in:

- Remote vessel control interfaces and protocols.
- Interpreting AI-generated situational data (e.g., object detection overlays).
- Emergency response procedures in remote contexts.
- Use of simulation tools for scenario-based training.

Training is supported by VR modules and simulators, offering immersive, hands-on learning experiences.

4.4. Maintenance and operational complexity

- **Hardware Maintenance:** Involves upkeep of onboard sensors, cameras, and embedded AI processors (e.g., Nvidia AGX Orin).
- **Software Updates:** Continuous improvement of AI models through active learning and remote deployment.
- **Operational Simplicity:** Centralized control reduces onboard complexity, but requires robust IT infrastructure and connectivity management.

Overall, the system reduces vessel-side complexity while shifting operational demands to the ROC and backend systems.

4.5. Safety considerations

- **Enhanced Situational Awareness:** AI-driven detection and radar fusion reduce collision risks.

- **Redundancy:** Secure, high-bandwidth communication ensures continuous data flow.
- **Human Oversight:** Remote operators retain control, supported by automated alerts and visual aids.
- **Regulatory Engagement:** Safety protocols are developed in collaboration with port authorities to meet evolving legal standards

5. Port Implementation Barriers & Enablers

5.1. PESTEL results

Barriers

- **Regulatory Uncertainty:** Lack of clear legal frameworks for remote and autonomous vessel operations, and
- **Fragmented Governance:** Inconsistent regulations and limited coordination across regions and authorities.
- **High Initial Investment:** Significant upfront costs for technology integration and retrofitting vessels.
- **Technological Integration Challenges:** Difficulty adapting legacy vessels and systems to new automation technologies.
- **Workforce Resistance:** Concerns over job displacement, skill gaps, and acceptance of new roles.

Enablers

- **Strong Public-Private Collaboration:** Engagement between technology providers, ports, and regulators.
- **Demonstration Projects:** Real-world pilots build trust, validate technology, and inform policy.
- **Digital Twin & Simulation Tools:** Enable safe testing, training, and iterative development.
- **Environmental Incentives:** Support from EU Green Deal and emissions reduction targets.
- **Flexible Remote Operations:** Centralized control centers improve efficiency and workforce flexibility.
- **Growing Demand for Sustainable Logistics:** Market interest in reducing road freight and emissions

Port Implementation Barriers & Enablers

Barriers

- Regulatory Uncertainty
- High Initial Investment
- Technological Integration Challenges
- Workforce Resistance
- Fragmented Governance
- Market Volatility

Enablers

- Strong Public-Private Collaboration
- Demonstration Projects
- Digital Twin & Simulation Tools
- Environmental Incentives
- Flexible Remote Operations
- Growing Demand for Sustainable Logistics

5.2. Lessons learned from the demonstrator

The inland automated vessel demonstrator provided valuable insights into both the technical feasibility and operational realities of remote and autonomous navigation. It highlighted the importance of integrated system design, stakeholder collaboration, and iterative testing in real-world conditions.

Key Lessons:

- **Remote operation is technically viable** under controlled conditions, but requires robust connectivity and real-time data integration.
- **Simulator environments and digital twins** are essential tools for safe development, testing, and operator training.
- **AI-based object detection and sensor fusion** significantly enhance situational awareness, but must be continuously improved through real-world data.
- **Operational flexibility**—such as switching between vessels—can reduce idle time and improve efficiency, but depends on seamless system coordination.

- **Regulatory engagement is critical** early in the process to enable exemptions and future-proof system design.
- **Human factors and change management** must be addressed to support workforce transition and build trust in new technologies.

6. Market Readiness & Scalability

6.1. TRL level

6 – 7 'Technology demonstrated in relevant environment' / 'System prototype demonstration in operational environment'

6.2. Scalability across ports

Europe's inland waterway network spans approximately **41,000 kilometers** and includes over **400 inland ports**, offering significant potential for scalable deployment of automated vessel technologies². The Seafar system is designed for adaptability, with a modular architecture that supports integration into diverse port environments. Its standardized control systems, AI-enhanced navigation, and remote operation capabilities require minimal retrofitting, making it suitable for both modern and legacy infrastructure. Digital twin environments enable rapid simulation and testing for new routes, while reliance on widely adopted technologies—such as GNSS, AIS, radar, and camera systems—ensures compatibility across European inland navigation corridors. The successful demonstration in the Port of Antwerp confirms the system's readiness for broader adoption.

6.3. Business model considerations (CAPEX, OPEX)

The transition to automated inland vessel operations involves both capital expenditure (CAPEX) and operational expenditure (OPEX) considerations that influence the business case for adoption.

Capital Expenditure (CAPEX)

- **Initial Investment:** Upfront costs include retrofitting vessels with remote control systems, installing sensor suites (GNSS, AIS, radar, cameras), and deploying onboard AI hardware (e.g., Nvidia AGX Orin).

² European Parliament Briefing (2022) [Inland waterway transport in the EU](#)

- **Infrastructure Setup:** Establishing a Remote Operation Center (ROC) and integrating digital twin environments for simulation and training also contribute to CAPEX.
- **Scalability Advantage:** Once core infrastructure is in place, additional vessels can be integrated at lower marginal cost, improving return on investment over time.

Operational Expenditure (OPEX)

- **Reduced Crew Costs:** Remote operation significantly lowers personnel costs by enabling one operator to manage multiple vessels and eliminating the need for onboard crew during idle periods.
- **Energy Efficiency:** Optimized routing and reduced idle time contribute to lower fuel consumption and emissions, reducing ongoing operational costs.
- **Maintenance:** While AI and sensor systems require periodic updates and calibration, overall maintenance is streamlined due to centralized monitoring and diagnostics.

The business model benefits from economies of scale, particularly in fleet operations, and aligns with broader sustainability goals, making it attractive for operators, port authorities, and logistics providers.

7. Timeline to Implementation

7.1. Expected deployment steps and dependencies

The deployment of inland automated vessels is expected to follow a phased approach, moving from controlled demonstrations to broader commercial adoption. Each phase builds on the technological, regulatory, and operational foundations established during the PIONEERS project and similar initiatives.

Initial deployments will likely focus on well-defined, low-risk routes such as canal sections between locks, where environmental conditions are predictable and remote operation has already been successfully demonstrated. Scaling beyond these use cases will depend on regulatory alignment, infrastructure readiness, and workforce adaptation.

Key Deployment Steps:

- **Pilot Operations Expansion:** Extend current demonstrations to additional vessels and routes under controlled conditions.

- Technology Standardization: Finalize integration of Remote Operation Center (ROC) protocols and vessel control systems (VCS) across different vessel types.
- Situational Awareness Enhancements: Continue development of AI-based object detection, segmentation, and radar-camera fusion systems.
- Simulator and Digital Twin Utilization: Use virtual environments for training, testing, and validating new navigation algorithms.
- Remote Crew Training: Develop and roll out training programs for remote captains and support staff.
- Stakeholder Engagement: Collaborate with port authorities, regulators, and unions to address legal, safety, and labor concerns.

Dependencies and Enablers:

- Reliable connectivity infrastructure for real-time control and data transmission
- Harmonized regulatory frameworks to support remote and autonomous operations
- Continued refinement of AI perception and decision-making systems
- Retrofit capability for existing vessels with minimal disruption
- Public and industry acceptance through transparency, safety, and demonstrated value

8. Contact Information

8.1. Contact for further details

References

- [Link to Deliverables full version](#)
- [QR Code and link to Training Session Video](#)
- [QR Code and link to Digital Campaign Video](#)
- [QR Code and Link to Transferability Survey](#)