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Study on Enabling Sustainable Management and Development of inland ports

Digitalisation Masterplan for Inland Ports and Terminals

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Summary

Inland ports have a crucial role in the European transport network, serving as critical nodes where multiple transport modes meet and perform operations that are indispensable in efficient supply chain management. Given the huge number of industrial activities taking place in inland ports, their strategic value extends far beyond transportation and logistics, encompassing environmental sustainability and economic growth, being aligned with the European Green Deal (EGD), the Sustainable and Smart Mobility Strategy (SSMS), the NAIADES III action plan, and especially supporting the EU's goal to reduce transport emissions by 90% by 2050. To support these objectives, the European Commission initiated the Green Inland Ports Study, with a focus on digitalisation to improve operational efficiency, facilitate modal shifts, and reduce the environmental impact of port operations.

This report, Deliverable 3.6, is a culmination of the work performed in Task 3 and it details a Digitalisation masterplan for inland ports and terminals designed to transform ports into smart, sustainable hubs. It outlines a vision supported by strategies, roadmaps, and actionable plans while mapping stakeholder interactions (B2B, B2G, G2G). Key objectives include assessing current and desired digital maturity, offering self-assessment tools (DMAT), and providing tiered guidelines to support digital transformation across all ports, regardless of starting level. The masterplan provides a particular roadmap for ports on how to use the transformative power of digitalisation to reach the objectives of modernising operations and increasing operational efficiency, improving intermodal connectivity, and, last but not least, supporting the decarbonisation of European transport systems using the positive effects of digitalisation on sustainability of port operations. This report underlines the role of advanced technologies, such as digital twins, Internet of Things, artificial intelligence, blockchain and predictive analytics, in driving these objectives while at the same time enabling ports to align with wider logistic network and the concept of the Physical Internet

Chapter 2 outlines a bold vision for the immediate future: European inland ports are seen as highly digitalised, efficient, environmentally sustainable, and integrated logistics hubs. The strategy designed to support this vision is founded on four basic pillars, that is, on four key action areas: 1) *digital technology implementation and integration*, prioritising the implementation/integration of cutting-edge digital technologies to modernise and increase the port operations efficiency, 2) *interoperability and stakeholder engagement*, promoting and supporting collaboration and interoperability between relevant stakeholders such as port authorities, operator, relevant government bodies, etc., 3) *digitalisation and environmental effect*, reduction of environmental footprint through digitalisation, and digitalisation of environmental management tools, and 4) *digital framework for intermodal connectivity*, developing frameworks that facilitate smooth connectivity with other modes of transport, promoting a comprehensive and interconnected transport network.

The *strategic recommendations* for the digitalisation of inland ports are designed in a way to address key gaps and barriers, bridging the void between the current and desired state, and in this way transforming the sector into a more operationally efficient, more environmentally sustainable and more interconnected system adding the "just in time" component to the intermodal transport.

The *roadmap* elaborated in this report provides a step-by-step guide for the digitalisation of inland ports, serving as a practical framework for the implementation of the digital transformation.

The *Action plan* translates the vision, strategy, and roadmap into tangible actions. The plan adopts a phased approach over ten years, with specific milestones and key performance indicators (KPIs) formulated a way to track the progress of the plan implementation. It also contains the elements of specific activities, effort and financial estimates using scalable models (e.g., T-shirt sizing for effort and €-scales for financial resources) for each strategic recommendation given in the Strategy, ensuring alignment with the diverse needs of ports.

Chapter 3 is dedicated to the mapping of G2B, G2G and B2B processes in the domain of port and terminal operations, as well as potentials for their digitalisation. The report demonstrates that the digitalisation of G2G, G2B, and B2B processes, including the digital exchange of documents and data, brings several key advantages. For example, it optimises operations through smooth coordination using standardised communication protocols and automated workflows, which reduce manual work, redundant processes, and the risk of human error. Centralised data management systems, such as Port Community Systems, ensure that information is easily accessible and reusable for relevant and authorised stakeholders. Digitalisation also elevates the levels of transparency and collaboration by enabling real-time data exchange and secure communication, fostering trust, accountability, and reduced conflicting situations among involved stakeholders. Finally, it reduces administrative costs as it facilitates the automation of repetitive tasks like customs declarations and invoicing while promoting sustainability through tools that support emissions tracking, compliance, and sustainability reporting.

Chapter 4 focuses on the development of self-assessment tools for digital readiness (digital maturity) and environmental conformity. The latter is just described in this deliverable as its full development took place in Task 4. The Digital maturity self-assessment tool (DMAT) is a simple toolbox designed to assist ports in assessing their digital readiness, or their digital maturity. The methodology for the DMAT includes the elaboration of five different digital maturity levels, starting with the level where ports have minimal or no digital tools at all, gradually progressing towards higher digitalisation levels where ports use sophisticated digital tools for various aspects of their operations and management. To determine the level of digital maturity, the so-called Digital Performance Index (DPI) was developed. The DPI is a quantitative measure of the assessment of various dimensions of digitalisation, which, depending on its score, assigns the assessed port a corresponding digital maturity level. Once the port self-determines its digital maturity level, it can easily see its position in digitalisation compared to other ports, and it can focus its further development on the dimensions of the digitalisation which have been scored lower in the assessment, if it aligns with their own needs and development plans.

Chapter 5 contains digitalisation guidelines whose prime purpose is to provide a structured approach and path for the digital transformation of inland ports, tailored to their unique digital maturity levels, needs, starting points and objectives. Guidelines are elaborated to facilitate self-assessment and strategic planning, supporting gradual progress across digital maturity levels. The guidelines also dedicate considerable attention to the reduction of environmental footprint of port operations through digitalisation, striving for zero-emission targets, and adopting the principles of the physical internet and synchromodality. Flexibility and scalability are enabled through the very segmentation of the progressive digital maturity levels, meaning that the guidelines can be used by both smaller, less developed ports, and by larger, digitally more advanced ports. Modular approach of implementation allows ports to adapt to regional conditions, ensuring compatibility with local systems and regulations. For each digital maturity level (level 2 and higher) the guidelines provide recommendations in the following elements: 1) strategic focus, 2) core actions and tools, 3) stakeholder engagement and training, 4) sustainability integration, and 5) monitoring and evaluation. Each digital maturity level is designed to serve as both a standalone framework and a take-off point to more advanced digital technologies, allowing ports to progress at their own pace and possibilities.

The Masterplan is concluded in Chapter 6 with lessons learned and final reflections.

List of abbreviations

AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AIS	Automatic Identification System
B2B	Business to Business
B2G	Business to Government
CESNI	Comité Européen pour l'Élaboration de Standards dans le Domaine de Navigation Intérieure
CO	Customs Office
CSV	Comma-separated values
DMAT	Digital maturity self-assessment tool
DPI	Digital performance index
DSS	Decision Support Systems
EA	Environmental Authority
EDIFACT	Electronic Data Interchange for Administration, Commerce and Transport
ELD	Electronic Logging Devices
EMS	Environmental Management System
EMT	Environmental Management Tools
EPM	Environmental Performance Measurement
ESB	Enterprise Service Bus
FF	Freight Forwarder
G2G	Government to Government
GNSS	Global Navigation Satellite System
GOS	Gate Operating System
GPS	Global Positioning System
HCN	Hinterland Container Notification
HMO	Harbour Master's Office
HPA	Hamburg Port Authority
HTTP	Hypertext Transfer Protocol
ID	Identification document
IoT	Internet of Things
IT	Information Technology
IWT	Inland waterway transport
JSON	JavaScript Object Notation
LL	Living Labs
LTC	Land Transport Companies
M2M	Machine to Machine
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
OCR	Optical Character Recognition
OCR	Optical Character Recognition
PA	Port Authority
PO	Port Operator
PP	Port Police
PS	Private sector

QC	Quay Crane
REST	Representational State Transfer
RFID	Radio Frequency Identification
RIS	River Information Services
RMG	Rail Mounted Gantry (Crane)
RTG	Rubber Tyred Gantry (Crane)
RTLS	Real-Time Location System
SA	Ship Agent
SC	Shipping Company
SPL	Smart Port Logistics
TI	Training and research institutions
TO	Terminal Operator
TOS	Terminal Operating System, Terminal Planning and Operating System
UC	Use Cases
VBS	Vehicle Booking System
VNF	Voies Navigables de France
VTMS	Vessel Traffic Management System
VTS	Vessel Traffic Services
WMS	Warehouse Management Systems
XAI	Explainable Artificial Intelligence
XML	Extensible Markup Language
XPdM	Explainable Predictive Maintenance

1 Introduction

1.1 Background

Inland ports are indispensable nodes of the global logistic network, having their major role in facilitation of the movement of goods via the economically most efficient and environmentally most friendly mode of transport – waterborne transport, that is, in this case, via inland waterways. Their strategic importance is recognised through their role and place in the Trans-European Transport Network (TEN-T), and their inclusion in the core network of the European transport corridors. Inland ports serve as intermodal junctions for at least two, and most frequently three different modes of transport – IWW, rail and road. Having the role of intermodal nodes, inland ports significantly contribute to the positive modal shift from less environmentally friendly transport modes (like road transport) to more sustainable ones. This makes them an important tool for achieving the European Green Deal's (EGD)[1] target of reducing transport-related emissions by 90% by 2050. This potential of inland ports has been recognised in EU's policy documents - the Sustainable and Smart Mobility Strategy (SSMS)[2] and the NAIADES III action plan[3]. The SSMS policy document emphasises the potential of inland ports to reach the status of zero-emission nodes, not only for transport, but also for the sustainable mobility, sustainable industry, clean energy and circular economy. This calls for a new plan for ports to be focused on identifying and implementing environmentally friendly and sustainable solutions, such as energy efficiency, environmental strategies, and monitoring tools to support the transition to renewable energy and zero-emissions port operations.

To contribute to the achievement of the EGD goals, the European Commission launched the Study in Enabling Sustainable Management and Development of Inland Ports (Green Inland Ports Study), This study, with this deliverable being its crowning part in the domain of digitalisation, has an ultimate goal to support European inland ports in their transformation towards green and sustainable hubs through the assessment of their environmental impact, through the exploration of the role of digitalisation in achieving this objective, and, finally, through the identification of opportunities for integration of inland waterway transport in urban mobility and short distance transport.

Digitalisation has an important role in facilitating the modal shift and in achieving the greener port operations, and at the same time be a great contributor to the achievement of economic development of ports through the increase of their operational efficiency. Thanks to the introduction and integration of digital technologies, inland ports can modernise their operations, improve coordination between transport modes, improve the visibility and traceability of cargo movements, improve their maintenance strategies, as well as monitor the environmental performance in the entire port or at the so called "hot spots" and act accordingly in case of observed anomalies. Advanced digital tools, such as the Internet of Things (IoT), data analytics, and artificial intelligence

1 Communication 640 (2019). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - The European Green Deal. Available: https://commission.europa.eu/publications/communication-european-green-deal_en

2 Communication 789 (2020). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Sustainable and Smart Mobility Strategy – putting European transport on track for the future, Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789

3 Communication 324 (2021). 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. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0324

(AI), allow ports to perform real-time monitoring, predictive maintenance and data-driven decision-making. Digital tools and their capabilities can not only improve ports' operational efficiency but can also support the implementation of sustainable practices, aligning port activities with the EU's sustainability goals. In this view, digitalisation is not just a technological upgrade or a trend that needs to be followed, but a strategic necessity. Digitalisation can help ports to become more efficient, to maintain or achieve high levels of competitiveness, and to become beacons of greening of transport operations.

1.2 Objectives of the report

The primary focus of Task 3 in this study is digitalisation. The main objective of Task 3 is to assess the potential of digitalisation to enhance the environmental sustainability of port operations by reducing their overall environmental impact, enabling multimodality, and promoting the sustainable development of inland ports. The findings of all sub-tasks of the Task 3 will be embedded in the current Digitalisation Masterplan for inland ports and terminals and will serve to support and boost the widescale implementation of digitalisation in inland ports across Europe.

This report represents the Deliverable 3.6 "Digitalisation masterplan for inland ports and terminals", which is the result of the work performed in the Sub-task 3.6: "Digitalisation masterplan for inland ports and terminals". In this view, the overall objective of the Sub-task 3.6 is to elaborate digitalisation masterplan, supporting the efforts of the wide-spread digitalisation of inland ports for the purposes of improvement of operational efficiency and reduction of the environmental footprint of inland port operations.

Specific objectives of the Sub-task 3.6 are the following:

- Formulate the digitalisation vision for inland ports, considering the EU policy documents such as EGD, SSMS, NAIADES III Action plan, and Implementation of the digitalisation vision for inland waterway transport as part of the European Green Deal.
- Support the vision with the necessary elements: the strategy, roadmap and action plan.
- Describe the current digitalisation state and formulate the desired state of digitalisation in inland ports.
- Propose strategic recommendations for port authorities, operators, policymakers, government sector. and industry stakeholders to implement the digitalisation of inland ports and/or to increase the digital maturity of inland ports.
- Accompany the strategy with the relevant roadmap and action plan.
- Map the B2B, B2G and G2G processes in inland ports that can benefit from digitalisation.
- Provide the toolboxes for the self-assessment of digital readiness/maturity, and environmental conformity of inland ports.
- Develop the guidelines for inland ports to implement digitalisation in accordance with their digital readiness/maturity level.

Reaching the above objectives has been supported by presenting the Task 3 progress at the Danube Ports Days 2023, initiating interactive discussions at the Danube Ports Days 2024, and testing the Digital Maturity Self-Assessment Tool (DMAT) with several port authorities and port operators.

2 Digitalisation vision

2.1 Vision

Inland ports have crucially important role in the development of the European transport network, acting as essential nodes of interconnection of at least two, and more frequently three, transport modes, thus contributing to the efficient flow of cargo throughout the network. As Europe moves forward towards the achievement of strategic goals outlined in its policy documents such as the European Green Deal, NAIADES III, the Sustainable and Smart Mobility Strategy, and the Inland Waterway Transport (IWT) Digitalisation Vision, the modernisation of inland ports in view of increase of operational efficiency and reduction of environmental footprint becomes the high value target.

To achieve these ambitious objectives, it is important to define a clear vision for the digitalisation of inland ports. This vision should be a founding pillar for any efficient digitalisation strategy and the development of a coherent roadmap an action plan accompanying the strategy. The vision should ensure that the chosen development path is aligned with the overall EU sustainability, efficiency, connectivity, and mobility goals, and it should provide directions for the coordinated progress.

Digital technologies, such as digital twins, artificial intelligence, blockchain, and predictive analytics, to name just a few, can be used to modernise inland ports, increase their operational efficiency, have intermodal connectivity and contribute to the greening of port operations. Therefore, the reliance on these technologies should also be clearly incorporated in the vision. From the point of view of connectivity, the vision should also support the development of synchromodality and the integration of ports into the Physical Internet[4], ensuring unhindered coordination between various modes of transport in both space and time.

Having stated the basic preconditions for the effective inland ports' digitalisation vision, the vision statement is formulated in the following way.

Vision statement:
Inland ports in Europe are transformed into smart, interconnected, and sustainable logistics hubs that are digitally integrated in the broader logistics network. Inland ports use advanced digital technologies, including, but not limited to, digital twins, artificial intelligence, blockchain, and advanced data analytics, with the purposes of optimisation of freight and passenger flows, facilitating the performing of efficient, transparent, and sustainable operations that are aligned with the goals of the European Green Deal, Sustainable and Smart Mobility Strategy, and Inland Waterway Transport Digitalisation Vision. Inland ports are also fully compatible nodes in the concept of Physical Internet. Collaboration with all relevant stakeholders and related data-sharing facilitates the contribution of inland ports to end-to-end visibility and control over supply chains.

Key principles of this vision are outlined in continuation:

Smart and connected infrastructure

- Inland ports are equipped with advanced digital infrastructure, including, but not limited to IoT sensors, automated handling systems, advanced analytic tools, AI-assisted vessel and traffic

[4] https://www.etp-logistics.eu/alice-physical-internet-roadmap-released/

management, allowing port and terminal managers to monitor activities in real time, as well as to make decisions under dynamic conditions. This digital infrastructure also lays the technological foundation for synchromodal operations
- The ports are fully digitally connected with the overall logistic network, including the relevant supply chains and their actors, thus facilitating secure and unhindered exchange of relevant data with other transport modes and involved stakeholders.

Digital twins and predictive analytics
- Digital twins go beyond the infrastructure and create a virtual replica of physical port operations. In this way, port operators make simulations, scenario analyses, and predictive modelling that are of crucial importance for long-term decision-making, planning, and strategic optimisation. Digital twins allow ports to test different operational strategies, identify inefficiencies, and predict maintenance needs before they arise, enabling proactive management. Digital twins provide a virtual replica of port operations in details determined by the scope, size and complexity of operations, as well as by the requested level of details by the operators.
- The use of these tools improves efficiency of operations, reduce downtimes, and improve the overall sustainability of port activities.

End-to-end data integration
- Inland ports do their part to facilitate end-to-end data integration for the entire logistics/supply chain, making sure that all relevant stakeholders (e.g. shippers, carriers, authorities, transport operators, etc.) have access to accurate and real-time information.
- End-to-end integration improves coordination, reduces administrative tasks, and makes the flow of goods much easier. Continuous coordination and communication between various actors in the supply chain is crucial for the implementation of synchromodal transport.

Automation and autonomous systems
- Highly digitalised ports are the founding pillar of automation. The widespread use of automation and autonomous systems, such as automated and autonomous cranes, automated and autonomous cargo handling equipment, intra-port vehicles contribute to the increased efficiency, safety, reliability, and even sustainability of inland port operations.
- In this view, by providing higher levels of digitalisation, inland ports facilitate the creation of necessary technological pre-conditions for the implementation of automated and autonomous cargo handling systems. It needs to be remembered that highly digitalised ports and terminals may have no automated and/or autonomous equipment at all, but even lightly automated and autonomous ports and terminals have to be digitalised at least to the degree necessary for the unhindered work of deployed automated and/or autonomous cargo handling equipment. For example, automated cranes or automated guided vehicles (AGVs) need digitalisation technology such as sensors and actuators for guidance, centralised control systems for management and monitoring, AI-based algorithms to allow autonomous systems to make operational decisions, etc.

Cybersecurity and data protection
- It goes almost without saying that inland ports put high priority to cybersecurity and data protection and that they implement robust measures to combat cyber threats.
- Inland ports comply with the highest standards for data governance, making sure that sensitive information is protected, and that relevant regulations are fully complied with.

Sustainability and greening of port operations
- Inland ports have an important role in the EU's decarbonisation efforts where deployment of digital tools and systems (e.g. sensors, advanced data analytics, smart energy management

systems, etc.) for monitoring, managing and reduction of energy consumption and emissions are the “front line soldiers” of those efforts.

- The greening of port operations does not come only as a “collateral” effect of the digital tools dedicated to port operations and management where environmental benefits occur indirectly, from optimised use of resources, congestion avoidance, optimised routes of vehicles and cargo handling equipment in ports, but also from dedicated, purpose made digital tools aimed at monitoring and managing environmental performance of ports, such as sensors for air and water pollutants, noise, vibrations, emission calculations, energy use, etc.

Integration with the Physical Internet

- Inland ports are integral components and nodes of the Physical Internet (PI), and they facilitate smooth transfer of goods within a standardised, modular logistics network. The concept of PI aligns very well with the concept of synchromodality as both concepts involve modular, standardised logistics networks where goods are dynamically routed based on optimal transport conditions. Inland ports that are integrated into the PI support synchromodal logistics by default.
- Digitalisation is a precondition for inland ports' integration into the Physical Internet, since it enables the requested level of connectivity, data exchange, and automation necessary for inland ports to function as efficient nodes in the PI network. For example, in the PI, data must be shared in real time between various stakeholders (ports, shipping lines, logistics providers, customs, etc.) across the entire supply chain so that the movement of goods is coordinated in the optimal way. Moreover, digital tools are necessary to help inland ports in the management of the modular PI containers by automating the processes of tracking, allocating, and routing them through the port. In addition to that, blockchain technology can be used to secure data exchange between involved stakeholders and increase mutual trust when tracking and handling PI containers.

Finally, the inland ports digitalisation vision and its key principles provide a strategic framework for the transformation of inland ports into digitalised, smart, sustainable and well-integrated nodes of the broader logistic network throughout the Trans-European Network – Transport (TEN-T). However, this vision is not a “self-inflatable rescue boat” as its realisation is closely linked not only to the adoption of advanced technologies, but also to the proper identification and addressing of the existing and/or potential gaps and barriers, varying from legal, financial, technical and functional, and workforce related gaps and barriers. The identification of gaps and barriers was performed in Deliverable D3.4[5], while the addressing of these gaps and barriers in combination with the inland ports digitalisation vision and its elements will be performed in the next sections, in the form of targeted strategic recommendations, accompanying roadmap and action plan that should direct the digitalisation process of inland ports.

2.2 Strategy

The strategy defines what needs to be achieved in terms of digitalisation, based primarily on the results of previous deliverables, with the focus on the gaps and barriers identified in Deliverable D3.4. In addition, the Strategy will consider the lessons learnt in the DIWA Masterplan[6] and PLATINA III IWT Policy Platform[7], as well as the findings from the two stakeholder surveys conducted during the elaboration of the Study. These inputs are combined with the consultants' expertise and altogether defined the *current state* of the digitalisation landscape in inland ports,

[5] Ecorys, et.al. (2024). Gaps and barriers in the development and implementation of digital tools, Deliverable D 3.4 of the *Study on Enabling Sustainable Management and Development of Inland Ports*, funded by the European Commission.

[6] Source: https://www.masterplandiwa.eu

[7] Source: https://platina3.eu

which is the starting point for the strategy that defines the *desired state* in the domain of inland port digitalisation. The strategy is aimed to be a targeted and high-level plan outlining the overall approach and focus areas needed for achieving the formulated vision. It identifies key action areas to guide the systematic implementation and integration of digital technologies in the inland port industry. In addition, the strategy provides a strategic framework aligning digitalisation efforts with the vision and objectives of the masterplan. It provides guidance on how inland ports can strategically use digital technologies to improve operational efficiency, collaboration, sustainability, connectivity with other modes of transport and synchromodality. The strategy is aimed to as a foundation for the development of the roadmap and action plan, providing basic conditions for a coordinated and purpose-driven digital transformation in inland ports.

The four ***key action areas*** of the Strategy are the following:

- Digital technology implementation and integration: prioritising the implementation/integration of cutting-edge digital technologies to modernise and increase the port operations efficiency.
- Interoperability and stakeholder engagement: promoting and supporting collaboration and interoperability between relevant stakeholders such as port authorities, operator, relevant government bodies, etc.
- Digitalisation and environmental effect: reduction of environmental footprint through digitalisation, and digitalisation of environmental management tools.
- Digital framework for intermodal connectivity: developing frameworks that facilitate smooth connectivity with other modes of transport, promoting a comprehensive and interconnected transport network.

2.2.1 Gaps and barriers in inland ports digitalisation

In order to implement the digitalisation vision for inland ports, the elements of the vision must be addressed, while at the same time considering the gaps and barriers for inland ports digitalisation. These gaps and barriers are clearly identified in the Deliverable D3.4 and are shortly summarised below:

Legal

- Fragmentation of the legal framework: hard to navigate.
- No legal standardisation of systems to use, plethora of systems in use.
- Clear gaps in the legal framework regarding liability issues: no coverage of cyber security legislation for inland ports.
- Overall liability challenges: unclear, no standardised solution.
- Data security regulations are a barrier for data sharing: harder to implement some digital innovations.
- No rule-out of the non-digital option: systems and personnel to service non-digital way of operation cannot be removed. Costs cannot be saved.

Financial

- Lack in available budgets for managing inland ports, and thus for digitalisation: due to a lack of understanding of local policymakers and politicians regarding the benefits of inland ports.
- Organisational fragmentation: due to the same issues as the bullet above, co-resulting in budget issues and unclarity.
- Subsidy framework is unclear and not always easily navigable.

Technical

- Port management needs for greening/modernisation not yet fully covered.

- Lack of standardisation in systems: reduced interoperability.
- Age of systems in place: not always suitable for interoperability with more innovative systems.
- Data quality is an issue: e.g. emissions monitoring is hampered by this.
- Regional non-harmony: differences in digitalisation 'level' between regions, difficult to standardise or navigate for region-crossing operators.
- Manual data input still in use: reduction in efficiency of systems and increased risk of human error.
- Cyber security is an ongoing area of concern: solutions require continuing attention and budget.

Workforce

- Capacity in the workforce is a gap: not enough skilled personnel available for all port management and digitalisation needs.
- Barriers such as cyber security, legal barriers and others mentioned above only increase the skill-level needed by the workforce.
- Organisational gaps: often there is no single port division but a fragmentation of port related responsibilities over multiple divisions.
- Organisational gaps: (related to the above) staff is often not port-specialised but has many other areas of responsibility.

2.2.2 Current and desired state of inland ports digitalisation

Since the development levels of digitalisation in inland ports vary tremendously, whereas some ports are still at the level of only email use as their top digital achievement, and others are highly developed (using the top-tier technology that exists today), it is very difficult to formulate the current and desired state of inland ports digitalisation that "fits all". In this view, considering the survey results, interviews with inland ports, expert knowledge, and identified gaps and barriers, the approach of "leaving no one behind" is applied in the formulation of the current state. This means that the current state is formulated in such way to include the situation in ports with very low levels of digitalisation, in order to "leave no one (no port) behind" in the assessment of the situation on digitalisation in European inland ports. Consequently, inland ports with higher levels of digitalisation will find that determined portions of the desired state are already implemented in their case and therefore less actions will be required from them.

Therefore, the definition of current and desired states for each of the four key areas of digitalisation strategy are given in the following tables:

Table 2-1: Current and desired state in the key area of digital technology implementation and integration

Current state	Desired state
• Many inland ports still largely rely on legacy systems and manual processes, causing inefficiencies and increased risk of human errors.	• All inland ports have established at least basic digital systems such as Port Community Systems (PCS) and facilitated better collaboration and exchange of data between stakeholders.
• Ports that have implemented some digital tools which are non-standardised and fragmented cause the effect of system fragmentation, making interoperability and integration difficult.	• Implemented standardised systems across ports and stakeholders through adaptation of interoperable and modular solutions for easier system integration.
• Budgetary constraints, especially in smaller ports, can hinder the adoption of digital technologies, even the entry level ones such as PCS.	• Financially phased digitalisation, starting with lower-cost technologies like PCS, and progressively introducing more advanced solutions, allowing ports to pursue digital transformation according to their financial

Current state	Desired state
	capacities, loan abilities and with the help of public-private partnerships where possible and necessary.
• Limited workforce digital skills and insufficient training in managing and maintaining both basic and advanced digital systems.	• Workforce skilled in digital technologies through appropriate training programmes and life-long education in operation and maintenance of digital systems.
• Cybersecurity measures are fragmented, and compliance with standards is limited.	• Comprehensive cybersecurity protocols are embedded into port systems, ensuring both full compliance with EU regulations and strong protection against cyber threats.
• Limited implementation of advanced digital technologies.	• Gradual adoption of modern digital technologies such as IoT, AI, and blockchain, for the purposes of efficiency increase and modernisation of operations.

Source: Consortium.

Table 2-2: Current and desired state in the key area of interoperability and stakeholder engagement

Current state	Desired state
• Stakeholders (port authorities, operators, etc.) often operate in data silos, causing inefficient communication and fragmented data sharing.	• Inland ports deploy digital collaborative platforms facilitating involved stakeholders to share data, collaborate in decision-making, for the purpose of improved overall efficiency.
• Lack of common standards in digital systems among stakeholders hinder smooth collaboration and data exchange.	• Stakeholders use standardised protocols for data exchange and system interoperability, ensuring smooth collaboration.
• Stakeholders are reluctant to share data due to concerns about data security and privacy regulations.	• Clear legal frameworks enable secure data sharing while complying with data protection regulations, boosting trust between stakeholders.

Source: Consortium.

Table 2-3: Current and desired state in the key area of digitalisation and environmental effect

Current state	Desired state
• Existing systems for tracking emissions, energy use, and environmental impact are rare, and provide poor-quality data.	• Ports deploy real-time monitoring tools, such as IoT sensors and AI, to accurately track environmental KPIs such as emissions and energy use throughout the port.
• Lack of digital tools for resource optimisation management which leads to inefficiencies and higher environmental footprint of port operations.	• Ports widely use AI and data analytics tools which improves resource management, reduces waste and emissions, and improves energy efficiency.
• Manual processes make it difficult for ports to comply with environmental regulations, such as emissions reporting and energy use tracking.	• Ports widely use digital tools for automated compliance with environmental regulations, including emissions tracking and reporting.
• Ports rarely use digital solutions to enable sustainable practices such as synchromodal transport, or to effectively reduce emissions originating from their activities.	• Sustainable logistics is enabled through digital tools such as synchromodal transport platforms and AI route optimisation, and environmental footprint of logistic significantly reduce the environmental footprint of logistics operations.

Source: Consortium.

Table 2-4: Current and desired state in the key area of digital framework for intermodal connectivity

Current state	Desired state
• Inland ports do not have real-time data exchange frameworks that would facilitate coordination between different transport modes, which is causing fragmentation of data systems across modes.	• Inland ports use data exchange tools and systems enabling real-time allowing real-time coordination and communication between transport modes.
• Non-existence of common protocols for intermodal data exchange, which prevents the smooth flow of information.	• Ports use standardised intermodal data sharing protocols for data exchange, enabling smooth information flows between different transport modes.
• Existing traffic management systems are insufficiently advanced, frequently leading to congestion and inefficiencies in intermodal transport.	• Ports use intelligent traffic management systems using AI and data analytics for the optimisation of transport flows and increase of efficiency, with little or no congestion issues.
• Ports are not fully equipped with the necessary physical and digital infrastructure for intermodal operations.	• Inland ports invest in both physical and digital infrastructure that fully supports efficient transfer of cargo and data between different modes of transport.

Source: Consortium.

2.2.3 Objectives of the strategy

The analysis of gaps and barriers, as well as the clear differentiation between the current and desired states that are obviously and logically closely related to the gaps and barriers, facilitates the definition of strategic and specific objectives of the strategy. Defining these objectives represents an important milestone in the elaboration of the purposeful and effective digitalisation strategy for inland ports. The overall goal of strategic and specific objectives is to provide a clear and structured framework for the proper steering of the transformation process, in line with the identified gaps and barriers, on the one hand, and determined current state and projected desired state on the other hand. Formed objectives will create a focused path for inland ports to appropriately address identified inefficiencies, improve the highly regarded stakeholder collaboration, sustainability, and intermodal connectivity. Strategic objectives encompass overall goals, while specific objectives tackle the details of strategic objectives broken down into actionable targets. This approach not only ensures that the strategy is comprehensive and practical, but it also allows for measurable progress across all four key action areas of the strategy. Finally, clearly defined objectives make the formulation of strategic recommendations easier, which, in turn, facilitates inland ports to achieve these objectives and thus realise their full potential in the digitalisation process.

Strategic and specific objectives of inland ports digitalisation strategy are defined and listed in the following table:

Table 2-5: Strategic and specific objectives of the key action areas in digitalisation strategy

Key action area	Strategic objectives	Specific objectives
Digital technology implementation and integration	• Drive the adoption and integration of modern digital tools with the purpose of improvement of operational	➢ Standardise digital systems among inland ports in order to provide the necessary minimal preconditions for smooth integration of different

Key action area	Strategic objectives	Specific objectives
	efficiency, optimisation of port processes, and modernisation of inland port operations.	systems and their interoperability, starting from initial to more advanced digital tools. ➢ Facilitate the financial planning and gradual (phased) implementation of digital tools, using various business models and even public-private partnerships, where possible and when needed. ➢ Design and implement relevant and continuous training and education programmes in digital skills for the port labour. ➢ Embed comprehensive cybersecurity protocols for full compliance with relevant regulations and protection against cyber threats.
Interoperability and stakeholder engagement	• Create and boost a collaborative digital environment between involved stakeholders in G2G, G2B and B2B interactions to facilitate the data share/exchange, improve collaborative and data-driven decision making and ensure system interoperability between inland ports.	➢ Deploy collaborative digital platforms in order to provide means for efficient data sharing, decision-making among stakeholders, and reduction of multiple data submission by users. ➢ Establish and/or promote the use of standardised protocols for data exchange in order to improve interoperability. ➢ Develop legal frameworks that protect data privacy and security while encouraging stakeholders to share data securely.
Digitalisation and environmental effect	• Use digital tools to reduce the environmental impact of inland port operations, improve resource management, and facilitate compliance with environmental regulations.	➢ Implement real-time monitoring tools for tracking of environmental KPIs such as emissions and energy consumption. ➢ Use AI and data analytics for the optimisation of resource management and minimisation of operations-generated waste and emissions. ➢ Automate compliance with environmental regulations through the deployment of digital tools for emissions reporting and sustainability tracking. ➢ Promote sustainable logistics through the use of digital tools and systems for synchromodal transport and route optimisation.
Digital framework for intermodal connectivity	• Develop a robust digital framework that can facilitate real-time coordination between different transport modes, support the exchange of relevant intermodal data, and improves the efficiency of intermodal operations in inland ports.	➢ Establish or agree upon real-time data exchange frameworks for the facilitation of smooth communication between stakeholders across transport modes. ➢ Standardise intermodal data-sharing protocols to make sure that the information flows are unhindered between different actors in different transport modes. ➢ Use AI and data analytics tools for optimisation of traffic management and reduction of congestion in intermodal operations.

Key action area	Strategic objectives	Specific objectives
		➢ Plan appropriate investments in both physical and digital infrastructure in order to ensure adequate preconditions for the efficient and sychronised cargo transfer and data exchange between transport modes.

Source: Consortium.

The strategic and specific objectives of the digitalisation strategy for inland ports were defined to match as a response to the identified gaps and barriers of inland port digitalisation, as well as to reflect the necessary steps to perform a transition from the current state to the desired state of inland ports digitalisation. Originating from the identified gaps and barriers and findings from the two stakeholders' surveys conducted during the elaboration of this Study, the *current state* of digitalisation in inland ports revealed, inter alia, various inefficiencies, siloed data sharing, rather low level of digitalisation of European inland ports on the average, opportunities to reduce the environmental footprint through digitalisation, and lack of coordination between transport modes. In contrast, the study team defined a *desired state* which foresees a modernised, fully digital landscape for ports, with digital tools and systems that are interoperable, capable of providing real-time data exchange, improving sustainability, and integrating and synchronising intermodal operations in ports. Therefore, ports would use advanced digital tools and systems for the improvement of their operational efficiency, reduction of the environmental footprint of port operations, and safe and secure exchange of data with relevant stakeholders.

In this view, strategic and specific objectives were carefully designed the close the gaps between the current and desired state. Doing so, these objectives aim to standardise systems and tools, propose phased implementation, improve interoperability and secure data sharing, enable more environmentally sustainable operations, and, finally, to develop a robust digital framework for intermodal connectivity. Each of the defined objectives targets specific elements of port operations where digitalisation is needed and where it can result in considerable benefits.

Finally, objectives have the role of providing foundations for the strategic recommendations that are built on the identified need and focus on actionable steps such as implementing advanced technologies, facilitating collaboration between involved stakeholders through the use of digital platforms, promoting sustainable operations, etc. Formulated objectives not only originate from a detailed understanding of existing challenges, but they also lay the groundwork for a transformative inland ports digitalisation strategy.

2.2.4 Strategic recommendations

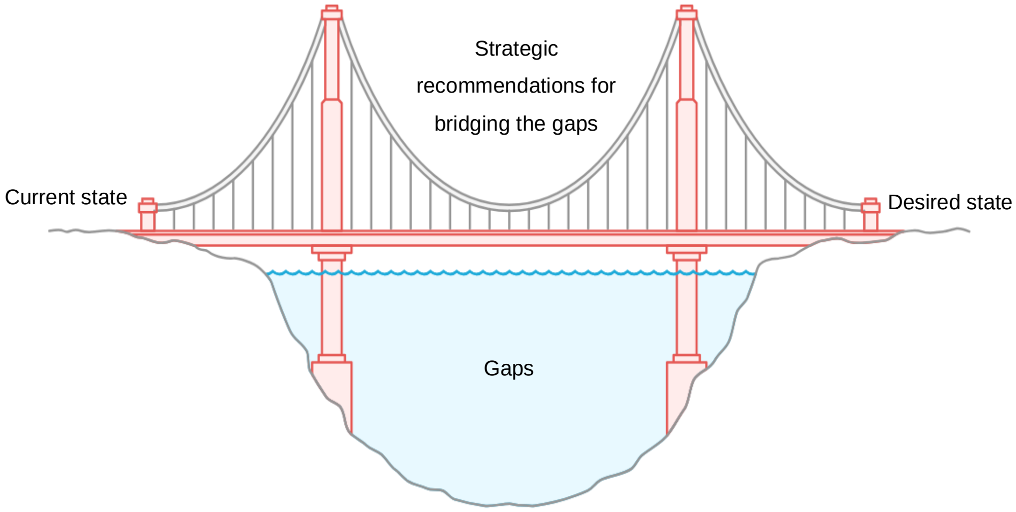
The strategic recommendations for the digitalisation of inland ports have to address key gaps and barriers, bridging the void between the current and desired state, and in this way transforming the sector into a more operationally efficient, more environmentally sustainable and more interconnected system adding the "just in time" component to the intermodal transport. These recommendations focus on four key action areas, as defined at the beginning of Section 2.2:

- Digital technology implementation and integration.
- Interoperability and stakeholder engagement.
- Digitalisation and environmental effect.
- Digital framework for intermodal connectivity.

Deployment of digital tools and systems, coupled with the promotion of intra-sectoral and extra-sectoral collaboration (where system interoperability plays a crucial role), improved environmental management with reduced environmental footprint of port operations, and improved intermodal operations with the special focus on synchronisation between involved transport modes, can help inland ports to align with relevant European transport policies and significantly improve their role in the transport network and supply chains. Strategic recommendations developed in this section can pave the way for operational modernisation and performance improvement, collaborative data-driven decision-making, and, last but not least, sustainable growth.

The logic used in defining strategic recommendations based on the gap analysis is illustrated in the figure below.

Figure 2-1: Illustration the logical process behind formation of strategic recommendations



Source: Consortium.

Strategic measures for inland ports digitalisation are listed in the following table:

Table 2-6: Strategic recommendations for inland ports digitalisation

Key action area	Strategic recommendations & description
Digital technology implementation and integration	• Tailor-made implementation of digital tools: inland ports should implement digital tools according to their digital maturity status and defined needs. Both "beginners" and advanced level digital tools will target improved collaboration and data-driven decision-making, real-time monitoring, optimisation of cargo handling, improve traffic management, and reduce inefficiencies and system fragmentation. • Phased digitalisation roadmap: closely related to the previous recommendation, ports should develop a phased approach for digital technology implementation starting from basic digital tools such as PCS, and then advancing towards more sophisticated digital solutions over time, thus addressing gradual development needs and possible budgetary constraints, and acting according to their concrete needs at a given moment or planning period. • System standardisation and interoperability: inland ports should ensure that the digital tools and systems they introduce are standardised, modular, and interoperable with both new and legacy port systems. This approach should successfully deal with the technical barriers of fragmented and non-harmonised digital systems.

Key action area	Strategic recommendations & description
	• Workforce training: ports should prioritise the development of relevant training programmes so that port labour is duly trained to operate and maintain digital technologies of different levels. • Cybersecurity framework: comprehensive cybersecurity protocols should be established from the very beginning of the digitalisation process, and they should be fully compliant with EU data protection and cybersecurity regulations in order to form a formidable barrier against potential cyberthreats to inland ports.
Interoperability and stakeholder engagement	• Collaborative digital platforms: inland ports should implement digital platforms that can facilitate real-time collaboration, data exchange and collaborative decision-making to port authorities and operators, transport operators (rail, road, etc.), logistic providers, and government bodies. Such actions will neutralise issues such as data silos, thus improving the data flow and overall efficiency. • Standardisation of data exchange: the development/use of common digital standards has to be promoted for all involved stakeholders, inside and outside of port areas. This will ensure system compatibility on the one hand and improve collaboration and address the technical and legal challenges caused by fragmented standards and non-secure data exchange practices, on the other hand. • Public-private partnerships: inland ports should explore the engagement in public-private partnerships (PPP) and various business models to alleviate financial burdens of digitalisation, thus providing the necessary resources and know-how for large-scale ventures in digital transformation projects. • Data security and legal frameworks: in order to duly address the data protection and cybersecurity challenges, inland ports should develop (or be actively included in developing) solid and clear legal frameworks that should be aligned with relevant EU legislation, which should, in turn, increase trust between stakeholders and improve collaboration. • Stakeholder training programmes: design and implement standardised training programmes for all relevant stakeholders in order to ensure their understanding of system interoperability, data sharing protocols, as well as cybersecurity aspects. This should strengthen the willingness of stakeholder to cooperate and share data, as well as reduce inefficiencies that may be cause by the lack of stakeholder engagement and unharmonised knowledge necessary for the proper use of digital tools and systems.
Digitalisation and environmental effect	• Real-time environmental monitoring: inland ports should implement various digital tools, from platforms for emission calculations in hot spots, to more advanced technologies such as IoT sensors and AI systems, that can enable tracking and management of environmental KPIs such as emissions, energy use, air and water quality, noise, etc, in real-time. In addition, these measures serve to address the lack of high-quality data and improve compliance with environmental regulations. • AI-powered optimisation tools for higher sustainability: ports should use AI-powered optimisation tools to improve energy efficiency, resource allocation and traffic management, and to reduce emissions as one of the optimisation effects. Such automation of resource allocation and port processes will result in lower operational costs and lower environmental footprint of port operations. • Automated environmental compliance: inland ports should implement digital solutions with the capabilities of automatic compliance with environmental

Key action area	Strategic recommendations & description
	regulations, including emissions reporting and energy use tracking, in order to reduce manual workload, ensure regulatory compliance, and bridge the gaps in legal and technical frameworks. • Promotion of synchromodal transport: promote, encourage and even incentivise if feasible the use of synchromodal transport through digital platforms that offer data exchange in real-time and AI-based route optimisation. Synchromodal transport is known to have the reduction of environmental footprint of logistic operations as one of its effects. • Zero-emission digital initiatives: ports should support innovations in environmental sustainability activities through integration of digital tools for zero-emission operations. These tools include applications, tools, systems, software or platforms and related equipment for smart energy management systems, management of electrified port infrastructure and handling equipment, digitalised management of vessel/vehicle charging stations, smart water and waste management systems, etc.
Digital framework for intermodal connectivity	• Real-time data exchange frameworks and systems: inland ports have to develop/implement cross-sectoral real-time data exchange technologies in order to improve coordination between different transport modes involved in supply chains, as this will facilitate smoother intermodal operations and address technical issues related to fragmented systems. This framework involves integration of digital platforms and software that allow real-time data sharing about the status of vessels, vehicles and cargo, transport schedules, and other key operational metrics. • Standardisation of intermodal protocols: deploy common data-sharing protocols such as UN/EDIFACT (Electronic Data Interchange for Administration, Commerce, and Transport), various ISO standards such as ISO 28005-1:2024 Electronic Port Clearance (EPC)[8], or eFTI (electronic Freight Transport Information)[9] or similar, to secure the information flows and improve coordination between different modes of transport. This measure addresses technical gaps related to regulatory fragmentation and it also contributes to smoother intermodal operations. • AI-driven traffic management: implement AI-based traffic management systems and data analytics for the purposes of transport flows optimisation, congestion reduction, improvement of resource utilisation and operational efficiency, and, most importantly, improvement of intermodal coordination. • Infrastructure for digital intermodal operations: inland ports should invest in both physical and digital infrastructure in order to facilitate efficient cargo and data transfer between various transport modes involved in supply chains. Improvement of intermodal connectivity in this aspect is achieved by upgrading traffic management systems and technical implementation of real-time data exchange systems - the actual hardware, software, and systems upgrades required for intermodal connectivity and providing the technical foundation for the real-time data exchange frameworks.

8 International Standards Organisation (2024). Ships and marine technology — Electronic port clearance (EPC) Part 1: Message structures and application programming interfaces, Edition 2. Available at: https://www.iso.org/standard/83881.html

9 European Commission (2024). Regulation (EU) 2020/1056 of the European Parliament and of the Council of 15 July 2020 on electronic freight transport information. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02020R1056-20240520

Key action area	Strategic recommendations & description
	• Physical Internet integration: inland ports should use digital technologies able to integrate their operations into the Physical Internet framework, so as to enable efficient, dynamic, and data-driven logistics networks. Such technologies may include digital management systems for modular containers, cloud-based collaborative platforms, synchromodal transport platforms, artificial intelligence and machine learning (ML) for predictive logistics, etc. This addresses the technical and financial barriers and enables ports to align with the long-term goals of synchromodal transport such as switching cargo between transport modes dynamically, based on real-time data.

Source: Consortium.

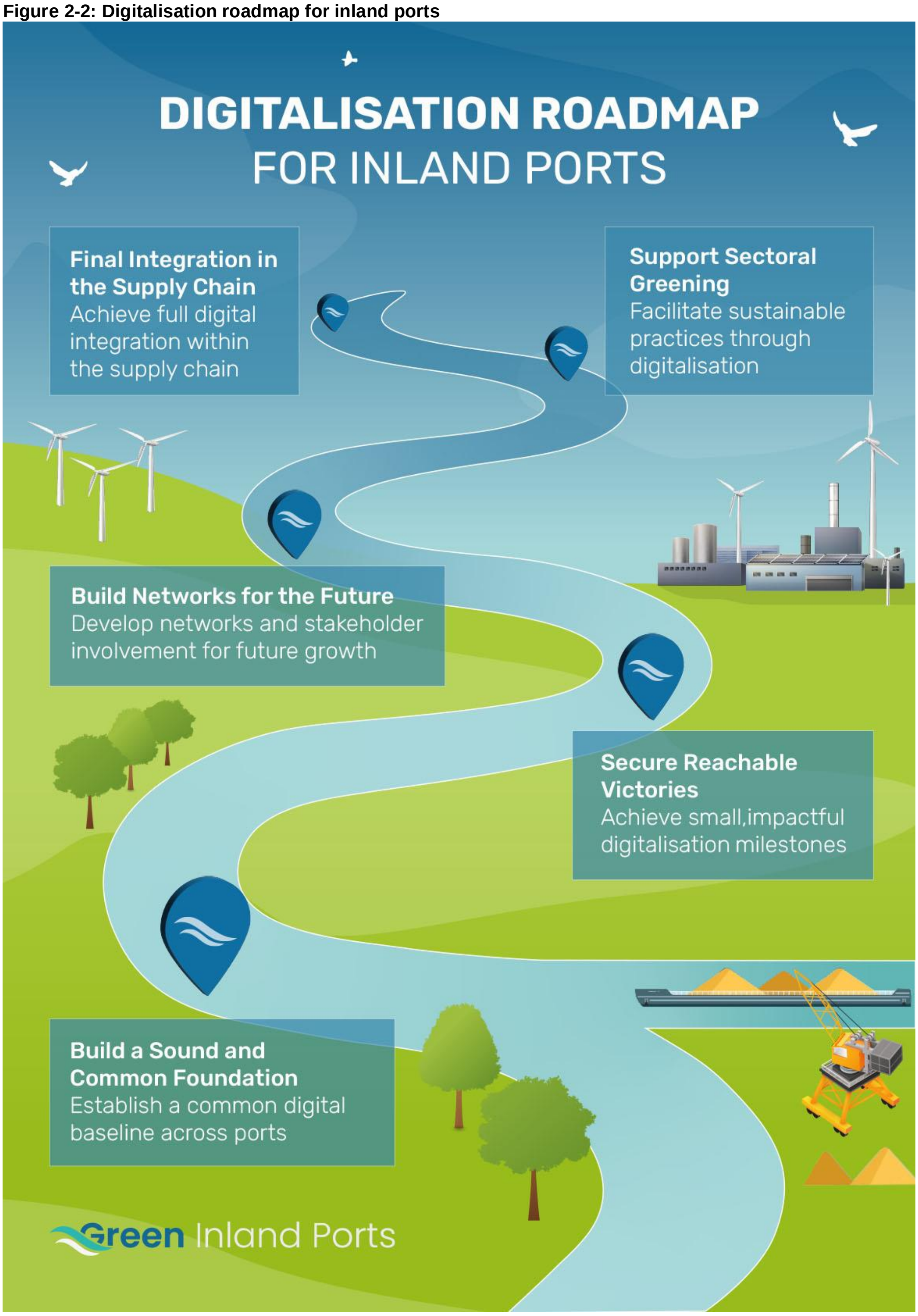
Every recommendation is formulated to support the realisation of specific objectives, allowing the transition of inland ports from the current digitalisation state to the desired digitalisation state, always taking into account the needs of operational efficiency, environmental sustainability and full digital integration into intermodal transport networks and supply chains.

2.3 Roadmap

Having defined a strategy, it is of vital importance to provide guidance to inland ports on the phasing (the when) of the strategic recommendations. The highest chance of reaching the end goals for digitalisation in inland port lays in the joint and similar-timed uptake of the strategy. In other words, ports will digitalise more easily if they are working on the same sub targets at the same time. The following roadmap provides a step-by-step guide for the digitalisation of inland ports, serving as a practical framework for the implementation of the digital transformation:

- Build a sound and common foundation
- Secure reachable victories
- Build networks for the future
- Support sectoral greening
- Final integration in the supply chain & innovative operations

Figure 2-2: Digitalisation roadmap for inland ports



Source: Consortium.

A methodology and more thorough explanation per step can be found in the separate paragraphs below. These paragraphs each contain an overall description of the specific step and two bullet sections. The first of those is the how-to section which includes necessary steps to take to complete the goals in the step successfully. The second is a summation of the relevant associated strategic recommendations per step.

It should be noted that this roadmap must be undertaken with the digitalisation strategy in hand as a logical starting point of the digitalisation journey. Furthermore, enacting the steps from the roadmap will have positive environmental impacts.

2.3.1 Build a sound and common foundation

It flows from earlier research (for instance in Sub-task 3.4 on gaps and barriers) that not all inland ports operate on the same digital level and that there is little standardisation regarding systems in use. A key barrier to further integration was the fact that many of the systems in use in ports for their current level of digitalisation are not (that) suitable to build upon for further development. This step in the roadmap's success condition would be a largely common situation between all inland ports regarding digitalisation, ideally including standardisation of systems, systems that are ready for further digitalisation and to see all inland ports on the same level of digitalisation. This includes that inland ports that have not yet started digitalisation at all are brought to the same, commonly denominated level of digitalisation as a starting point (the common foundation). Other inland ports could be further along in their digitalisation journey, but the common foundation shall at least be achieved in every port committed to this roadmap.

How-to:

- Define a common starting point of digital services offered and work towards it. Ensure that this starting point has all necessary basis aspects to reach the end goal as envisioned in the digitalisation strategy.
- Raise awareness and funds.
- Ensure stakeholder cooperation.

Associated strategic recommendations and action areas:

- Phased digitalisation roadmap
- System standardisation and interoperability
- Cybersecurity framework
- Standardisation of data exchange
- Public-private partnerships
- Data security and legal frameworks
- Stakeholder training programmes
- Infrastructure for digital intermodal operations
- Standardisation of intermodal protocols

2.3.2 Secure reachable victories

When the step above has been finalised, the first small steps towards the implementation of the digitalisation strategy can be set. In this step, the attention should be on small, reachable digitalisation steps that both showcase the power of digitalisation to the end users and can act as satisfiers for the stakeholders- showing that their work and investments are paying off already. This step is indeed of intermediary nature and might be classified as small. However, making this step all about reaching relatively simple to reach digitalisation goals is beneficial in the sense that it will heighten spirits, raise awareness and might contribute to raising necessary funds for further steps.

How-to:

- Starting from the common starting point, assess easily reachable digitalisation goals as the next steps.
- Using the funds and stakeholder networks gathered and generated under the previous step, take the identified easily reachable digitalisation steps.

- Keep paying attention to standardisation and other basic points as described in the digitalisation strategy during the execution of this work.
- Showcase results, use this to raise awareness, funding and to get further necessary stakeholder support and involvement.

Associated strategic recommendations and action areas:
- Phased digitalisation roadmap.
- Tailor-made implementation of digital tools.

2.3.3 Build networks for the future
When the "easy" steps have been taken, it is time to prepare to reach the end-goal and to set steps that are needed to reach it. Standardisation and involvement of stakeholders, at this time needed across the entire supply chain, remain vital enablers of success. In a sense this step is not much different than the last, but it targets digitalisation goals that are more complicated to reach. Therefore, this step will probably take more time, effort and funding than the steps before.

How-to:
- Start building and implementing overarching networks and systems for inland ports covering a large geographical scope.
- Integrate local sub-systems and prioritise easy usage for the end users.
- Identify, according to the digitalisation strategy an order of digitalisation goals to reach.
- Keep paying attention to standardisation and other basic points as described in the digitalisation strategy during the execution of this work.
- Keep showcasing results and share lessons learned across stakeholder networks.

Associated strategic recommendations and action areas:
- Workforce training
- Collaborative digital platforms
- Real-time data exchange frameworks and systems
- Phased digitalisation roadmap
- Tailor-made implementation of digital tools
- Zero-emission digital initiatives

2.3.4 Support sectoral greening
Inland ports and all their users are facing steep challenges regarding greening of their activities to support a sustainable future. As nodes of transport, inland ports have a vital role to play to facilitate this challenge. Apart from greening of inland port physical activities, digitalisation can facilitate many aspects of the greening challenge. This step should not be considered as the only step where all environmental effects of digitalisation are concentrated. Instead, this step should be understood as the step that emphases the scaling-up and system-wide impact of greening efforts.

How-to:
- Build and implement systems to monitor emission performances of all actors in inland ports.
- Make this data standardised and allow for interoperability for different stakeholders to make use of data.
- Monitor needs arising from regulations regarding emissions reporting and make sure data monitoring and standardisation is set up accordingly.

Associated strategic recommendations and action areas:

- Real-time environmental monitoring
- Automated environmental compliance
- Promotion of synchromodal transport

2.3.5 Final integration in the supply chain & innovative operations

Having set the steps described as above, it is time to set the final step towards maximum supply chain integration of inland ports by digitalisation. This step contains the most complicated action areas, mainly associated with the use of Artificial Intelligence systems and usage of Physical Internet. It might be necessary to take this step with phased groups of inland ports and allow unwilling ports to abstain from this step in the closest future.

How-to:
- Target the usage of Artificial Intelligence for further optimisations of efficiency in traffic management, sustainability, maintenance and other areas.
- Work toward physical internet operations to facilitate the above.

Associated strategic recommendations and action areas:
- AI-powered optimisation tools for higher sustainability
- AI-driven traffic management
- Physical Internet integration

2.4 Action plan

2.4.1 Overview

The action plan serves as an integral part of the Digitalisation strategy, translating the strategic vision, objectives, and recommendations into actionable steps. It provides a clear and structured framework for implementing the strategy outlined in Sections 2.1 (Vision), 2.2 (Strategy), and 2.3 (Roadmap) of this report. The action plan aims to facilitate the systematic and phased implementation of the digitalisation transformation for inland ports across Europe and globally, while at the same time ensuring that such transformation is contributes to European Green Deal's goals for sustainability.

In this view, this action plan aims to guide port authorities and operators, government organisations, and other public and private sector stakeholders in the implementation of the digitalisation strategy of a port (if the digital transformation is intended for a single port) or a port system (if the digital transformation encompasses multiple ports, such as those of the same region, organisation, country, or a river basin).

The scope of the plan encompasses:

- Phased implementation of digitalisation measures tailored to the needs and maturity levels of different ports.
- Coordination among stakeholders for the purposes of interoperability and collaborative engagement.
- Allocation of estimated resources necessary to align financial, technical, and human capacities with the goals.
- Monitoring and evaluation mechanisms to track progress and ensure continuous improvement.

The action plan is directly fed by the strategy and roadmap presented in Sections 2.2 and 2.3. While the strategy defines the key action areas and strategic objectives, and the roadmap outlines the high-level phases of implementation, the action plan goes into the operational level details. It translates the strategic recommendations into specific actions, identifies responsible stakeholders, and establishes timelines and milestones.

This approach helps that the digital transformation of inland ports progresses in a cohesive and coordinated manner, targeting the crucial reasons of digitalisation, that is, improved operational efficiency, environmental sustainability, and intermodal/synchromodal connectivity. This, in turn, bridges the gaps between strategic vision and practical execution, providing the solid foundation for the achievement of the very purposed of the Digitalisation Masterplan.

In a nutshell, while the roadmap indicates us where we are going and in what sequence, the action plan explicitly tells us how to get there by breaking down the strategic recommendations into actionable measures and by assigning the necessary timelines and resources to them.

2.4.2 Structure of the Action plan

The structure of the action plan provides its foundations and details the phasing, roles and responsibilities of stakeholders, resource allocation, and effort estimation. This should ensure that the digitalisation strategy is applied systematically and effectively across inland ports participating in the process of digital transformation.

The implementation of the digitalisation strategy will follow a phased timeline aligned with the five steps of the roadmap in order to ensure a structured approach.

The structure of the Action plan contains the following elements:

- Key action area identifier (from the Digitalisation strategy)
- Strategic recommendations
- Breakdown strategic recommendations into of specific activities
- Estimated timeframe for implementation for each strategic recommendation
- Estimated work efforts
- Estimated financial efforts
- Involved (responsible) stakeholders
- KPIs to track the progress of strategic recommendations

Key action areas and strategic recommendations with their descriptions are elaborated in Section 2.2 (Strategy), while the approach to estimating timeframes, resource allocation (efforts and financial estimates), as well as involvement of stakeholders is explained in continuation.

Next element of the Action plan is the estimated timeframe for implementation of each strategic recommendation. Maximum foreseen period for the digital transformation is taken to be ten years, matching the targeted duration of each step of the Roadmap (Section 2.3) which is approximately two years for each step. The time needed for the implementation of each strategic recommendation, as well as its commencement (in the corresponding step) is estimated based on experts' experience and opinion within the consortium.

Thereafter, estimated work efforts are given using the so-called T-shirt size scale used in agile software development (S-M-L-XL-XXL)[10]. For this Study, the scaling is adopted in the following grades:

- S: Minimal effort - e.g., initial digital assessments.
- M: Moderate effort - e.g., deploying single-use systems like PCS.
- L: Significant effort - e.g., multi-stakeholder platform integration.
- XL: Large-scale effort - e.g., AI and Physical Internet projects.
- XXL: Complex, long-term effort - e.g., full intermodal and supply chain integration.

Estimated financial efforts, of course, cannot be given precisely at this stage. Instead, they are given using a growing scale (€-€€-€€€), as follows:

- €: Up to 100K€ — suitable for foundational digital tools and training programs.
- €€: Between 100K€ and 1000K€ — for deploying collaborative platforms and environmental monitoring systems.
- €€€: Upwards of 1000K€ — for large-scale investments such as AI-driven systems and Physical Internet integration.

Moving forward, the next element of the Action plan is the proposed involvement of stakeholders. Typical stakeholders and their roles are as follows:

- Port authorities (**PA**), as they drive the adoption of digital tools, ensure compliance with regulatory frameworks and data governance, and collaborate with other stakeholders to promote interoperability and connectivity.
- Terminal (port) operators (**TO**), to implement and manage digital technologies for cargo handling and storage and participate in training programs to improve the digital skills of the port workforce.
- Government bodies (**GB**), to provide regulatory support and align digitalisation initiatives with EU policies, and to facilitate funding opportunities and public-private partnerships.
- Private sector entities (e.g., freight forwarders, vessel operators, logistic operators, investors) (**PS**), needed for the purposes of collaboration in deploying digital platforms and systems, and for data sharing to improve intermodal connectivity and joint decision-making.
- Technology providers (**TP**), to develop and deploy interoperable and scalable digital solutions, as well as to offer training and technical support to stakeholders.
- Training and research institutions (**TI**), to collaborate in designing and execution of training programmes and development of AI algorithms and other research and development activities.
- Environmental authorities (**EA**), to collaborate in compliance with environmental KPIs, to collect reports on environmental performance.

Finally, the last element of the Action plan is the set of KPIs used for the purposes of tracking the progress of implementation of strategic recommendations and the Action plan itself. KPIs are aligned with the strategic recommendations outlined in Section 2.2.4. Each KPI provides a clear metric for evaluating progress and outcomes within the four key action areas of the digitalisation strategy.

2.4.3 Plan details

10 https://doasync.com/blog/what-is-t-shirt-sizing/

Table 2-7: Action plan for digitalisation of inland ports

KA identifier	Strategic recommendation	Specific actions	Time ambition	Effort	Financial	Stakeholders	KPIs
Key action area 1 Digital technology implementation and integration	Tailor-made implementation of digital tools	• Identify and prioritise digital tools suitable for foundational implementation. • Procure and deploy PCS in pilot ports (if multiple ports participate in digitalisation process). • Develop guidelines for integrating PCS into workflows. • Test PCS effectiveness through trials.	Step 1-2 (0-3 years)	M	€€	PA, TO, IT	• KPI 1: Percentage of ports adopting foundational digital tools • KPI 2: Percentage reduction in operational inefficiencies (e.g., time savings, cost reduction).
	Phased digitalisation roadmap	• Conduct a baseline digital maturity assessment. • Develop a phased implementation plan. • Deploy further digital tools (e.g., TOS). • Introduce advanced technologies (e.g., IoT, AI). • Secure funding (including through public-private partnerships).	Prep actions: Step 1-2 (0-4 years) Gradual tech implem.: Step 1-5 (0-10 years)	M	€€	PA, TO, GB, PS	• KPI 1: Completion of baseline digital maturity assessments across participating ports. • KPI 2: Number of phased implementation plans developed and operationalised. • KPI 3: Percentage of ports progressing from foundational to advanced technologies.
	System standardisation and interoperability	• Define and agree on common data exchange standards. • Pilot interoperability projects between ports. • Train IT staff in standardised systems. • Conduct annual audits on interoperability compliance.	Step 1-3 (0-4 years)	L	€€	PA, TO, TP	• KPI 1: Number of ports/users adopting standardised data exchange protocols. • KPI 2: Percentage compliance with interoperability standards among participating ports/users. • KPI 3: Number of system audits conducted annually to ensure compliance.
	Workforce training	• Design training programs tailored to digital maturity levels.	Step 1-5 (0-10 years)	M	€€	PA, TO,	• KPI 1: Number of training programs designed and conducted.

KA identifier	Strategic recommendation	Specific actions	Time ambition	Effort	Financial	Stakeholders	KPIs
		• Conduct training sessions for port employees and stakeholders. • Develop certification programs for key skills. • Evaluate the impact of training on productivity.	(ongoing)			GB, TI	• KPI 2: Number of trained and/or certified employees. • KPI 3: Percentage of productivity increase.
	Cybersecurity framework	• Develop comprehensive cybersecurity policies. • Implement advanced threat detection systems. • Conduct regular cybersecurity audits. • Train staff in cybersecurity protocols.	Step 1-5 (0-10 years) (ongoing)	L	€€	PA, TO, TP	• KPI 1: Percentage of ports with fully implemented cybersecurity frameworks. • KPI 2: Number of cybersecurity audits conducted annually. • KPI 3: Annual reduction in reported cybersecurity incidents.
Key action area 2 Interoperability and stakeholder engagement	Collaborative digital platforms	• Design a platform prototype for data sharing. • Pilot the platform with stakeholders. • Implement improvements based on feedback. • Launch the platform sector-wide with training.	Step 3-4 (4-6 years)	L	€€€	PA, PS, TP	• KPI 1: Number of collaborative platforms fully deployed. • KPI 2: Percentage of stakeholders actively participating in real-time data sharing.
	Standardisation of data exchange	• Conduct consultations on data exchange requirements. • Develop technical documentation for standards. • Host webinars on adopting standards. • Monitor compliance with data exchange standards.	Step 1-3 (0-4 years)	L	€€	PA, TP, PS	• KPI 1: Percentage of stakeholders adopting standardised data exchange protocols. • KPI 2: Increase in volume of data exchanged securely and efficiently. • KPI 3: Number of training sessions conducted to ensure proper implementation of protocols.
	Public-private partnerships	• Identify potential private sector partners. • Develop PPP frameworks. • Secure funding and commitments.	Step 1-3 (0-6 years)	M	€€	PA, GB, PS	• KPI 1: Number of established public-private partnerships.

KA identifier	Strategic recommendation	Specific actions	Time ambition	Effort	Financial	Stakeholders	KPIs
		• Launch pilot projects with PPP funding.					• KPI 2: Total amount of co-financed investments secured through PPP. • KPI 3: Percentage or number of digitalisation projects supported by PPP.
	Data security and legal frameworks	• Develop legal frameworks aligned with EU laws. • Establish stakeholder agreements for secure data sharing. • Monitor legal compliance. • Provide training on data security protocols.	Step 1-5 (0-10 years) (ongoing)	L	€€	PA, GB, PS	• KPI 1: Number of legal frameworks developed and aligned with EU regulations. • KPI 2: Number of stakeholder agreements for secure data sharing. • KPI 3: Number of training sessions conducted for stakeholders on legal and data security aspects.
	Stakeholder training programmes	• Develop standardised training programs on interoperability. • Conduct workshops for stakeholder alignment. • Distribute training materials. • Evaluate training effectiveness.	Step 2-5 (0-10 years)	M	€€	PA, TO, PS, TI	• KPI 1: Number of annual training programs conducted for stakeholders. • KPI 2: Number of stakeholders trained. • KPI 3: Increase in stakeholder collaboration and data sharing after training programs.
Key action area 3 Digitalisation and	Real-time environmental monitoring	• Install IoT sensors for emissions, noise, air and water quality, and energy use tracking. • Develop platforms for reporting environmental KPIs in real time. • Train staff to use monitoring systems effectively. • Publish periodic environmental performance reports.	Step 3-4 (3-6 years)	L	€€	PA, TO, TP, EA	• KPI 1: Number of ports implementing IoT-based environmental monitoring systems (or number of implemented systems). • KPI 2: Percentage reduction in greenhouse gas emissions from port operations. • KPI 3: Number of environmental KPIs tracked in real-time.

KA identifier	Strategic recommendation	Specific actions	Time ambition	Effort	Financial	Stakeholders	KPIs
	AI-powered optimisation tools for higher sustainability	• Collaborate with AI developers for custom tools. • Pilot AI tools for resource planning. • Expand successful AI implementations. • Train staff in AI system operations.	Step 3-5 (3-10 years)	L	€€€	PA, TP, TI	• KPI 1: Number of AI-based optimisation tools implemented across participating ports. • KPI 2: Percentage of improvement in energy efficiency and resource allocation (kWh/t cargo handled, crane usage rates, idle times, etc.). • KPI 3: Reduction in operational costs due to AI optimisation.
	Automated environmental compliance	• Implement automated tools for emissions tracking and automatic reporting. • Integrate compliance tools into existing systems. • Pilot compliance automation projects. • Scale successful tools sector-wide (throughout the port systems).	Step 3-4 (3-6 years)	M	€€	PA, TP, EA	• KPI 1: Number of ports implementing automated compliance tools (or no. of tools implemented). • KPI 2: Percentage compliance with environmental regulations by Year 6. • KPI 3: Reduction in manual workload for compliance reporting.
	Promotion of synchromodal transport	• Develop platforms for managing synchromodal logistics. • Partner with logistics providers for sustainable practices and tool development. • Pilot synchromodal systems. • Scale successful systems sector-wide.	Step 3-5 (3-10 years)	L	€€	PA, GB, TO, PS	• KPI 1: Number of ports/users using synchromodal transport platforms. • KPI 2: Percentage of increase in cargo volume moved using synchromodal transport solutions. • KPI 3: Reduction in emissions per ton-kilometre for logistics operations.
	Zero-emission digital initiatives	• Develop tools for the management of electrified mobile and immobile assets, equipment, and charging infrastructure. • Install smart energy systems.	Step 3-5 (3-10 years)	L	€€€	PA, TP, GB	• KPI 1: Number of implemented zero-emission digital tools (e.g., smart energy management systems).

KA identifier	Strategic recommendation	Specific actions	Time ambition	Effort	Financial	Stakeholders	KPIs
		• Pilot water and waste management digital systems. • Scale digital initiatives for zero-emission operations.					• KPI 2: Percentage reduction in emissions directly attributed to zero-emission tools. • KPI 3: Number of pilot projects successfully uptaking zero-emission digital initiatives.
Key action area 4 Digital framework for intermodal connectivity	Real-time data exchange frameworks and systems	• Design systems for intermodal data exchange. • Pilot digital platforms with logistics operators. • Scale implementation to logistics hubs. • Establish maintenance schedules.	Step 3-5 (3-10 years)	L	€€€	PA, TO, PS, TP	• KPI 1: Number of real-time data exchange frameworks operationalised. • KPI 2: Percentage of reduction in cargo dwell time through improved coordination. • KPI 3: Number of transport modes integrated within real-time frameworks.
	Standardisation of intermodal protocols	• Identify key intermodal protocols (e.g., UN/EDIFACT) and standards. • Develop and conduct stakeholder training programs. • Pilot protocol applications. • Monitor and refine protocol effectiveness.	Step 2-5 (2-10 years)	L	€€€	PA, TO, GB, PS	• KPI 1: Number of ports/users adopting standardised intermodal protocols. • KPI 2: Percentage of improvement in intermodal operations due to standardised protocols. • KPI 3: Reduction in technical barriers to intermodal coordination (resolved technical issues, decrease in errors, reduced time for system integration, etc.).
	AI-driven traffic management	• Develop AI algorithms for traffic flow optimisation. • Pilot AI-driven traffic systems. • Expand deployment based on results. • Train staff in managing AI systems.	Step 3-5 (3-10 years)	L	€€€	PA, TO, PS, TP	• KPI 1: Number of deployed AI-driven traffic management systems. • KPI 2: Reduction in congestion and transport delays.

KA identifier	Strategic recommendation	Specific actions	Time ambition	Effort	Financial	Stakeholders	KPIs
							• KPI 3: Percentage of improvement in resource utilisation due to AI-driven traffic management.
	Infrastructure for digital intermodal operations	• Upgrade terminal equipment for data exchange. • Install cargo and vehicle tracking systems. • Secure funding for infrastructure upgrades. • Review upgrades to meet operational needs.	Step 3-5 (3-10 years)	XXL	€€€	PA, TO, PS	• KPI 1: Number of ports upgrading physical and digital infrastructure for intermodal connectivity. • KPI 2: Percentage of increase in seamless cargo and data transfer between transport modes. • KPI 3: Total investment in infrastructure upgrades.
	Physical Internet integration	• Develop and/or prepare for modular container systems management and operations. • Implement cloud-based platforms for logistics coordination. • Pilot predictive logistics systems. • Scale initiatives across ports and networks.	Step 4-5 (7-10 years)	XL	€€€	PA, TO, TP, PS	• KPI 1: Number of ports/users integrating digital technologies into the Physical Internet framework. • KPI 2: Percentage of improvement in dynamic logistics capabilities. • KPI 3: Number of collaborative platforms supporting Physical Internet operations.

Source: Consortium.

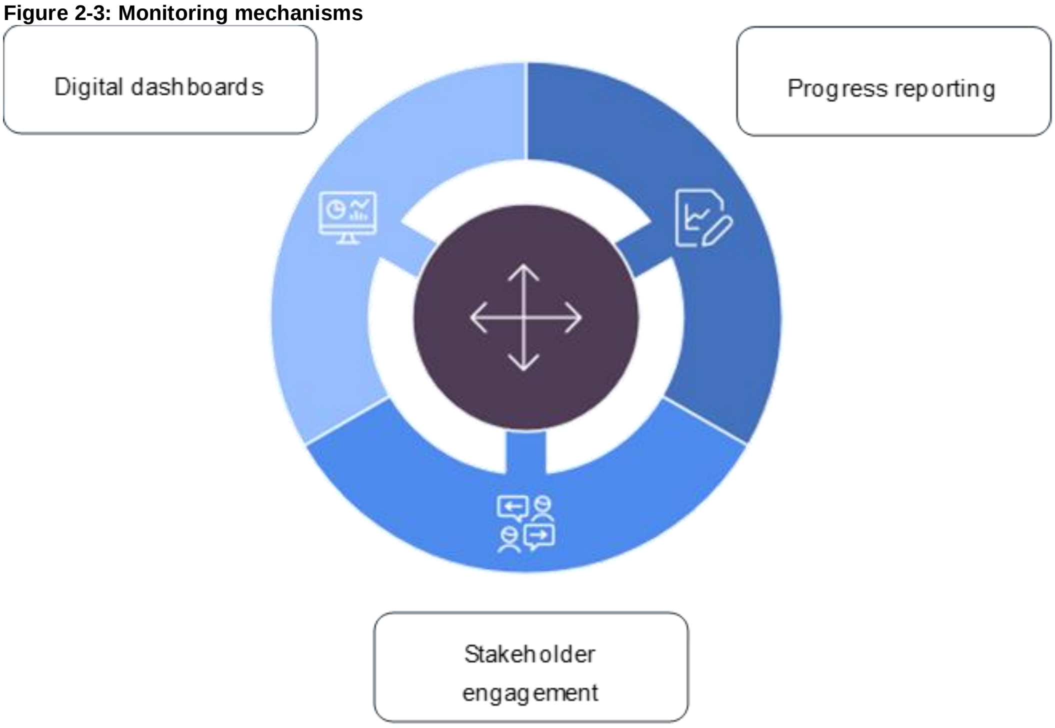
2.4.4 Monitoring mechanisms and evaluation framework

Apart from the defined KPIs, in order to track the progress of the Action plan implementation, usual mechanisms can be established:

- Progress reporting, including regular progress reports by involved stakeholders, submitted at agreed time periods, and containing, inter alia, details of completed specific actions, encountered challenges, and proposed adjustments.
- Stakeholder engagement, involving periodic stakeholder workshops to review progress and share feedback, and open communication channels to address issues timely.
- Digital dashboards, encompassing development of real-time dashboards for the visualisation of progress against KPIs, whereas these digital dashboards should be accessible to key stakeholders for transparency and accountability.

Monitoring mechanisms are illustrated in the figure below.

Figure 2-3: Monitoring mechanisms



Source: Consortium.

Evaluation framework consists of three main elements:

- Mid-term evaluations, which are conducted at the midpoint of the roadmap, for example, after 5 years. They are focused on assessing progress towards intermediate milestones and specific actions, and they can identify the adjustments that are needed to stay on track for achieving long-term goals.
- End-of-roadmap evaluation, including overall evaluation at the end of the ten-year implementation period, assessing the success in achieving strategic objectives and the digitalisation vision for inland ports.
- Feedback loops, which are used to include evaluation findings into ongoing projects for continuous improvement, and to refine future iterations of the Action plan.

2.4.5 Milestones

The timeline aligns with the five steps of the roadmap and encompasses the specific actions outlined in the Action plan, providing a clear sequence of activities and checkpoints to track progress. Key milestones for the Action plan are listed in the table 2-8 below.

Table 2-8: Milestones for the Action plan

Year 1
M1: Completion of digital maturity assessments for participating ports.
M2: Deployment of foundational PCS in pilot ports.
M3: Launch of initial workforce training programs.
Year 2
M4: Development of a cybersecurity framework and standardised protocols.
M5: Completion of PCS pilot testing and integration guidelines.
M6: Submission of the first progress report by stakeholders.
Year 3
M7: Demonstration of early successes through cost-effective digital solutions.
M8: Expansion of PCS deployment to additional ports.
M9: Organisation of stakeholder workshops for the alignment of expectations and best practices sharing.
Year 4
M10: Intermediate integration of digital tools across participating ports.
M11: First round of environmental monitoring tools installed and operational.
M12: Mid-term evaluation to assess progress and refine strategies.
Year 5
M13: Establishment of collaborative platforms for data sharing and stakeholder engagement.
M14: Full implementation of real-time data exchange frameworks.
M15: Training sessions for interoperability solutions and protocols.
Year 6
M16: Rollout of AI-driven resource optimisation tools in pilot ports.
M17: Expansion of collaborative platforms to additional stakeholders.
M18: Submission of feedback and updates through stakeholder meetings.
Year 7
M19: Scaling sectoral greening efforts, including widespread deployment of compliance tools.
M20: Launch of synchromodal transport platforms for sustainable logistics.
M21: Submission of the second progress report highlighting environmental gains.
Year 8
M22: Advanced deployment of AI tools for emissions reduction and resource management.
M23: Training sessions to enhance workforce readiness for intermodal connectivity.
M24: Progress evaluation to measure sector-wide greening impacts.
Year 9
M25: Integration of AI-driven traffic management systems into operational workflows.
M26: Upgrades for infrastructure for automated cargo handling.
M27: Initial testing of Physical Internet concepts in selected ports.
Year 10
M28: Final evaluation of the Digitalisation Masterplan implementation.
M29: Achievement of full intermodal connectivity.
M30: Presentation of success stories and lessons learned.

Source: Consortium.

3 Digital ports landscape mapping the G2B, G2G and B2B processes in ports and terminal operations

3.1 Inland ports stakeholders participating in B2B, B2G and G2G processes

Inland ports represent an important nodal infrastructure of the European transport network, facilitating the transfer of goods between different modes of transport such as water (sea and/or inland waterway), rail, and road. Activities taking part in inland port operations include a very wide scope of entities, both governmental (public) and commercial (business). All these entities have their specific roles, determined by the regulatory frameworks and practices of the trade. While performing their jobs, these entities ensure the smooth flow of goods, services, and information. They are interconnected through complex, and sometimes very complicated processes, frequently involving the exchange of data, permits, certificates and different sorts of documents that are customary and/or compulsory in port and logistics operations, and international trade. These processes and interactions (also referred to as: *communication channels*) are subject to digitalisation, and their digital transformation offers considerable potential to improve the efficiency, sustainability, security of the processes, and thus to increase the speed of the operations in inland ports.

3.1.1 Typical government (public) bodies operating in inland ports

Inland ports are industry sites subject to wide scope of local, national and supranational legislation regulating and guiding the activities taking place in ports. In this view, various government organisation have regulatory, monitoring and supporting roles in different aspects of port operations. Exact type and number of organisations having such roles in inland ports vary from country to country and depend largely on the overall legal system and the organisation of port governance. In general, these organisations typically include the following:

- Port authority (PA). An organisation in charge of overall governance of the port, ensuring the adequate use of port infrastructure, compliance with safety regulations and development plans. It may be involved in commercial operations of a port, although in many countries all over the world is has just a landlord and a regulator role, leaving the operations to independent commercial entities, public and/or private.
- Harbour Master Office (HMO) (a.k.a. Port captaincy). This organisation is usually in charge of overseeing navigation safety, sometimes also vessel traffic management in the port zones and its approaches, as well as enforcement of safety standards on inland waterways, ensuring unhindered and safe vessel traffic.
- Harbour pilot (HP). This organisation typically belongs to the governmental sector, provides certified pilots trained and experienced in navigating vessels in areas that may be new to the regular masters (skippers) of vessels navigating to/from an inland port. This organisation is not typical for all inland ports but may be rather frequent in remote waterways not often frequented by vessels, or in mixed (sea and inland) ports capable of handling both sea and inland vessels.
- Customs authorities (CO). Customs authorities (customs office) are typically in charge of export/import procedures control and management, as well as border security in view of the legality of goods entering or leaving the port.
- Port police (Immigration, or border police) (PP). This government body is in charge of enforcing and maintaining border security, general law enforcement in the port area, control of the

movements of people and crews, as well as ensuring that the traffic of persons entering and exiting the port complies with immigration laws.

- Sanitary and veterinary authorities (SV). This type of governmental organisation is in charge of ensuring the compliance with health and safety regulations for the goods, particularly foodstuffs, livestock and agricultural products being handled in ports. They frequently carry out relevant inspections and issue appropriate certifications.
- Environmental authorities (EA). In some cases, port may (or will in the future) host (or report to) organisations empowered by the law to enforce environmental regulations, keep track on emissions and pollution, and ensure compliance with environmental standards. In a simpler approach, port authorities may assume the role of environmental authorities, at least in terms of overseeing of environmental performance of ports and elaborating reports on environmental compliance.

3.1.2 Typical business (commercial) entities operating in inland ports

Commercial business that can take place in inland ports create the widest possible myriad of business entities that can be involved in commercial operations. For the purposes of this Study, the most common business entities operating in a port involve at least the following entities:

- Port/terminal operators (TO). As the term suggests, this type of organisations perform the commercial (operational) management of port facilities, loading/unloading of vessels and vehicles, cargo handling, yard handling, storage of cargo awaiting transit or customs clearance, etc. If a business entity operates the entire port, it is usually referred to as the port operator, and if it operates only one (or more, but not all) terminal in a port that has multiple terminals it is usually referred to as the terminal operator.
- Vessel operators (VO). This type of commercial organisations include vessel owners, managers and/or operators, providing waterborne transport of cargo from/to ports.
- Freight forwarders and logistic operators (FF). These organisations represent cargo owners and importers/exporters in ports, coordinate the movement of cargo between different transport modes interacting in ports and manage the overall logistics processes across supply chains. They also usually act as customs agents/brokers, performing customs clearance for exporters and importers (and for cargo in transit), handle cargo documentation and assist importers and exporters (or cargo shippers and receivers) in delivering/distributing their cargo to/from ports from/to hinterland destinations, ensuring compliance with import/export/transit regulations.
- Ship (or port) agents (SA). These companies represent vessel owners or operators, coordinating all necessary services, including, but no limited to, berth booking, cargo handling, and documentation.
- Rail transport and road transport operators (land transport companies - LTC). These companies offer road and rail transport services for transfer of cargo from ports to hinterland destinations and vice-versa.
- Surveyors and other inspection companies (SI). These organisations perform various survey and inspections, such as draft surveys, cargo inspections, ensuring quality, quantity, or condition compliance for stakeholders such as insurers or cargo owners.

This refined list focuses on the core commercial players critical to inland port operations.

3.1.3 Typical interactions between government and business entities (G2B)

Interactions (processes) elaborated in this section may not necessarily reflect the exact situation in every single inland port in Europe or in the world. Instead, the interactions identified and described here represent a rough crosscut of the G2B processes in inland ports on a global scale. Exact interactions, of course, depend on national legislation and local practices of the trade, and may differ not only from country to country, but sometimes also from port to port within the same country. Interactions and types of information and documents exchanges in such interactions listed in this section may not reflect the exact situation in each inland port. Instead, they intend to encompass the widest possible scope of inland ports that may significantly differ from one another.

G2B processes in inland ports are typically processes related to operational efficiency. Operational efficiency directly impacts businesses (e.g. port/terminal operators, freight forwarders, and vessel operators) interacting with government entities. These stakeholders depend on efficient government processes to avoid bottlenecks. Examples include customs clearance procedures that greatly affect cargo dwell times, or processes of allowing port entrance (by the Port authority or Harbour Master Office), that influences the vessel turnaround time in ports.

G2B processes include the exchange of data and documents between government bodies and business (commercial) entities. Examples of processes, data and documents include licensing, permitting, customs procedures, goods certificates, clearances, etc. Mapping of most common G2B processes, including the typical types of data and/or documentation that are exchanged between government and business entities is depicted in continuation:

Table 3-1: Mapping of G2B processes and data flows in inland ports

Government entity	Type of process/interaction	Data/Documents exchanged	Business entity
Port authority	• Monitoring port operations • Enforcing port regulations • Approving port fees • Port use agreements, etc.	• Safety standards • Port tariffs and fees • Lease and concession agreements • Berth allocations	Port/terminal operators
	• Berth management • Safe navigation • Charging vessel related fees and charges • Handling emergencies and incidents	• Entrance/exit clearance • Berthing approval • Port tariffs and fees • Arrival/departure notice • Emergency and incident reports • Crew lists • Vessel documents	Vessel operators (seagoing+inland)
	• Monitoring and managing land traffic in the port • Monitoring and managing cargo flows on the land side • Coordination of logistic processes	• Cargo documents • Customs documents • Entry/exit permits for cargo • Traffic and access permits	Freight forwarders & logistic operators
Customs authority	• Clearing of import, export and transit cargoes • Customs related handling of vessels and vehicles	• Cargo documents • Vessel documents • Crew documents	Vessel operators[11]

[11] These processes and data exchange can be carried out via ship (port) agent.

Government entity	Type of process/interaction	Data/Documents exchanged	Business entity
	• Control access to cargo • Monitoring storage compliance • Monitoring bonded (customs) storage • Management of customs-cleared goods	• Cargo documents • Certificates (e.g. origin, quality, quantity, etc.) • Inspection reports	Port/terminal operators
	• Ensuring compliance with customs regulations • Facilitation of cargo clearance • Handling of import/export documentation	• Customs declarations • Cargo manifests • Certificates (e.g. origin, quality, quantity, etc.) • Clearance documents • Inspection reports • Duty payment reports	Freight forwarders and logistic operators
Environmental authority	• Monitoring of environmental impact • Enforcing of sustainability regulations • Pollution control management	• Environmental compliance certificates and reports • Pollution control plans • Incidents protocols and plans	Port/terminal operators
	• Emissions monitoring • Enforcement of pollution control measures on vessels in port areas	• Emission logs and compliance reports • Waste disposal requests and reports	Vessel operators
Harbour Master Office (Port captaincy)	• Navigation safety overseeing • Enforcement of navigation rules in port areas	• Berthing permits and schedules • Safety protocols • Notices to Skippers • Incident reports • Crew certificates	Vessel operators
Harbour pilot	• Safe navigation within port area	• Pilotage requests and certificates • Navigational instructions • Emergency protocols	Vessel operators
Port police (Immigration/Border police)	• Access control • Security of cargo areas • Personnel movement control	• Immigration compliance documents • Access permits • Inspection schedules and announcements	Port/terminal operators
	• Maintaining security of vessels and crews • Ensuring compliance with border security rules • Inspection of crew documentations	• Crew lists • Crew documents • Security clearances • Access permits • Incident and violation reports	Vessel operators

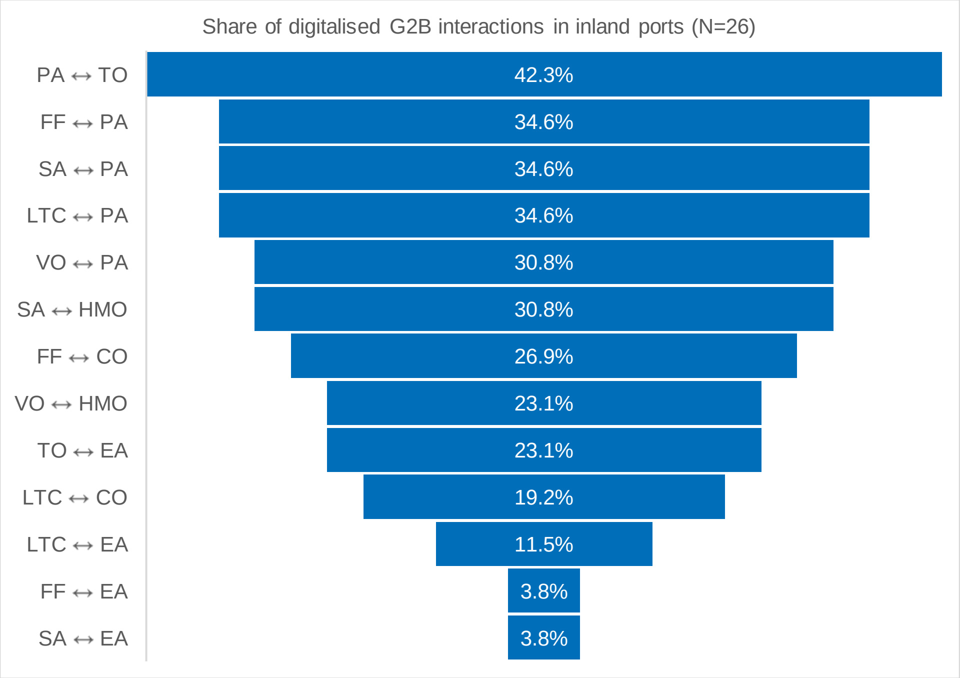
Government entity	Type of process/interaction	Data/Documents exchanged	Business entity
Sanitary and veterinary authorities	• Ensuring compliance with health regulations for certain goods and animal products	• Sanitary certifications • Veterinary health certificates • Quarantine orders • Cargo inspection reports	Port/terminal operators
	• Coordination of import/export of goods subject to sanitary and veterinary inspections • Compliance with regulations	• Cargo manifests • Health and sanitary certificates • Inspection reports • Quarantine orders • Import/export certificates for certain goods	Freight forwarders and logistic operators

Source: Consortium.

In the above table, some processes, information and exchanged documents may appear repeated in different interactions. This is because, depending on the governance and organisational structure of an inland port, such processes may be carried out by different organisations. For example, freight forwarders may exchange the same cargo documents with the port authority, port/terminal operator and the customs authorities, whereas the purpose of such exchange is different in each organisation (entity). Processes may also appear repeated depending on the direct or indirect interactions between different stakeholders. For example, cargo owners may interact with the customs authority directly, or indirectly, via freight forwarders.

Notable share of G2B interactions is already digitalised, which was validated through a survey conducted during the elaboration of the Study. The share of digitalised G2B interactions is illustrated in the following graph:

Figure 3-1: Share of digitalised G2B interactions in inland ports



Source: Consortium.

3.1.4 Typical interactions between government entities (G2G)

Interactions between government entities, or G2G processes, can include interactions between different government entities, such as Port authorities, Customs, Harbour Master Office, to name a few. G2G processes are of crucial importance for regulatory compliance, safety, and security. For example, Customs authorities may be required to share data on certain cargo with the Port police or Sanitary authorities for the purposes of ensuring the compliance of such cargo with legal and/or health requirements. Stakeholders from the government sector typically exchange the information and documents related to the vessel, crew, and cargo. Similarly to the interactions described in the previous section, the interactions, information types, and document exchanges described in this section are not intended to reflect the specific situation of every inland port. Instead, the aim is to capture a broad scope that encompasses the diverse operations and requirements of various inland ports across Europe and globally.

Possible interactions (non-exhaustive) between different government entities related to inland port operations are listed in the following table:

Table 3-2: Mapping of G2G processes and data flows in inland ports

Government entity	Type of process/interaction	Data/Documents exchanged	Government entity
Port authority	• Coordination of port operations, ensuring navigational safety and vessel traffic management	• Vessel schedules and berthing allocations • Incident and emergency reports • Regulatory compliance records	Harbour Master Office (Port captaincy)

Government entity	Type of process/interaction	Data/Documents exchanged	Government entity
	• Cooperation in customs procedures and inspections in the port[12]	• Cargo manifests • Inspection schedules • Import/export clearance records	Customs authority
	• Monitoring and enforcing environmental regulations in the domain of port operations	• Emission and pollution monitoring data • Environmental impact assessment reports • Environmental compliance reports • Waste disposal and hasardous material handling records	Environmental authorities
Customs authority	• Cooperation in enforcing security at port borders • Managing of the movements of cargo and people	• Customs clearances • Security access logs • Surveillance reports • Personnel entry and exit records	Port police (Immigration/Border police)
	• Cooperation in inspection of goods requiring both customs and health clearances	• Inspection and clearance certificates • Quarantine and health documentation • Import/export clearance documentation	Sanitary/Veterinary authorities
Port police (Immigration/Border police)	• Cooperation in access control to port areas where sensitive goods are handled and in enforcement of health and safety regulations	• Entry permits and health inspection reports • Quarantine certificates • Emergency response procedures for health risks	Sanitary/Veterinary authorities
Harbour Master Office (Port captaincy)	• Cooperation in maintaining safe navigation and security within port areas, particularly for vessel arrivals and departures	• Vessel entry/exit logs • Emergency response plans • Incidents and violations reports	Port police (Immigration/Border police)
Environmental authorities	• Cooperation in control of inspection of goods carrying varying levels of environmental risks, such as dangerous goods or waste	• Dangerous goods inspection reports • Compliance certificates • Quarantine and containment records	Sanitary/Veterinary authorities

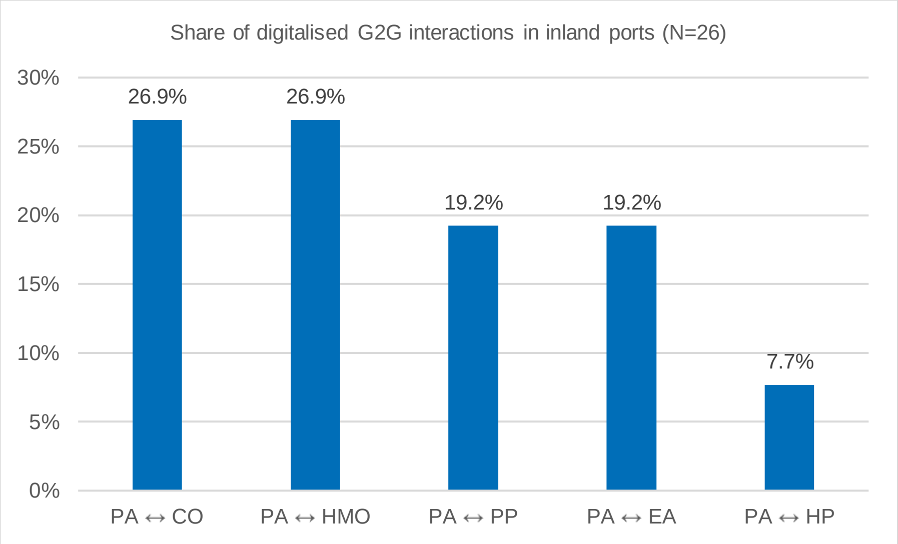
Source: Consortium.

12 WCO & IAPH (2023). Guidelines on Cooperation between Customs and Port Authorities. Available at: https://www.wcoomd.org/-/media/wco/public/global/pdf/topics/facilitation/instruments-and-tools/tools/wco-iaph-guideline/wco-iaph-guidelines-on-cooperation-between-customs-and-port-authorities_en.pdf?db=web

Similar to G2B interactions, the processes, information and documents exchange in G2G interactions can also overlap due to the interconnected roles and jurisdictions of different government entities that can be involved in inland port operations. This overlapping occurs because multiple governmental authorities, such as customs authorities, port authorities, sanitary authorities, and others, use similar (or same) datasets or documents for their own purposes that may significantly differ from one another. For example, a single cargo declaration or cargo manifest might be required by customs for customs clearance, by environmental authorities for emissions monitoring, and by operating port authorities for infrastructure management.

The survey demonstrated the following results for the digitalisation of G2G interactions in inland ports:

Figure 3-2: Share of digitalised G2G interaction in inland ports



Source: Consortium.

3.1.5 Typical interactions between business entities (B2B)

Business-to-business (B2B) interactions in inland ports are an important component of any supply chain, and they involve multiple stakeholders, including, inter alia, port/terminal operators, freight forwarders, shipping companies, logistic providers, ship (port) agents, etc. These interactions fall into the category of supply chain optimisation processes, which are inherently a business-to-business concern, involving stakeholders like freight forwarders, logistics operators, and transport companies, among others. These actors coordinate closely to ensure that cargo moves unhindered through the supply chain. Interactions between commercial (business) stakeholders typically include the exchange of operational data, logistic coordination, instructions for cargo handling, cargo and vessel documents, etc. For example, shipping companies need to deliver the cargo and vessel documents to the ship agent which, in turn, processes these documents and submits them to port/terminal operators, customs, freight forwarders, etc. Similarly, a freight forwarder might exchange cargo documents with a warehouse operator or coordinate with trucking companies for last-mile delivery.

Possible interactions between various business stakeholders are listed in the table below:

Table 3-3: Mapping of B2B processes and data flows in inland ports

Government entity	Type of process/interaction	Data/Documents exchanged	Government entity
Port/terminal operators	• Coordination in loading/unloading of cargo and berth scheduling	• Estimated Time of Arrival (ETA) notices • Berthing arrangements • Cargo manifests and stowage plans • Dangerous cargo declarations	Vessel operators
	• Coordination of cargo handling and storage, and timely transfer of goods	• Cargo handling instructions • Storage space and inventory availability • Customs clearance statuses and cargo reception/release documents	Freight forwarders and logistic operators
	• Coordination of berthing, cargo handling.	• Berthing requests and vessel arrival notices • Cargo documents (manifests, Bills of Lading, declarations, etc.) • Notice of readiness	Ship (port) agents
	• Ensuring that the goods meet required standards during handling and storage within the port/terminal	• Inspection schedules • Access permits • Compliance and inspection reports • Dangerous goods handling and storage certificates	Surveyors/Inspection companies
Vessel operators	• Facilitation of the logistics of port entry, berthing, loading/unloading, and services for the vessel. • Crew services for incoming vessels	• Cargo documents • Crew change lists • Provisions list • Operational requirements • Notice of Readiness • Arrival/departure reports • Service and supply requests	Ship (port) agents
	• Synchronisation of transfer of goods between waterborne transport and land transport	• Vessel schedules • Coordination plans • Cargo weight declarations • Cargo specifications • Transit documents • Inspection certificates	Road/Rail transport operators
	• Coordination of shipping schedules • Managing cargo logistics	• Cargo documents • Shipment schedules • Cargo tracking information	Freight forwarders and logistic operators

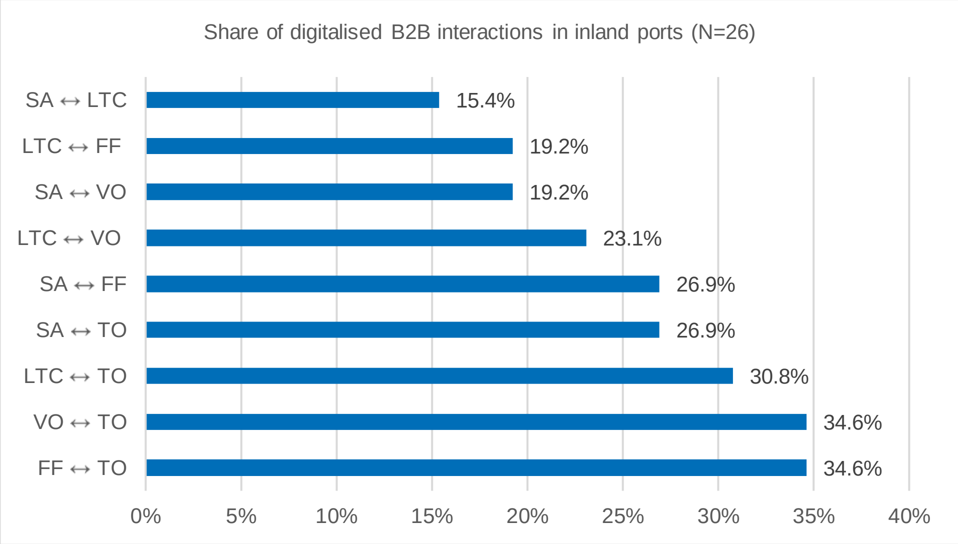
Government entity	Type of process/interaction	Data/Documents exchanged	Government entity
	• Transfer of cargo between modes	• Customs documents • Cargo certificates • Cargo handling instructions	
Freight forwarders and logistic operators	• Coordination of collecting/distribution of cargo from/to hinterland destinations to/from inland ports	• Cargo pick-up and delivery schedules • Load specifications • Weight declarations • Customs documents • Shipping instructions	Road/Rail transport operators
	• Arrangement of goods inspection for compliance with quality, quantity, safety and regulatory standards	• Inspection requests and schedules • Inspection certificates • Surveyor's reports • Cargo condition reports	Surveyors/Inspection companies
	• Coordination of arrivals • Customs clearance coordination • Coordination of handling of cargo for efficient movement through the port	• Arrival notices • Handling instructions • Customs clearance documents • Cargo reception and delivery notes	Ship (port) agents

Source: Consortium.

Just like in case of G2B and G2G interactions, the processes, information and documents exchange in B2B interactions can be intertwined as the roles of different business entities taking part in inland port operations can significantly overlap. This is caused by different peculiarities of each trade, relations between business entities, types of contracts, even local traditions, etc. Multiple business entities can use the same or similar cargo documents and other documents depicting the features of the vessels, vehicles, cargo, processes, and so on.

Finally, B2B interactions are also subject to digitalisation, and a notable share of inland ports has already embarked on a digitalisation journey in this aspect of their operations, as demonstrated in the results of the survey conducted during the study, shown in the below figure.

Figure 3-3:



Source: Consortium.

3.1.6 *Digitalisation of G2B, G2G and B2B processes in inland ports*

As it has been demonstrated throughout the Study, digitalisation holds immense potential for improvements of efficiency, transparency, and sustainability in inland ports operations. This is by no means different when G2G, G2B, and B2B processes and interactions, as described in the previous section, are concerned.

Digitalisation of G2G, G2B, and B2B processes, including the digitalisation of the documents and data they exchange in their usual work, has the following benefits:

- Optimised operations. Digital platforms can provide smooth coordination of work between various governmental and business stakeholders through the standardisation of communication protocols and automation of different workflows. This can reduce manual work and redundant processes, as well as the risk of human error in G2G, G2B, and B2B interactions.
- Centralised management of data. Unified digital frameworks, such as Port Community Systems (PCS) ensure that the entered data is accessible and reusable for various processes and stakeholders having the right/permit to access and use the data.
- Improved transparency and collaboration of governmental and business stakeholders. Whether it involves regulatory compliance (G2G), operational efficiency (G2B), or supply chain optimisation (B2B), digital solutions, digitalisation develops trust and cooperation through enabling data exchange in real time and secure communication between different entities (stakeholders) involved in the process. In addition, this ensures accountability and reduces causes for disputes.
- Cost reduction and efficiency improvements. Digitalisation can automate repetitive tasks and thus reduce administrative burdens are related costs. Such tasks include, for example, customs declarations or invoicing, that can be digitalised with relative ease with the technologies that are available today.
- Sustainability and compliance. Digitalisation can support greening of G2G, G2B, and B2B interactions using tailor-made digital tools and systems for emissions tracking, sustainability reporting, and automated compliance checks.

Digitalisation can also have a specific role in specific interactions:

- In G2G interactions, digital platforms promote cooperations and interoperability among government entities, enabling efficient exchange of both regulatory and operational data. This helps in eliminating siloed workflows and facilitates timely responses to critical events, such as safety or environmental incidents.
- In G2B interactions, digital tools can simplify regulatory compliance for businesses and commercial organisations, which has a direct positive impact on the improved flow of goods and reduced delays. Digital tools for this type of interactions can, for example, support automated submissions and validations of permits or customs documents.
- In B2B interactions, integrated digital platforms enable and boost collaboration between various commercial organisations, while at the same time optimising cargo handling, transport coordination and other logistic processes. Typical digital tools used in this type of interactions include real-time tracking applications, predictive analytics and blockchain for secure exchange of documents.

Strategic recommendations for the digitalisation of G2G, G2B, and B2B interactions and processes are covered by all four key action areas of the strategy, elaborated in Section 2.2.4.

4 Toolbox for self-assessment tools for digital readiness and environmental conformity

4.1 Digital maturity self-assessment tool

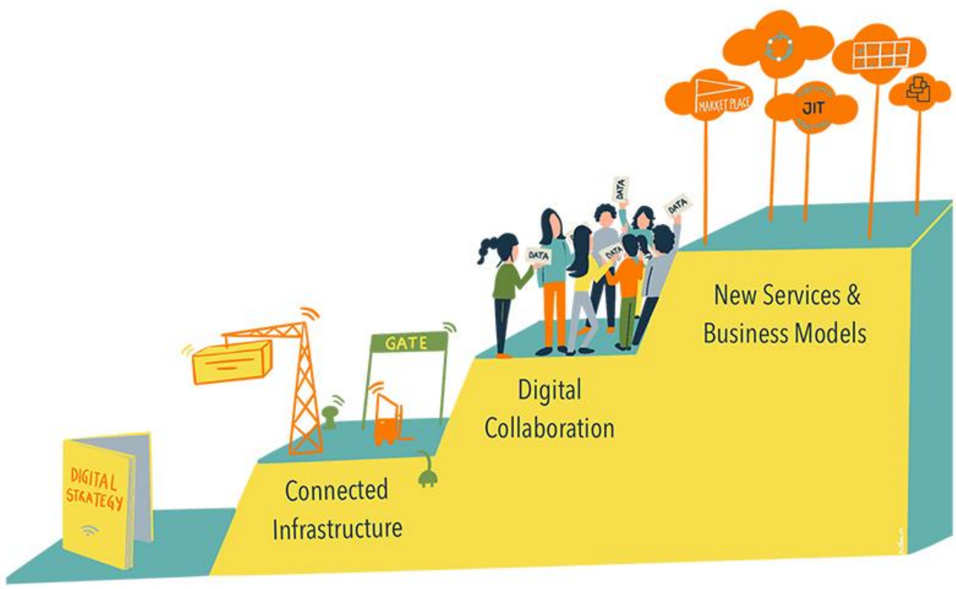
Since recent years, the interest of inland ports in digital technologies is growing. Some ports have progressed significantly on their digitalisation journey, while many are lagging, due to the widest possible array of reasons, such as lack of skills, lack of funding, ignorance, reluctance to changes, lack of trust in digital technologies, to name a few.

In order to contribute to the creation of the awareness of the importance of digitalisation with all its benefits, from increased operational efficiency, via environmental gains, to the facilitation of automation as the next steps towards smart inland ports, the Study team has developed a simple, yet efficient Digital maturity assessment toolbox (DMAT). DMAT can help ports to understand where they are in terms of digitalisation, and to benchmark their digital readiness, or, in other words, digital maturity compared to other ports. Finally, as a part of the *digitalisation guidelines* (elaborated in Chapter 5), DMAT can help inland ports identify areas for improvement, and track their progress over time.

4.1.1 Digital maturity levels

The Technical proposal prepared by the Study team for the tendering purposes lists three levels of maturity: 1) connected infrastructure, 2) digital collaboration, and 3) new services and business models. These three levels have been proposed by Lind, et.al.[13] on the basis of experience of Swedish sea and inland ports, resulting in the so-called "Trafikverket model", illustrated in the below figure.

Figure 4-1: Trafikverket model of digital maturity in ports



Source: Lind, et.al.

13 Lind, M., Haraldson, S., Lind, K., Lundman, J., Karlsson, M., Olsson, E., Bach, A. (2021). *Hamnen som digital nod* (in Swedish), Report 2021-9-30, Trafikverket

However, both expert knowledge of the European port sector and the insights obtained through the two surveys conducted during the elaboration of this Study, demonstrated that this model, although appropriate, is not sufficient to encompass those inland ports that have not yet embarked on a digitalisation journey and whose "digital reaches" are, at this moment, minimal or non-existent. In this view, the Study team proposes two simple additions to the three existing levels – the lowest level (*new level 1*) which encompasses those ports that do not use any digital tools, or they use them at the minimal, basic level, and the intermediate level (*new level 2*) for those ports that use basic digital tools, primarily for administrative purposes, such as digital invoicing and billing systems, digital tariff and fee calculations, digital customs declarations, digital cargo documents (waybills, manifests, etc.) and similar.

Therefore, the five proposed levels of digital maturity for inland ports are the following:

- Level 1: Minimal or no digital tools.
- Level 2: Basic digital tools
- Level 3: Connected infrastructure.
- Level 4: Digital collaboration.
- Level 5: New services and business models.

Level 1, *minimal or no digital tools*, represents the starting stage of digital maturity of inland ports, where the degree of deployment of digital tools and systems is either very limited (basic) or non-existent. In this case, ports still rely heavily on manual processes, with basic IT infrastructure (such as networked personal computers or laptops, internet, etc.) in place, but with minimal or no use of advanced digital tools. Communication and data sharing (mostly cargo and/or vessel documents) between port stakeholders is primarily performed using simple methods such as e-mails, faxes and mobile phones, while data collection is rudimentary involving spreadsheets or similar manual systems. Port management may have commenced initial discussions about digitalisation, but with little or no strategy or irrevocable commitment to digitalisation. At this level, inland ports typically operate with no or limited digital support, relying primarily on physical processes in performing port operations.

Level 2, *basic digital tools*, covers those ports that ventured into the basic digitalisation of routine administrative tasks, such as preparing digital bills and invoices, implementation of software for calculating fees and tariffs, submission and processing of customs declarations with digital tools, use of digital systems for managing cargo-related paperwork (e.g. bills of lading, cargo manifests, etc.), or that are deploying partial digital automation of administrative tasks without digitalisation of port infrastructure.

The next level in the proposed model is level 3, *connected infrastructure*. This means that the ports have started equipping their facilities with relevant sensors (primarily IoT sensors), so that those facilities can be monitored and controlled. These facilities can include physical infrastructure such as quays, storage areas, gates, etc.), as well as cargo handling equipment, cranes, etc. Connected infrastructure provides ports a basic digital capability to streamline port operations and reduce associated costs. Additionally, it enables port stakeholders to exert control over the infrastructure they manage and/or operate, and control over the deployment of their resources in the sense of their physical status, maintenance needs or current utilisation, so that those stakeholders can improve their efficiency and use the collected data for planning purposes.

The fourth level, *digital collaboration*, involves the possibility of sharing data not only internally, but also with other port stakeholders and external stakeholders such as forwarders or carriers (logistic companies, rail operators, trucking companies, etc.), cargo owners, and so on. Practically, this means that various port stakeholders can create better planning conditions for themselves, having a real-time and data-supported overview of the situation with the cargo and its transport, handling and storing, and improved supply chain visibility. This, in turn, facilitates smooth flow of information related to the status of good and transport. In order to enable effective digital collaboration between various stakeholders and their digital tools and systems, certain standards are required for compatibility between involved digital technologies, both technically and semantically, which was elaborated in more details in the Deliverable D3.3 Catalogue of upcoming projects, tools and technologies supporting enhanced interoperability and analysis of process optimisation perspectives.[14]

The fifth and the highest digital readiness/maturity level is called *new services and business model*. The design and implementation of new services and business models require connected infrastructure and digital collaboration as its main foundation pillars. These services and business models can be offered to users by port managers or operators themselves, by other stakeholders on behalf of the port, or these can be fully outsourced to third-party providers. These services include, but are not limited to the following examples:

- Digital freight marketplaces, which can be in the form of a digital platform allowing shippers, freight forwarders, and carriers to match cargo with available transport capacity in real-time, while ports (or 3rd party providers) can provide these services and charge a subscription or commission fee for use of the platform.
- Predictive maintenance as a service, where ports can use digital twins and IoT sensors to monitor equipment such as cranes, automated handling systems, and infrastructure, collecting data on their current structural or operational status. Analysis of the collected data in real-time can anticipate failures even before they occur, while these services can be offered to various operators (of infrastructure, suprastructure, and equipment) also on a subscription basis.
- Data-driven optimisation of port operations, where this activity can also be perceived as a service to port and terminal operators, warehouse operators, stevedoring companies, etc. For example, AI-based tools can provide optimisation on cargo handling, vehicle flow, and workforce allocation, like in the cases of Port of Montreal (Canada), Antwerp (Belgium) or Trier (Germany).[15] Ports can monetise these tools by licensing the technology to other inland or seaports or by offering operational consultancy based on data-driven insights.
- Digital customs and regulatory compliance platform, where inland ports can offer integrated customs and regulatory clearance services through a convenient digital platform, selling faster and more efficient processing of cargo as a product/service. Such services could also be offered by third-party digital service providers, who would handle paperwork, fees, and regulatory requirements on behalf of users, generating revenue through service fees.
- Synchromodal transport coordination, through a digital platform offering real-time, synchromodal transport solutions. These platforms, developed by or for inland ports, coordinate cargo movements and handling across multiple transport modes. Through optimisation of cargo flows and through switching between modes in real-time. This coordination and optimisation services help reduce congestion, environmental impact and non-productive movements of vehicles and vessels. Port can monetise this service by offering it to logistic companies that manage intermodal transport.
- Energy management and sustainability monitoring, where ports can offer energy optimisation services for shipping and cargo handling, based on digital energy management systems deployed in ports. These systems offer insights that can be used to optimise energy use, reduce emissions,

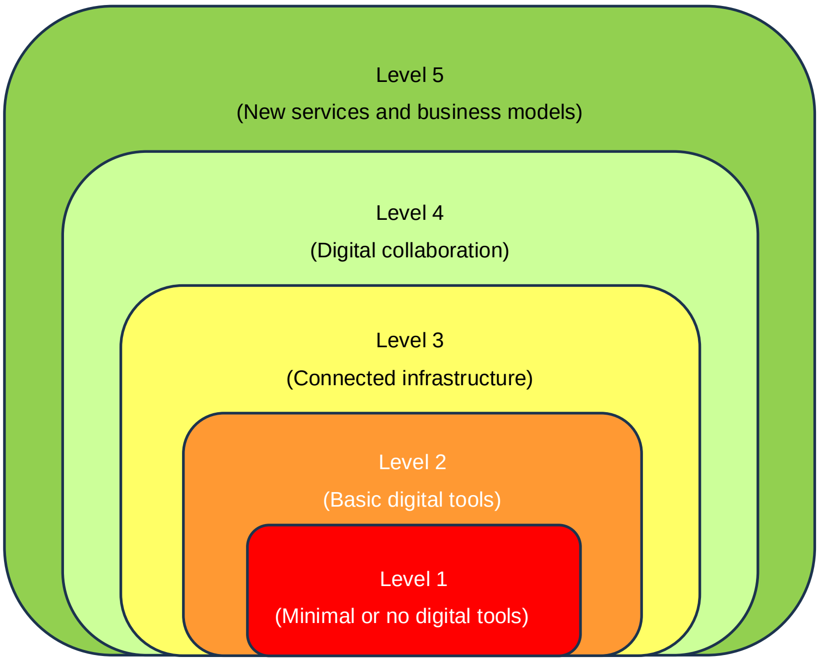
[14] Ecorys, et.al. (2024). Catalogue of upcoming projects, tools and technologies supporting enhanced interoperability and analysis of process optimisation perspectives, Deliverable D 3.3 of the *Study on Enabling Sustainable Management and Development of Inland Ports*, funded by the European Commission.

[15] Ecorys, et.al. (2024). Inventory of good practices on EU and international level, Deliverable D 3.5 of the *Study on Enabling Sustainable Management and Development of Inland Ports*, funded by the European Commission.

and meet sustainability targets, and all these services are sellable to terminal operators and stevedores, for example.

To summarise, the digital readiness/maturity levels are structured in such a way that each higher level encompasses and surpasses the preceding lower level(s), as illustrated in the following figure.

Figure 4-2: Digital readiness/maturity levels



Source: Consortium

Each of these five levels has its own five “dimensions”, or aspects of digital maturity, that are used for the assessment of a port’s digital maturity level, on the basis of criteria developed for each dimension:

Level 1: Minimal or no digital tools
This level represents the starting point where digitalisation efforts are either minimal or non-existent.

Dimensions:

- Basic IT infrastructure.
  - *Criteria: Availability of basic IT hardware, simple networking, use of basic office software*. At this level, ports may have only basic IT equipment like PCs or laptops, minimal networking, (e.g. Local Area Network – LAN), and minimal office software. Integration of such tools or use of advanced digital tools is not yet at any notable level.
- Digital awareness and strategy consideration.
  - *Criteria: Initial discussions or plans about digitalisation, management commitment*. Port management (either of a port authority or port operator) starts to understand the importance and benefits of digitalisation, initiating early-stage discussion or rough plans to implement digital tools, but no concrete actions are taken yet.
- Manual processes with minimal digital support.
  - *Criteria: Reliance on manual processes, use of basic digital tools like spreadsheets*. Ports still perform activities in the “old way”, using primarily manual processes, but sometimes using also basic tools like spreadsheets for the purposes of data entry or simple calculations.

- Basic communication tools.
  - *Criteria: Basic data collection using simple tools (e.g. Word, Excel, Access, etc.) and absence of automated systems.*
    Ports use basic communication methods (email, phones, fax) for coordination, while any data collection activities are not regular and are performed by simple office software, with no automation of any kind, and no advanced functionalities (manual data entry, manual compilation and analysis, manual data update, no auto-scheduling, no automated alerts and notifications, etc.).
- Minimal data collection and reporting.
  - *Criteria: Basic data collection using simple tools (e.g. Word, Excel, Access, etc.) and absence of automated systems.*
    Data collection is still manual, using basic software for reporting, but the data is limited, unstructured, and not used for real-time decision-making.

Level 2: Basic digital tools

At this level, ports introduce simple digital tools to perform and/or manage determined specific administrative or operations-related processes.

Dimensions:
- Digital invoicing and billing systems.
  - *Criteria: Use of digital invoicing systems for managing payments and billing.*
    Ports are gradually switching from manual invoicing to digital systems, where creation of invoices, billing, and payment processes can be done electronically. Nevertheless, these digital systems might not be completely (or at all) integrated with other port operations, and they do not "talk" to other systems in the port (e.g., cargo management, berth scheduling, or gate access control).
- Digital calculation of port fees and tariffs.
  - *Criteria: Implementation of software for digital calculation of tariffs, fees, and service* charges.
    Ports start using purpose-made software to automatically calculate port fees and other tariffs, which notably improves accuracy and reduces errors in charging for port services.
- Digital customs declaration.
  - *Criteria: Electronic submission and processing of customs documentation.*
    Customs documents are handled digitally, enabling faster and more reliable and efficient customs clearance. Digital submission of customs data and documents (cargo manifests, import/export declarations, various certificates and permits), allows ports to process and store customs-related documents.
- Digital cargo documentation.
  - *Criteria: Use of digital systems for managing cargo-related paperwork (e.g., waybills, manifests, etc.).*
    These systems replace traditional paper-based processes, leading to improved speed, reliability, and easier access to documentation which can be stored locally or externally (own servers or cloud-based ones). Such systems allow, for example, shipping companies or freight forwarders to enter details about the cargo into digital forms, while these automatically fill in the cargo documents with relevant data. This speeds up the whole process as the system eliminates multiple manual entries of data into different documents.
- Basic administrative automation.
  - *Criteria: Partial digital automation of administrative tasks without digitalisation of port infrastructure.*
    Applied digital systems (basic software solutions) involve the automation of basic workflows, such as scheduling, payrolls, document management and automated reporting. The digital

automation is partial as it does not fully digitise or automate every aspect of port operations but focuses strictly on administrative and back-office tasks, without involving any digitalisation or automation of port's physical facilities.

Level 3: Connected infrastructure
Gradual introduction of more advanced and interconnected digital tools, creating additional values to port operations.

Dimensions:

- Infrastructure connectivity.
  - *Criteria: Sensors on physical objects - connectivity of quays, gates, bridges, storage areas, etc.*
    Physical infrastructure (such as cranes, storage areas, gates) becomes equipped with different sensors that collect data on the status, usage, structural health, occupancy, environment, and other parameters. This connectivity allows ports to monitor these facilities in real-time and optimise operations based on the collected data.
- Operational monitoring.
  - *Criteria: Real-time monitoring of port activities (cargo, vehicles), basic automation.*
    Ports deploy digital systems throughout the port and on vehicles and cargo handling equipment so that they can monitor key operational parameters such as movement of cargoes and vehicles, and their status. Ports also implement basic automation meaning that they automate certain routine and repetitive tasks related to port operations. This includes using digital systems to monitor and control aspects of port activities in real-time, providing faster response times and reducing the reliance on manual interventions. For example, information from various monitoring devices is automatically displayed on a control dashboard, allowing operators to see the current location, movement, and condition of cargoes and vehicles without manually tracking them, via port workers and, say, radio connection with them. In addition, first automated alerts and notifications are created here. For example, cargo status updates (such as cargo unloaded, cargo moved to storage, or cargo ready for pickup) are generated and transmitted to the relevant stakeholders automatically through digital systems.
- Data collection and storage.
  - *Criteria: Centralised data collection, basic data storage systems.*
    This involves the existence of a central collection and storing digital facility, which is used for the storage and analysis of collected data. Data from various operations is collected centrally and stored for analysis. However, the use of this data is still at a basic level, focusing on operational record-keeping and not yet being used for more advanced purposes like deep analysis, predictive maintenance, or optimisation of port operations in real-time. Data that is collected may include the arrival/departure times of vessels and vehicles, cargo movement logs, billing records, etc. The port uses this data to generate historical records, use them for statistical purposes, compliance with regulations, and for the handling of disputes or discrepancies (e.g., billing disputes or tracking down missing shipments). There are foundations for more advanced digital applications, but at this stage, the ports are still primarily using digital tools to keep track of what has already happened rather than to optimise or predict future operations.
- Digital infrastructure interoperability.
  - *Criteria: Different digital tools (e.g., IoT sensors, monitoring systems, databases) within the port are fully integrated and capable of exchanging data seamlessly.*
    Various digital systems used in ports are becoming interoperable, enabling the smooth flow of data between IoT devices, databases, and monitoring systems. This integration facilitates necessary preconditions for improved coordination between different activities in the domain

of port operations. Digital systems applied in ports can now “talk” to each other and exchange data without hindrances. This level of interoperability provides a more cohesive operational environment, contributing to the port’s overall efficiency, although still within the limits of basic automation and connectivity. The interoperability at this stage is not yet advanced enough to handle complex tasks, such as predictive analytics or to optimise collaborative operations with external stakeholders (which come at higher levels of digital maturity). Instead, the port’s primary goal is to create a well-integrated internal system where data from all its operations can be accessed, shared, and used to improve day-to-day operations.

- Initial data-driven decision-making.
  - *Criteria: Use of collected data for basic operational decisions.*
    Ports start using data for decision-making, but still at a basic and limited level. Data is mainly used to support immediate operational needs, like, for example, cargo scheduling or infrastructure maintenance. In case of cargo scheduling or management, data on cargo movements can be used to improve scheduling or cargo management. For instance, if a port's system detects that certain cargo handling areas are underused, it can reallocate resources to avoid delays or congestion. The use of data at this stage is more reactive rather than predictive. Ports are using data to deal with their current operational problems rather than for forecasting or long-term planning.

Level 4: Digital collaboration
Going up the ladder, this level’s core feature is collaboration and data sharing between the port (including all its internal stakeholders) and its external stakeholders for the purposes of improved efficiency and coordination.

Dimensions:
- Data sharing with internal and external port stakeholders.
  - *Criteria: Secure data sharing within the port and with external partners.*
    This involves implementing secure protocols and standards for exchanging real-time data among various stakeholders (e.g., terminal operators, customs authorities, shipping lines, freight forwarders, rail operators, trucking companies, etc.). Applied digital tools in this domain focus on secure, transactional information flows. The main goal here is to facilitate seamless information flow for the purposes of improved operational efficiency, improved customs clearance, and increased transparency in supply chain management. Ports may use technologies like blockchain to ensure secure and immutable data exchanges.
- Collaborative planning.
  - *Criteria: Joint planning tools for coordinating operations with stakeholders.*
    Ports are moving towards digital platforms that have the features of allowing multiple stakeholders to participate in collaborative planning (coordination of activities and resources through shared digital tools) processes, apart from just data sharing. These planning processes include, but are not limited to, scheduling berthing windows, cargo delivery, and coordination of truck and/or barge arrivals. These features of collaboration reduce bottlenecks and inefficiencies as they ensure that all relevant stakeholders involved in the supply have access to data and plans in real time. Chains are aligned with real-time data and plans. Digital tools like collaborative portals, cloud-based platforms, and APIs can significantly facilitate these joint operations among involved stakeholders.
- Supply chain visibility.
  - *Criteria: Real-time tracking and visibility of goods throughout the supply chain.*
    This refers to the use of systems that provide end-to-end visibility throughout the entire logistics chain, from the port to the destination. It includes integration with partners' systems to track cargo movements, statuses, and estimated arrival times. IoT-enabled sensors, RFID

technology, and GPS tracking are often used to provide this level of visibility, which helps improve coordination, reduces delays, and enhances customer service.

- Digital communication platforms.
  - *Criteria: Degree of use of advanced communication tools (portals, collaborative software) provide broader and more advanced digital spaces for all types of interactions, including but not limited to operational data exchange.*
    Use of platforms that allow real-time communication and collaboration between different teams, departments, and external partners. This goes way beyond basic email and telephone communication, incorporating advanced systems like cloud-based communication platforms (e.g. Microsoft Teams), digital dashboards, or port community systems (PCS) that enable stakeholders to access and exchange critical information instantly.
- Advanced data analytics.
  - *Criteria: Implementation of data analytics tools for improving decision-making.*
    Ports use advanced data analytics software to analyse the vast amount of data collected from various digital systems and sensors, which allows them to make more informed, reliable and data-driven decisions. Predictive analytics, as an example, can be used for forecasting demand, optimising resources, and minimising operational disruptions. For instance, predictive algorithms might be applied to maintenance scheduling, cargo traffic forecasting, or even energy management and environmental performance management.

Level 5: New services and business models

This is currently the highest possible (in terms of technological and innovative advancements) level of digital maturity for ports, where ports use advanced digital capabilities to create new services and business models.

Dimensions:

- Development of new digital services.
  - *Criteria: Creation of new services using digital tools, e.g., digital marketplaces, predictive maintenance as a service, digital cargo management (tracking via IoT and RFID), smart energy management (emission monitoring and energy usage optimisation services for tenants and operators, etc.), blockchain-based transaction services, etc.*
    At this level ports start developing innovative digital services, such as online platforms for booking, tracking, and managing cargo services. Examples also include predictive maintenance services that offer insights into equipment structural status and failures before they happen, digital cargo management that can track goods through IoT devices, and smart environmental and energy management systems that monitor emissions and optimise energy usage throughout the port. These services can offer new revenue streams for the port, create added value for port services, and improve user experience.
- Innovation in business models.
  - *Criteria: Introduction of new business models using digital capabilities (subscription-based services, digital platforms on pay-per-use principles, outcome-based pricing models, revenue-sharing digital models, etc.).*
    Ports begin adopting new business models facilitated by digitalisation, such as offering subscription-based access to certain digital services (e.g., port monitoring data), pay-per-use services (e.g., real-time tracking systems for shipments), or outcome-based models where fees are charged based on performance metrics rather than flat rates. For example, a port can charge based on the reduction in fuel consumption achieved through better logistics coordination, which, in turn, is enabled by performed data analytics. Another example is outcome-based predictive maintenance, where, instead of paying flat rate for maintenance, users can pay on the basis on the reduction of equipment downtime or cost savings achieved through predictive maintenance services. Synchromodal transport coordination, for

example, can be charged as a service to logistics companies, coordinating cargo movements across various modes of transport and charging fees for optimisation services.

- Use of emerging technologies.
  - *Criteria: Implementation of AI, blockchain, and IoT for advanced solutions*.
    This criterion assesses the involvement of integration of latest technologies to modernise port operations. For example, artificial intelligence (AI) can be used for tasks like optimising vessel docking schedules or predicting port congestion. Blockchain technology can be applied to create secure and immutable records of cargo transactions, such as shipping document management system. Finally, IoT sensors could track everything from the location of containers to environmental conditions throughout the port and even inside covered storages.
- Integration with wider digital ecosystems.
  - *Criteria: Participation in wider or digital platforms and networks, such as Global Shipping Business Network (GSBN), RiverPorts Planning and Information System (RPIS), etc*.
    Ports participate in larger global digital ecosystems, allowing them to be connected with worldwide shipping platforms and trade networks. This participation enables ports to coordinate better with international partners, facilitates the uninterrupted data exchange across borders. It also allows ports to benefit from global standards in trade, logistics, and security. Examples of such digital platforms and networks are Global Shipping Business Network (GSBN) or RiverPorts Planning and Information System (RPIS), which provide visibility and transparency across the wider supply chains.
- Continuous improvement and innovation.
  - *Criteria: Ongoing refinement of digital services, fostering innovation*.
    Ports at this level constantly and continually refine and upgrade their existing digital services, and introduce new ones, thus creating and fostering a culture of continuous innovation. This can be done by allowing customers and users of different digital services to provide their inputs on the experiences with the existing digital services. Additionally, own staff can be encouraged to propose new ideas and solutions. Ports are fully dedicated to improvements and are open to new technologies as they emerge, or they are fully involved in the development of new digital technologies, tools and systems, either directly, through internal development departments or own spin-offs, or through cooperation with the developers and manufacturers of digital solutions.

The above digital maturity levels, their dimensions and assessment criteria are summarised in the below table.

Table 4-1: Assessment dimensions and criteria

Digital maturity levels	Assessment dimensions	Criteria / Explanation
Level 1 (Minimal or no digital tools)	Basic IT infrastructure	Availability of basic IT hardware, simple networking, use of basic office software.
	Digital awareness and strategy consideration	Initial discussions or plans about digitalisation, management commitment.
	Manual processes with minimal digital support	Reliance on manual processes, use of basic digital tools like spreadsheets.
	Basic communication tools	Use of email, mobile phones, radios for communication.
	Minimal data collection and reporting	Basic data collection using simple tools (e.g. Word, Excel, Access, etc.) and absence of automated systems.

Digital maturity levels	Assessment dimensions	Criteria / Explanation
Level 2 (Basic digital tools)	Digital invoicing and billing systems	Use of digital invoicing systems for managing payments and billing.
	Digital calculation of port fees and tariffs	Implementation of software for digital calculation of tariffs, fees, and service charges.
	Digital customs declaration	Electronic submission and processing of customs documentation.
	Digital cargo documentation	Use of digital systems for managing cargo-related paperwork (e.g., waybills, manifests, etc.).
	Basic administrative automation	Partial digital automation of administrative tasks without digitalisation of port infrastructure.
Level 3 (Connected infrastructure)	Infrastructure connectivity	Sensors on physical objects - connectivity of quays, gates, bridges, storage areas, etc.
	Operational monitoring	Real-time monitoring of port activities (cargo, vehicles), basic automation.
	Data collection and storage	Centralised data collection, basic data storage systems.
	Digital infrastructure interoperability	Different digital tools (e.g., IoT sensors, monitoring systems, databases) within the port are fully integrated and capable of exchanging data seamlessly.
	Initial data-driven decision-making	Use of collected data for basic operational decisions.
Level 4 (Digital collaboration)	Data sharing with internal and external port stakeholders	Secure data sharing within the port and with external partners.
	Collaborative planning	Joint planning tools for coordinating operations with stakeholders.
	Supply chain visibility	Real-time tracking and visibility of goods throughout the supply chain.
	Digital communication platforms	Degree of use of advanced communication tools (portals, collaborative software) that provide broader and more advanced digital spaces for all types of interactions, including but not limited to operational data exchange.
	Advanced data analytics	Implementation of data analytics tools for improving decision-making.
Level 5 (New services and business models)	Development of new digital services	Creation of new services using digital tools, e.g., digital marketplaces, predictive maintenance as a service, digital cargo management (tracking via IoT and RFID), smart energy management (emission monitoring and energy usage optimisation services for tenants and operators, etc.), blockchain-based transaction services, etc.

Digital maturity levels	Assessment dimensions	Criteria / Explanation
	Innovation in business models	Introduction of new business models using digital capabilities (subscription-based services, digital platforms on pay-per-use principle, outcome-based pricing models, revenue-sharing digital models, etc.).
	Use of emerging technologies	Implementation of AI, blockchain, IoT for advanced solutions.
	Integration with global digital ecosystems	Participation in global digital platforms and networks, such as Global Shipping Business Network (GSBN)[16], RiverPorts Planning and Information System (RPIS)[17], etc.
	Continuous improvement and innovation	Ongoing refinement of digital services, fostering innovation.

Source: Consortium.

4.1.2 Digital performance index (DPI)

Basic key performance indicator of the digital readiness/maturity of inland ports is defined as the Digital performance index (DPI), which is designed to quantify the level of digital maturity of ports. The DPI is set in the following way:

Scoring mechanism

In their self-assessment process, inland ports have to evaluate each dimension in each level, using the criteria as explained in the previous section. The process of self-assessment is simple – ports have to check whether they have or do not have what is explained in each dimension of each level. If they have assets or achievements as explained in each dimension's criteria, they can assess the degree of such development with the value (grade) higher than zero. Values (grades) that can be assigned to each dimension are from 0 (zero) to 4 (four):

- 0: Non-existent or very minimal.
- 1: Basic or initial efforts.
- 2: Moderate or partially implemented.
- 3: Advanced or nearly complete.
- 4: Fully implemented and optimised.

Ports need to self-assess all dimensions in all five levels.

DPI is then calculated according to the simple formula:

$$DPI = \frac{\sum_{i=1}^{n} Level_n \, score \, obtained}{\sum_{i=1}^{n} Maximum \, score \, for \, Level_n} \times 100\%$$

With the above values (grades) setup, the maximum score for each level can be 20 points, and the maximum total score can be 5 (levels) x 20 = 100 points.

The DPI can determine the *average level of digital maturity* in the following way:

16 https://www.gsbn.trade
17 https://rheinports.eu/en/

DPI score	Corresponding level of port's digital maturity
DPI = 0-20%	Level 1 – Minimal or no digital tools
DPI = 21-40%	Level 2 – Basic digital tools
DPI = 41-60%	Level 3 – Connected infrastructure
DPI = 61-80%	Level 4 – Digital collaboration
DPI = 81-100%	Level 5 – New services and business models

Example:

Let us assume that a hypothetical inland port self-assessed its own digital maturity in the following way:

Table 4-2: Example of a Digital Performance Index (DPI) calculation for a hypothetical port

Level	Dimensions	Obtained score	Maximum score
Level 1	Basic IT infrastructure	3	4
	Digital awareness and strategy consideration	2	4
	Manual processes with minimal digital support	4	4
	Basic communication tools	3	4
	Minimal data collection and reporting	2	4
		∑=14	∑=20
Level 2	Digital invoicing and billing systems	3	4
	Digital calculation of port fees and tariffs	4	4
	Digital customs declaration	2	4
	Digital cargo documentation	3	4
	Basic administrative automation	3	4
		∑=15	∑=20
Level 3	Infrastructure connectivity	4	4
	Operational monitoring	3	4
	Data collection and storage	4	4
	Digital infrastructure interoperability	3	4
	Initial data-driven decision-making	2	4
		∑=16	∑=20
Level 4	Data sharing with internal and external port stakeholders	3	4
	Collaborative planning	2	4
	Supply chain visibility	2	4
	Digital communication platforms	3	4
	Advanced data analytics	1	4
		∑=11	∑=20
Level 5	Development of new digital services	2	4
	Innovation in business models	1	4
	Use of emerging technologies	2	4
	Integration with global digital ecosystems	2	4
	Continuous improvement and innovation	1	4
		∑=8	∑=20
	Total score:	∑∑=64	∑∑=100
			DPI = (64/100)x100%=64%

Source: Consortium.

Interpretation

Total DPI can be anywhere between 0% and 100%. Obviously, inland ports with higher digitalisation levels would likely score the dimensions of the first level high, while the scores for the remaining dimensions should match what that concrete port really has and uses in its normal work. It is deemed illogical that, for example, a port assigns high scores to dimensions listed under, say, levels 3 to 5, and that it assigns very low scores for dimensions listed under level 1, because if a port scores low on a dimension “basic IT infrastructure”, it is impossible to score high on any dimensions from the Level 2 and higher. Such scoring would distort the overall assessment and would not give a clear insight into a digital maturity of a port.

Fair scoring is given in the above example, leading to a result of a DPI = 64%, meaning that this hypothetical port is highly digitalised and that its level of digital maturity corresponds to the Level 4 – Digital collaboration. Scores of individual dimensions can clearly show where further improvements are possible. For example, low scores (e.g. 0, 1 or 2 points) given to the dimension of digital customs declaration in Level 2, or to the dimension of the advanced data analytics in Level 4, means that there is room for improvement in those particular dimensions/aspects of digitalisation.

4.2 Environmental conformity toolbox

4.2.1 Overview

The Tender Specifications require a self-assessment tool for environmental conformity as part of Task 3. While digitalisation is considered a supporting service to improve environmental conformity, evaluating and measuring environmental conformity is not part of the digitalisation process itself. This chapter provides a description of the environmental conformity tool, but its actual development will take place in Task 4.

The environmental maturity level of an inland port reflects its progress in adopting sustainable practices, minimising ecological impacts, and aligning operations with environmental standards and regulations. It assesses the degree to which environmental considerations are integrated into the port’s planning, operations, and decision-making processes. This concept is crucial for ensuring that inland ports contribute to regional and global sustainability goals while maintaining their economic viability.

Inland ports that demonstrate environmental maturity are those that proactively set clear sustainability goals, monitor their progress, and implement targeted actions to enhance their environmental performance. These ports often adopt advanced technologies, such as renewable energy systems and emissions-reducing equipment, to minimise their ecological footprint. By tracking metrics like air and water quality, waste management efficiency, and carbon emissions, they can identify areas for improvement and adjust strategies accordingly. Additionally, these environmentally mature ports engage stakeholders, including local communities, governments, and industry partners, to promote collaborative efforts toward sustainability. Transparent communication about the port’s environmental impacts, goals, and performance builds trust and encourages collaboration on sustainability initiatives. Their commitment not only ensures regulatory compliance but also strengthens their reputation as leaders in fostering a greener, more sustainable transportation industry.

Within the GRIP project and especially as part of the GRIP ESMS the environmental maturity of an inland port is be evaluated using a framework or index that considers the port's performance across the levels showed in the figure below. It evolves through five levels. At Level 1, the port focuses on monitoring legislation and ensuring basic compliance with environmental laws. By Level 2, it develops a set of goals to improve environmental performance and align with evolving standards. At Level 3, the port has a place monitoring tools and reports on its performance. At Level 4, ports design and execute specific actions to address the goals established in Level 2, using the data and insights collected during Level 3 to ensure these actions are effective and impactful. Finally, at Level 5, the port achieves environmental leadership, by incorporating sustainability in its strategic corporate plan.

Environmental maturity levels are illustrated in the figure below.

Figure 4-3: Environmental maturity levels

Source: Consortium.

The environmental maturity levels and requirements for an inland port to be classified to one of these levels is presented in continuation.

4.2.2 Level 1: Monitor the Legislation

The journey to environmental maturity begins with being informed and understanding relevant environmental legislation and regulations. Inland ports should continuously monitor changes in local, national, and international environmental laws to ensure compliance. This step involves staying informed about emissions standards, waste management policies, and sustainability requirements. Inland ports who belong to this level are the least environmental mature.

4.2.3 Level 2: Set environmental goals

Level 2 represents the next significant step for inland ports on their journey to achieving environmental maturity. At this stage, ports move beyond basic compliance with environmental legislation and establish Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) environmental targets. These targets could focus on critical goals such as reducing greenhouse gas emissions, improving energy efficiency, enhancing water conservation, or transitioning to greener energy sources.

Moreover, ports at Level 2 begin recognising the importance of engaging stakeholders in their environmental sustainability efforts. They start taking initial steps to design strategies for involving stakeholders in this journey, laying the groundwork for stronger collaboration.

To determine whether an inland port qualifies for Level 2, the following set of questions is used:

1. *Have you set SMART goals for reducing energy usage?*
2. *Have you set SMART goals for transitioning to greener energy sources, such as renewable energy, hydrogen, or cleaner fuels?*
3. *Have you set SMART goals for reducing air emissions (e.g., greenhouse gases and air pollutants)?*
4. *Have you set SMART goals for repurposing or developing greener infrastructure, such as installing shore power systems, utilising daylight energy for port buildings, or constructing more sustainable facilities?*
5. *Have you set SMART goals for optimising operations to develop greener performance indicators for the future?*
6. *Have you set SMART goals for reducing noise and/or odour pollution?*
7. *Have you set SMART goals for waste and water management?*
8. *Have you set SMART goals for maintaining soil quality?*
9. *Have you set SMART goals to support modal shift?*
10. *Have you identified and created a network of local stakeholders, including their names, types of industries, contact emails, and phone numbers?*

For an inland port to be classified as belonging to Level 2, it must answer "yes" to at least three of the questions above. This ensures that the port has made tangible progress in adopting SMART targets and fostering stakeholder engagement.

4.2.4 Level 3: Monitor and report progress

To ensure accountability and transparency, inland ports must establish systems to monitor their progress toward environmental goals. Regular reporting on key metrics—such as energy consumption, waste generation, and emissions levels—enables ports to identify successes and areas for improvement. Publishing data on these metrics and providing a Corporate Social Responsibility (CSR) report are essential practices for environmentally mature ports. Transparent communication of results fosters trust with stakeholders, secures ongoing support, and demonstrates to the broader community that the port is actively setting and monitoring its environmental targets.

At Level 3, inland ports have established clear goals and actively monitor and report their progress. These ports also strengthen engagement with stakeholders by sharing performance results and encouraging feedback to improve their strategies.

To assess whether a port qualifies for Level 3, the following questions are considered:

1. *Do you have digital systems in place to monitor your performance against the environmental goals?*
2. *Do you monitor air emissions (e.g., greenhouse gases and other pollutants)?*
3. *Do you track your energy consumption?*
4. *Do you monitor water and soil quality?*
5. *Do you measure noise levels?*
6. *Do you track odour levels?*
7. *Do you publicly disclose the results of your monitoring activities?*
8. *Do you publish a Corporate Social Responsibility (CSR) report?*

9. *Do you share monitoring results directly with stakeholders? Do you have strategies to encourage stakeholder feedback on these results?*

A port that has already achieved Level 2 and can answer "yes" to at least two of the above questions qualifies as a Level 3 port. This level represents a significant step forward, where the port not only sets environmental goals but also monitors its progress on critical areas, reports its findings, and fosters greater transparency and collaboration with stakeholders.

4.2.5 Level 4: Implementation of actions to reach these goals

Inland ports must take proactive measures to achieve their environmental targets by implementing technologies, operational adjustments, and strategic partnerships that foster sustainability. This involves actions such as investing in renewable energy sources, optimising logistics to minimise emissions, and embracing circular economy principles. At Level 4, ports design and execute specific actions to address the goals established in Level 2, using the data and insights collected during Level 3 to ensure these actions are effective and impactful.

To progress from Level 3 to Level 4, ports must demonstrate that they have developed and implemented actionable plans for each goal identified and measured in earlier levels. These actions reflect a strong commitment to sustainability and environmental stewardship.

The following questions assess whether a port qualifies for Level 4:

1. *Have you developed actionable plans to reduce energy consumption?*
2. *Have you established actions to transition to greener energy sources, such as renewable energy, hydrogen, or cleaner fuels?*
3. *Have you set measures to reduce air emissions, including greenhouse gases and other pollutants?*
4. *Have you initiated actions to reduce noise and/or odour pollution?*
5. *Have you created plans to improve waste and water management?*
6. *Have you implemented actions to maintain soil quality?*
7. *Have you developed strategies to support modal shifts, such as promoting short-range urban logistics or multimodal transportation?*
8. *Have you conducted a materiality analysis to identify what matters most to your stakeholders regarding environmental sustainability, and are you aware of their efforts to enhance environmental performance?*
9. *Have you actively engaged your stakeholders in the design and implementation of your environmental action plans?*

A port that has achieved Level 3 and answers "yes" to more than two of these questions qualifies for Level 4. At this stage, inland ports demonstrate a strong commitment to their sustainability journey by translating their goals into tangible, effective actions.

4.2.6 Level 5: Sustainability embedded: excellence in environmental leadership

At Level 5 of an environmental port's maturity model, the port demonstrates a high degree of environmental sustainability integration into its operations and governance. Environmental sustainability is fully embedded in the corporate strategy, reflecting its importance in decision-making, planning, and overall port operations. The inland port has implemented comprehensive systems to monitor environmental impacts, including emissions, energy efficiency, waste management, and biodiversity conservation. Regular assessments and measurements ensure accurate tracking of performance against the set sustainability targets. The inland port has successfully completed at least one full cycle of the previous levels, which typically includes goal setting, monitoring, evaluation, and action implementation. It engages stakeholders, including local communities, businesses, and policymakers, to share monitoring results and sustainability progress. An inland port of Level 5 operates on a model of continuous improvement, using lessons learned from the first cycle to set more ambitious goals and enhance sustainability efforts. This level represents a port that not only acknowledges its environmental responsibilities but actively works to integrate sustainability into its core operational framework, setting an example for others in the industry.

Ports that have successfully completed Level 4 and meet both of the following criteria qualify for Level 5:

- Criterion 1: The inland port demonstrates that it has completed the full cycle of goal setting, monitoring, and action at least once. Additionally, it has established a long-term sustainability strategy, designed for the next 10–15 years, which is fully integrated into its corporate strategy.
- Criterion 2: The inland port actively and consistently engages stakeholders in the development and implementation of its sustainability strategy.

Achieving Level 5 reflects a port's deep commitment to sustainability, long-term planning, and stakeholder collaboration.

In Task 4 the questions and levels will be organised into an Excel-based questionnaire, which will be distributed to ports alongside the GRIP-ESMS. Ports can complete the questionnaire to determine their current maturity level and identify their starting point before implementing the GRIP-ESMS. This approach enables ports to assess their initial environmental maturity and track improvements after implementing the EMS. Additionally, the questions and criteria for advancing to higher levels will be reviewed and refined as part of Task 4, following the completion of the pilot implementation of the GRIP-ESMS.

5 Digitalisation guidelines

5.1 Overview

5.1.1 Introduction

Digital transformation of inland ports is not a matter of luxury, but a matter of necessity from multiple standpoints. If digitalisation is not taken seriously, inland ports will, sooner or later, start lagging not only in development, but primarily in operational efficiency when compared to ports that took the lead in digitalisation or embarked upon the digitalisation journey. When combined with the rest of the actors taking part in the supply chains who embarked on a digitalisation journey, non-digitalised ports may become a bottleneck in supply chains in a matter of months, thus endangering not only the supply chains in question, but also their own competitive position. Since the digitalisation brings not only operational efficiency benefits but also environmental ones (both direct and indirect), inland ports may improve their environmental position as well. It should be remembered that the digitalisation affects environmental footprint on inland ports directly using monitoring and managing environmental KPIs in ports' hot spots, and indirectly – through the optimisation of the traffic flows (of vessels, trucks, trains, cargo handling equipment, etc.) in ports, thus causing reduced consumption of energy and reduced emissions.

In this view, from automating routine administrative tasks to the use of cutting-edge technologies such as AI, blockchain, IoT and similar, digitalisation offers a wide array of opportunities for the improvement of operational efficiency of inland ports. Since digital transformation can rarely be uniform, port differ in their digital maturity levels, availability of resources, as well as readiness, capability and need to adopt advanced digital technologies. Having in mind this diversity, digitalisation guidelines are designed to serve as a comprehensive framework for supporting ports in their digitalisation development at all digital maturity levels, from those starting on their digitalisation journey to those ports targeting higher digitalisation capabilities.

5.1.2 Purpose and scope

The fundamental purpose of these digitalisation guidelines is to provide a structured approach and path to digitalisation of inland ports, tailored to their unique needs, "take-off" points, and targets. In this view, these guidelines aim to provide guidance for digitalisation of ports on all digital maturity levels – from those that are on level 1 (minimal or no digital tools), to those that have highly developed digital tools being on level 4, targeting the highest levels of digitalisation maturity according to the current defined standards.

With these features in mind, the guidelines aim to:

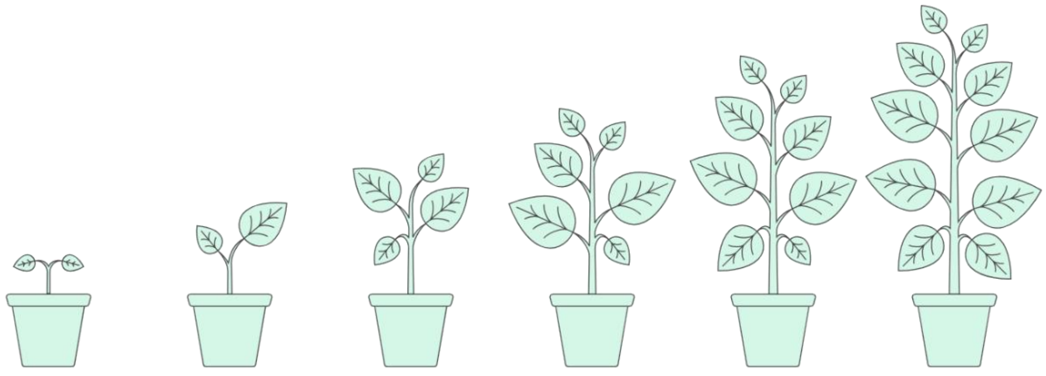
- Facilitate self-assessment and strategic planning. Inland port can use the Digital Maturity Self-Assessment Tool (DMAT) to assess their own current digital maturity level, which can help them identify their own strengths and weaknesses, gaps, potential improvement areas. This tool serves as an entry point for the alignment with the guidelines.
- Support gradual progress across digital maturity levels. The guidelines are structured to address each level of digital maturity, starting from Level 2, if Level 1 is the lowest level.
- Align with sustainability and synchromodality goals. The guidelines dedicate considerable attention to the reduction of environmental footprint of port operations through digitalisation, striving for zero-emission targets, and adopting the principles of the physical internet and

synchromodality. These elements have their own important role in achieving more sustainable and more resilient transport network.

- Promote flexibility and adaptability. Coming from the fact that each inland port operates in its unique context and environment, the guidelines present scalable solutions to ports of varying sizes, available resources, and regional challenges. Flexibility and scalability are enabled through the very segmentation of the progressive digital maturity levels. In this way, smaller or less-resourced ports can begin at Level 2, focusing on basic tools like digitised invoicing and customs systems, without the need to deploy significant investments in the initial stages. In a similar fashion, medium-sized ports can aim for Level 3 or 4 and deploy integration of various IoT sensors and collaborative systems such as PCS, while large ports can aim directly for the highest digital maturity levels deploying AI-driven systems, blockchain technologies, and similar, provided that they have the necessary resources.
- Support interoperability and modularity. Early stages of the digitalisation journey can focus on standalone digital tools, such as invoicing or scheduling software. Subsequent stages can encompass interoperable systems like PCS, which are designed to evolve with additional functionalities (e.g., advanced analytics, multi-stakeholder collaboration). Modular implementation allows ports to adapt to regional conditions, ensuring compatibility with local systems and regulations.
- Allow deployment of “sustainability for all” principles. Regardless of size or resources, all ports can benefit from the guidelines’ sustainability focus. In this way, basic tools, such as emissions tracking and digital documentation, are achievable for smaller ports. Larger ports can deploy advanced AI systems earlier to optimise resource use and minimise environmental impacts. This tiered approach ensures that even ports with limited resources can contribute to the reduction of environmental footprint of inland ports operations.

The purpose of the guidelines is illustrated in the figure below.

Figure 5-1: Purpose of the guidelines in achieving the digital maturity of inland ports



Source: Consortium

5.1.3 The role of the Digital Maturity Self-Assessment Tool (DMAT)

A brief revisit of the DMAT is needed here in order to explain the role of the tool in the guidelines, being its integral part. The DMAT primarily helps ports to evaluate their current state of digitalisation in an objective way. In this view, the DMAT provides a structured framework for the self-assessment of different aspects of inland ports’ digital maturity, pinpointing the location of individual ports on the digital maturity scale, measuring the following:

- Technology adoption and integration, which examines the extent to which digital tools and systems are applied and interconnected in the domain of port operations.
- Interoperability and collaboration, where the tool assesses the ability of port's systems to share data and collaborate effectively with both internal and external stakeholders.
- Operational efficiency, where the tool evaluates improvements that are achieved through automation, real-time monitoring, and optimisation of resource allocation.
- Innovation and new business models applied, evaluating the degree of application of innovative services in inland ports and their participation in wider digital ecosystems.

In a nutshell, the DMAT results allow ports to identify their current maturity level and use the results as inputs for the guidelines, following the relevant sections of the guidelines to address gaps and advance toward higher maturity levels, according to their needs.

5.1.4 Structure and approach

The guidelines are organised in a way to allow ports to gradually progress from lower maturity levels to the higher ones. Due to the flexibility of the guidelines, ports can opt to advance one level at a time, and even dimension by dimension (within the same maturity level), which is more suitable for smaller ports with less financial resources available, or ports can even progress two or more levels at the same time, which can be the option for larger ports which want to undertake radical and quick digital transformation. Naturally, since each level builds on the capabilities established in the previous one, ports cannot skip all parts on one level to progress to a higher one.

For each digital maturity level (level 2 and higher) the guidelines provide recommendations in the following elements:

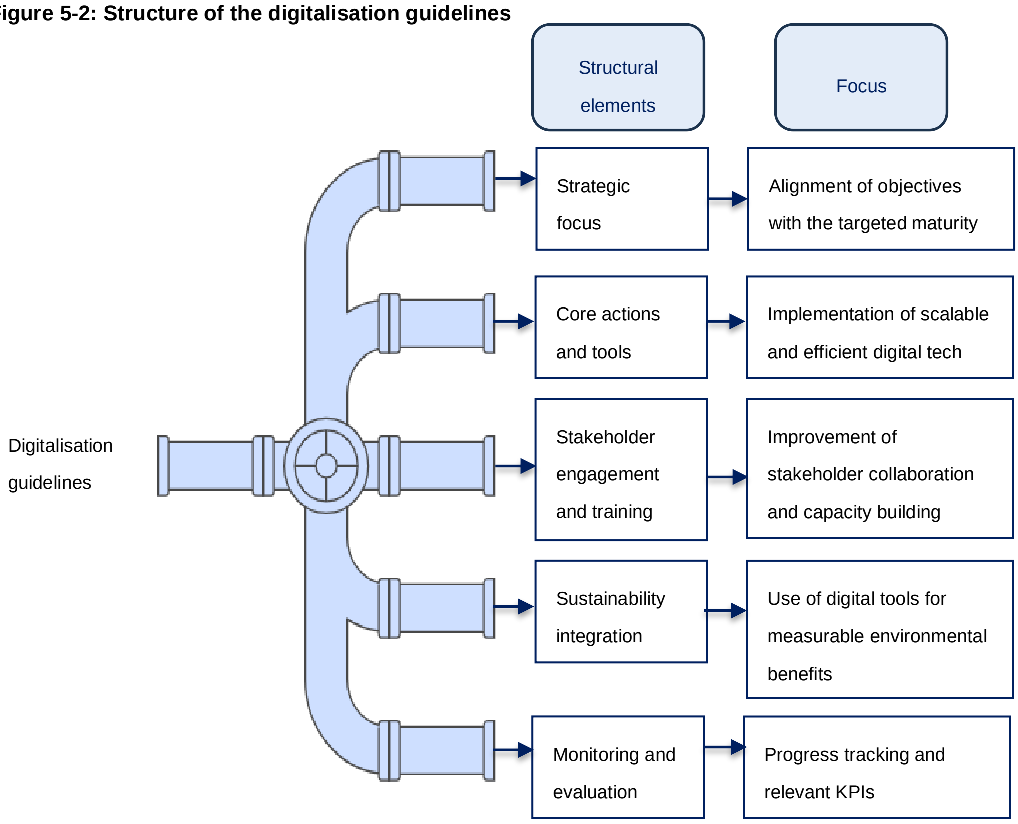
- Strategic focus. Each maturity level sets the stage with the clear definition of its strategi objectives, enabling the alignment of efforts with the port's digital targeted maturity level and operational priorities. In this way ports can remain focused on achievable goals with lower risks of overinvestments or misaligned initiatives of other strategic development areas.
- Core actions and tools. The guidelines here involve practical and scalable steps and recommendations for the implementation of different digital technologies, aligned with the ports needs and available resources. Here, specific actions, such as implementation of IoT sensors, deployment of PCS, or integration of AI-driven analytics are proposed, always having in mind that ports can adopt any tools gradually, thus ensuring that digitalisation efforts are feasible and impactful at the same time.
- Stakeholder engagement and training. This domain includes measures to improve stakeholder collaboration and build up workforce for using and maintaining digital technologies applied in ports since these measures are crucial for the successful implementation of digital tools. The emphasis is on creation of ambient of trust and cooperation, especially when data-sharing platforms (such as PCS) are introduced for the first time or expanded with more services, data scope and stakeholders.
- Sustainability integration. Each level integrates guidance and recommendations for using digital tools to achieve both direct and indirect environmental benefits that are measurable whenever possible. This ensures the alignment of digitalisation efforts with targeted sustainability goals. Here, concrete tools are recommended, such as IoT sensors for real-time emissions monitoring, digital platforms for promotion of green logistics such as synchromodality.
- Monitoring and evaluation. Finally, the guidelines contain set of recommendations for continuous tracking of digitalisation progress so that inland ports can keep the progress aligned

with their strategic objectives. Key performance indicators (KPI) and methods for tracking progress are recommended whenever possible.

Each digital maturity level is designed in such way to serve as both a standalone framework and a take-off point to more advanced digital technologies, allowing ports to progress at their own pace and possibilities.

In summary, the structure of the guidelines is illustrated in the figure below.

Figure 5-2: Structure of the digitalisation guidelines



Source: Consortium

5.1.5 Key benefits

Benefits of following the guidelines largely match those of the digital transformation itself, and include increase in operational efficiency, improvement of environmental parameters both directly and indirectly, improved stakeholder collaboration, innovation-based growth, etc. Moreover, the guidelines have the sole purpose to *guide* the ports to either start their digitalisation journey or to move up the digital maturity levels according to their needs and available resources.

Key benefits of using these guidelines are summarised in the following table:

Table 5-1: Key benefits of using the guidelines

Benefit domain	Details
Operational efficiency	• Automation of routine processes, resulting in reduced manual workload and risk of human error. • Use of real-time data for optimisation of resource allocation and minimisation of congestion.
Environmental sustainability	• Monitoring and reduction of emissions, waste and energy consumption.

Benefit domain	Details
	• Easier compliance with environmental regulations or targets through digitalised and automated tools.
Improved stakeholder collaboration	• Increase of security in data sharing and collaborative decision-making through the use of interoperable digital systems. • Building up and increasing trust and harmonisation among stakeholders involved in the supply chain.
Wider integration	• Connection with cross-border platforms and digital ecosystems. • Alignment with physical internet principles. • Facilitation of standardised protocols for unhindered cross-border operations.
Innovation and growth	• Possibility to launch new business models, such as predictive maintenance services and digital freight marketplaces. • Monetisation of digital capabilities for the creation of additional revenue streams.

Source: Consortium

5.2 Guidelines for Level 2 digital maturity level

5.2.1 Strategic focus

The first and the most important step for the Level 2 is to develop a solid and tailored digitalisation strategy to set a solid foundation for any development direction. This strategy should clearly define objectives, define the current and desired state, identify gaps in current processes, and outline actionable steps needed for the implementation of digital tools primarily designed to improve operational efficiency, and set the stage for the implementation of digitalisation-enabled sustainable practices. The alignment of the strategy with the port's long-term goals will ensure that this initial digitalisation strategy has a structured and sustainable approach to digital transformation in inland ports, preparing the port for more advanced level of digitalisation, integration and collaboration.

Key actions in this element of the guidelines are listed in the following table:

Table 5-2: Elements of the strategic focus in Level 2 – tailored digitalisation strategy

Strategic focus – Development of a tailored digitalisation strategy
Key actions **Define objectives** • Focus on automating manual administrative processes (billing, invoices, fees calculation, etc.). • Set targets to reduce human error, improve data accuracy, and save time in routine and repetitive tasks. • Emphasise the benefits of digitalisation on the long run, for example, improved operational efficiency and reduced costs of operations. **Perform a gap analysis** • Identify areas where digital tools can replace and/or speed up manual processes. • Assess the existing IT infrastructure (e.g., availability of computers, internet connectivity, and basic software). **Secure resources** • Perform a financial estimate to cover the identified gaps, and identify funding sources, such as own budget, public-private partnerships, loans, subsidies, grants, etc.

Strategic focus – Development of a tailored digitalisation strategy
Integrate environmental goals • Include basic environmental tracking objectives, such as monitoring energy consumption and paper reduction through digitisation. **Set up an implementation timeframe** • Determine several phases of implementation, starting with the digital tools that will provide the highest possible impact in shortest possible time, such as invoicing systems, or electronic arrival report declaration.

Source: Consortium.

5.2.2 Core actions and tools

This step focuses on the deployment of basic and simple digital systems that replace or speed up manual and paper-based processes.

Key actions in this element of the guidelines are enclosed in the table below:

Table 5-3: Elements of the core actions and tools in Level 2 – basic digital tools

Core actions and tools – Implement basic digital tools
Key actions **Digital invoicing and billing systems** • Migrate from manual billing/invoicing to automated digitalised systems to reduce errors speed up the process. • Procure relevant software solutions compatible with other systems to create the core for future integrations. **Fees and tariffs calculation tools** • Deploy purpose-built software to calculate port fees and tariffs. • Include modules for modifiable rates on the basis of dynamic variables such as services offered, vessel and cargo types, cargo volumes, etc. **Digital customs declaration** • Agree with the Customs authorities to deploy digital tools for electronic cargo declarations for faster customs clearance. • Make sure that such tools are fully compliant with the national customs regulations. **Digital cargo documents** • Replace hard copy versions of manifests, waybills, and other cargo-related documents with digital formats. • Use cloud-based systems for secure and safe storage and use of digital documents.

Source: Consortium

In parallel with the introduction of basic digital systems, inland ports need to start building the cybersecurity for their digital domains.

Key actions related to the initial steps in cybersecurity are the following:

Table 5-4: Elements of the core actions and tools in Level 2 – cybersecurity foundations

Core actions and tools – Cybersecurity foundations
Key actions **Secure data access** • Implement password protection and user authentication protocols. • Apply role-based access to ensure data is available to authorised personnel only. **Systems protection** • Install basic antivirus and firewall software to protect against common threats. • Ensure regular updates of software and operating systems **Education of employees** • Design relevant basic cybersecurity training programs and train employees accordingly.

Source: Consortium

5.2.3 *Stakeholder engagement and employees training*

Success of the digital transformation process at Level 2 strongly depends on the support of stakeholders and awareness and readiness of ports' employees.

Key actions in this element of the guidelines are listed in the following table:

Table 5-5: Elements of the stakeholder engagement and employees training in Level 2 – raising awareness and building capacity

Stakeholder engagement and employees training – raising awareness and building capacity
Key actions **Organisation and performance of awareness campaigns** • Organise workshops and information/demonstration events to inform stakeholders on the need to go digital and on the benefits digitalisation will bring to ports and their stakeholders. • Highlight the efficiency and cost-saving benefits of digitalisation to stakeholders. • Use success stories from other ports as examples to build momentum. **Employees training** • Organise workshops on basic digital literacy and the importance of cybersecurity. • Design training program and perform training of employees to operate new digital tools. **Collaboration with stakeholders** • Involve stakeholders, such as terminal operators and customs authorities, in planning and training sessions to ensure alignment and harmonisation from the very beginning.

Source: Consortium.

5.2.4 *Sustainability integration*

Although Level 2 focuses on basic tools, small steps toward environmental sustainability can be integrated from the very beginning, which is important for the creation of awareness about the importance of environmental impacts of inland port operations. Key actions within these structural elements of the guidelines should concentrate on the impact of digitalisation on the environmental performance of inland ports.

Key actions in this element of the guidelines are listed in the following table:

Table 5-6: Elements of the sustainable integration in Level 2 – commencement of environmental tracking

Sustainability integration – commencement of environmental tracking
Key actions **Commence tracking basic environmental KPIs (eKPI)** • Use spreadsheets or basic software to record or estimate energy consumption, waste generation, and emissions, measured by basic commercially available measuring instruments or estimated through the use of different methodologies. • Include reporting on chosen eKPI as an integral part of reports on daily operations. **Development of awareness on the need to reduce paper usage** • Set targets for reducing paper usage by digitising as much documentation and workflows as possible at this stage. • Organise workshops and educational sessions to inform stakeholders on the environmental benefits of digitalisation. **Preparations for future integrations** • Make sure that data collected at this stage is stored in formats compatible with advanced systems at higher maturity levels.

Source: Consortium.

5.2.5 Monitoring and evaluation

Monitoring and evaluation are of crucial importance, especially at the early stages of digital transformation. These activities help ports to spot problems and setbacks, identify any wrongdoings or deficiencies, and to assess the pace of digital transformation, adjusting the processes on the run.

Key actions related to the monitoring and evaluation are listed in the following table:

Table 5-7: Elements of monitoring and evaluation in Level 2 – assessment, review and preparation

Monitoring and evaluation – assessment, review and preparation
Key actions **Setting up evaluation metrics** • Measure time savings for different processes, monitor error rates and paper usage. • Track the adoption rate of new tools by port employees and stakeholders. • Track suggestions and complaints on functionalities of introduced digital tools. **Regular reviews** • Schedule periodic reviews to check the progress and react on challenges, problems and any other issues. • Keep the implementation plan dynamic – based on feedback and results of the reviews. **Preparation for upgrades to Level 3** • Identify areas (own assessments, surveys with stakeholders) where more advanced digital tools, such as IoT sensors or real-time monitoring, could provide most notable and quick impact and additional value.

Monitoring and evaluation – assessment, review and preparation
• Commence planning for infrastructure upgrades and more advanced digital tools.

Source: Consortium.

Summary of expected outcomes

The completion of Level 2 digital maturity level will bring the following benefits to inland ports:

- Established digitalisation strategy as the first systematic and programmed plan for digital transformation.
- Digitalisation of basic administrative functions, such as billing, invoicing, and cargo documentation, resulting in improved efficiency.
- Built foundations for environmental monitoring and basic sustainability metrics.
- Created awareness on the digitalisation benefits for all stakeholders and improved digital skills of own workforce.

5.3 Guidelines for Level 3 digital maturity level

Activities in Level 3 focus on creation of a connected operational environment by integrating different digital technologies, such as IoT-enabled systems, real-time monitoring tools, and introducing a basic Port Community System (PCS). This elementary PCS supports infrastructure connectivity, interoperability, data exchange, and operational efficiency, setting the stage for advanced collaboration in Level 4.

5.3.1 Strategic focus

A revised strategy is needed to ensure alignment between IoT integration and the initial implementation of a PCS. This strategy needs to outline how IoT devices will collect and share real-time data to enhance PCS functionalities, such as scheduling and cargo tracking. It should also address the technical and operational challenges of integrating IoT with existing infrastructure while ensuring that these tools work aligned to improve efficiency. The alignment of these elements will allow the strategy to set a foundation for unhindered collaboration and progressive digitalisation at Level 3.

Key actions related to the first revision of the digitalisation strategy in Level 3 are listed in the following table:

Table 5-8: Elements of the strategic focus in Level 3 – infrastructure connectivity and PCS deployment

Strategic focus – Strategy for infrastructure connectivity and PCS deployment
Key actions **Objective definition** • Prioritise real-time monitoring (for example: gates, handling areas, berths…) and basic data exchange through IoT and PCS integration. • Set up a framework for scaling PCS functionalities in subsequent maturity levels, where such framework includes, but is not limited to modularity, interoperability, scalability, user-centric design, etc. **Assessment of existing systems and gaps** • Evaluate current IT and operational systems to determine compatibility with IoT devices and PCS.

Strategic focus – Strategy for infrastructure connectivity and PCS deployment
• Identify key processes (e.g., cargo documentation, scheduling) to be digitalised through PCS. **Planning for gradual PCS implementation** • Start with basic PCS features (e.g., data exchange, cargo tracking, scheduling). • Make sure that PCS development is fully aligned with the port's operational needs and stakeholder readiness. **Securing the funds** • Use different funding options, such as public-private partnerships, grants, own budget, loans or subsidies to fund PCS implementation and IoT infrastructure.

Source: Consortium.

5.3.2 Core actions and tools

In Level 3, this element of the guidelines focuses on implementation of IoT tools to create IoT-enabled infrastructure which, in turn, provides the data foundation for PCS functionality and operational optimisation.

Key actions focused on the deployment of additional digital technologies are listed in the following table:

Table 5-9: Elements of the core actions and tools in Level 3 – IoT and real-time monitoring tools

Core actions and tools – Implementation of IoT and real-time monitoring digital tools
Key actions **Deployment of IoT sensors on "hot spots" throughout the port** • Install sensors on cranes, gates, berths, storage facilities, and other critical infrastructure. • Monitor usage, occupancy, maintenance needs, and environmental conditions (e.g., emissions, temperature, air quality, etc.). **Enabling of real-time monitoring systems** • Centralise IoT data into digital dashboards accessible to port operators and integrated with PCS. • Track cargo movements, vehicle locations, and asset utilisation in real-time. • Deploy entry level digital twins for the real-time monitoring of port activities (cargo, vehicles, vessels, etc.). **Setting up of the alert systems** • Use IoT data to generate automated alerts for maintenance, congestion, operational and/or environmental anomalies.

Source: Consortium.

One of the main roles of the PCS is to act as a digital hub, which is supporting data exchange and coordination of work between involved port stakeholders.

Key actions related to the foundational PCS establishment are listed in the following table:

Table 5-10: Elements of the core actions and tools in Level 3 – Basic PCS implementation

Core actions and tools – Implementation of basic PCS
Key actions

Core actions and tools – Implementation of basic PCS
Deployment of core PCS functions • Enable digital cargo documentation (e.g., manifests, waybills) to replace manual processes and reduced paper-based documents. • Facilitate basic scheduling for berth management, cargo movements, and equipment use. **Integration of IoT data into PCS** • Use the PCS to consolidate IoT-generated data for real-time status updates on cargo, vehicles, and infrastructure. • Provide access to relevant real-time data for internal stakeholders, such as terminal operators and port authorities. **Establishing secure data exchange** • Implement initial data-sharing protocols to allow smooth interoperability between PCS and other port digital systems. • Begin aligning with international standards for data exchange (e.g., UN/EDIFACT, ISO 19845). **Supporting collaboration between stakeholders** • Allow limited access to external stakeholders (e.g., customs authorities, logistics providers) for relevant data. • Build stakeholder confidence in PCS by ensuring and demonstrating data security, usability, and win-win situations of relevant data sharing and exchange.

Source: Consortium.

IoT and PCS data provide real-time visibility of port operations, as they allow better tracking of equipment, cargo, and vehicle movements. This information helps port operators to identify bottlenecks, underutilised assets, and different types of inefficiencies in the allocation of available port resources. Automation of routine processes like scheduling and monitoring can help ports to reduce idle times for equipment and optimise the use of space in storage areas, for example. Moreover, predictive insights from IoT sensors further improve maintenance planning, reducing any unexpected downtimes. When combined, all these tools enable smarter decision-making, resulting in more efficient and cost-effective port operations.

Key actions in the field of optimisation of resource management are listed in the below table:

Table 5-11: Elements of the core actions and tools in Level 3 – Optimisation of resource management

Core actions and tools – Optimisation of resource management
Key actions **Energy efficiency** • Use IoT data to track and optimise energy consumption in port operations. • Identify inefficiencies, such as idle equipment, and take corrective measures. **Predictive maintenance** • Use IoT data through the PCS to predict and schedule maintenance, thus reducing downtimes and related costs. **Optimisation of storages and inventories** • Monitor cargo movements and storage space usage in real-time through PCS integration.

Core actions and tools – Optimisation of resource management
• Allocate resources dynamically (e.g. shifting underutilised equipment to busy areas) to avoid bottlenecks and maximise throughput by reducing idle times and optimising the use of assets during peak and off-peak periods.

Source: Consortium.

5.3.3 Stakeholder engagement and employees training

In Level 3, training of employees empowers the workforce with the relevant knowledge and skills to properly and effectively operate IoT systems and PCS related tools, which results on significant reduction of errors during implementation. Such training sessions ensure that workers learn to properly interpret real-time data and use it to make informed decisions that, in turn, improve operational efficiency. Regular training sessions also help build confidence in using digital systems and innovations, especially in the early phases of their implementation when natural fear of the unknown may cause certain degree of reluctance to use digital tools and scepticism in their efficiency. In this phase, activities related to stakeholders focus on constant workshops and demonstration sessions to familiarise them with the digital environment in the port, demonstrate obvious benefits for all involved, and build trust in data security.

Key actions related to the stakeholder engagement and staff training at this Level are listed in the following table:

Table 5-12: Elements of the stakeholder engagement and staff training at Level 3 – Workforce capacity building

Stakeholder engagement and staff training – Workforce capacity building
Key actions
Workforce training sessions on the use of IoT systems and PCS • Organise training for operating IoT-equipped infrastructure and PCS interfaces. • Educate staff on proper interpretation of real-time data for the purposes of data-driven decision-making.
Deepening of the digital literacy • Organise training courses on data entry, system troubleshooting, and basic cybersecurity practices. • Educate staff on case-studies where PCS has an important role in improving efficiency and collaboration.
Continued work on deeper stakeholder trust and involvement • Organise regular workshops to familiarise stakeholders with PCS functionalities and benefits. • Address feedback and concerns about data security and privacy through transparent communication.

Source: Consortium.

5.3.4 Sustainability integration

Environmental sustainability retains is high importance at Level 3, with activities focused on integrating digital tools to monitor and reduce the environmental impact of inland port operations. Ports can deploy IoT sensors to track emissions, energy consumption, and use of different resources usage in real time, providing clear vision of optimisation potentials. In addition, the PCS can support environmental goals by digitising workflows, reducing paper usage, and optimising cargo movements to minimise idle times, avoid congestion and reduce fuel consumption. These basic elements set the stage and prepare the port for more advanced sustainability related activities in subsequent levels of digital maturity.

Key actions in this element of the guidelines are listed in the following table:

Table 5-13: Elements of sustainability integration at Level 3 – Improving environmental monitoring

Sustainability integration – Improvement of environmental KPI monitoring
Key actions **Real-time tracking of environmental KPIs** • Deploy IoT sensors throughout the port to monitor emissions, noise, air and water quality, and energy use. • Integrate environmental IoT sensors with PCS to allow centralised reporting on environmental data. **Identifying and combating inefficiencies** • Analyse IoT and PCS data to pinpoint sources of emissions and energy wastage. • Implement tailored and targeted measures using available digital tools and systems features to reduce the port's environmental footprint. **Preparatory activities for advanced analytics** • Start with collecting high-quality (accurate, reliable, comprehensive, and in interoperable formats) environmental data to prepare input data for AI-driven analytics at Level 4.

Source: Consortium.

Tools related to synchromodality are purposedly assigned to the sustainability related elements of the guidelines. Synchromodality begins with using systems that enable real-time coordination between multiple transport modes, such as road, rail, and waterways. These systems allow cargo flows to be dynamically adjusted based on decisive factors such as availability, cost, or efficiency, which improves overall logistics flexibility. For example, a PCS integrated with transport schedules allows operators to reroute cargo from delayed rail services to available trucks, whenever possible. This initial coordination between transport modes builds the foundations for advanced synchromodal planning and optimisation in higher digital maturity levels.

In addition, basic synchromodality tools contribute to sustainability by enabling more efficient cargo routing and minimising resource waste across transport modes. For example, rerouting cargo to available rail services instead of trucks reduces fuel consumption and emissions, harmonising transport operations with environmental goals. Optimisation of multimodal logistics allows ports to lower their environmental footprint without jeopardising their operational efficiency.

Key actions for synchromodality at this level are listed in the table in continuation.

Table 5-14: Elements of sustainability integration in Level 3 – Basics of synchromodality

Sustainability integration – Introduction of basic synchromodality tools
Key actions **Enabling of data sharing for coordination work between transport modes** • Use PCS to share scheduling and cargo data with rail, road, and water transport stakeholders. • Establish basic communication links (e.g. digital messages via PCS, PCS generated SMS notifications, and similar) to avoid bottlenecks during cargo transfers. **Optimisation of cargo flows**

Sustainability integration – Introduction of basic synchromodality tools
• Use real-time IoT and PCS data to balance cargo movements dynamically between transport modes or between handling and storage areas. • Use available digital tools to identify opportunities for reduction of delays, congestions, and emissions during cargo transfers. **Informing and educating stakeholders** • Organise workshops and training sessions for internal and external stakeholders on the use of PCS for synchromodal transport and coordination of schedules.

Source: Consortium.

5.3.5 Monitoring and evaluation

Continuous evaluation permits ports to continuously monitor the performance and effectiveness of IoT systems and PCS, and to identify potential problems or inefficiencies in very early stages. Analysing stakeholders' feedback and collected data allows ports to perform informed and dynamic adjustments with the goal of improving the system integration and its functionalities. identifying any issues or inefficiencies early. Since operational needs may change over time, regular evaluation of systems can help that they evolve in line with the operational changes.

Key actions in this element of the guidelines are listed in the following table:

Table 5-15: Elements of monitoring and evaluation in Level 3 – KPI monitoring, reviews and planning

Monitoring and evaluation – Performance metrics, reviews and advancement planning
Key actions **KPI tracking** • Monitor cargo throughput, equipment uptime, vessels and vehicles waiting and operational times in port, and data-sharing frequency through PCS. • Evaluate the accuracy and timeliness of IoT-generated data (regular checks and calibrations of IoT sensors against known standards or reference measurements, latency tests, etc.). **Performing regular reviews** • Organise regular assessments of PCS functionality and stakeholder satisfaction. • Use feedback to adapt or fine-tune systems and address identified or potential issues. **Planning and preparation for advancement to Level 4** • Identify opportunities to expand PCS functionalities for advanced collaboration. • Begin integrating additional stakeholders and preparing for predictive analytics.

Source: Consortium

Summary of expected outcomes

Achieving Level 3 digital maturity will provide the following benefits for inland ports:

- Deployment of an entry level PCS with the capabilities to integrate IoT data and facilitate basic collaboration between various stakeholders.
- Realised real-time visibility into operations, which improves decision-making and increases operational efficiency.

- Reduction of waste of resources and lowered environmental impact through better monitoring and optimisation.
- Preparation of stakeholders for more advanced digital collaboration in Level 4.

5.4 Guidelines for Level 4 digital maturity level

Progressing towards Level 4, inland ports should focus on establishing advanced collaboration among stakeholders by expanding and advancing the capabilities of the Port Community System (PCS) introduced in Level 3. This phase involves integrating operational tools (software, platforms, etc.) like Terminal Operating Systems (TOS), IoT-based platforms, and advanced environmental monitoring systems apart from PCS improvements, to list a few. In addition, predictive analytics, advanced data sharing, and real-time decision-making platforms and capabilities are introduced to achieve unhindered collaboration, visibility of supply chains in real-time (dynamic visibility), and optimised transport and environmental performance of involved operations. The combination of these systems provides even better connectivity of relevant involved stakeholders, possibilities for their collaboration, finally resulting in even more improved efficiency and sustainability.

5.4.1 Strategic focus

Widening and updating the digitalisation strategy is the first important step in achieving the Level 4 digital maturity. It should align the expanded PCS and related tools with the port's operational, environmental and collaborative objectives, as these may have been changed over time. This involves not only enhancing PCS functionalities but also integrating complementary tools such as Terminal Operating Systems (TOS) and IoT-based platforms to create a unified operational framework. This is of particular importance for organisations that are not only landlord port authority, but also an operating one. To ensure that all systems work in perfect cohesion and support advanced digitalisation, the updated and expanded strategy needs to address gaps in data sharing, resource allocation, and stakeholder collaboration. In this view, the updated strategy needs to set clear objectives for predictive analytics, real-time decision-making, and multimodal coordination, always considering the need to improve the overall efficiency and sustainability of port operations. Moreover, the strategy should prioritise flexibility to adapt to technological advancements and changing stakeholder needs. Regular updates of the strategy should make sure that the development paths are aligned with international standards and best practices, driven by the goals to create innovative environment and higher operational resilience.

Key actions of importance for the update of the digitalisation strategy are listed in the table below:

Table 5-16: Elements of the strategic focus in Level 4 – Digitalisation strategy update

Strategic focus – Update of the digitalisation strategy
Key actions **Expanding objectives** • Add the functionalities and capabilities to PCS to include AI-driven predictive analytics, real-time decision-making tools, and collaborative planning systems. • Include goals for integrating operational platforms (berth booking, cargo management, yard handling) such as Terminal Operating Systems (TOS) to support terminal-level operations like cargo handling and equipment scheduling. • Set specific targets for stakeholder engagement and environmental performance optimisation.

Strategic focus – Update of the digitalisation strategy
Addressing stakeholder needs • Engage stakeholders to identify additional functionality requirements for PCS, TOS, and IoT integration. • Include external stakeholders, such as customs authorities and transport operators, in strategic planning. **Integration of data sharing protocols** • Set up secure, real-time data-sharing protocols between PCS, TOS, and other platforms. • Ensure compliance with international standards like UN/EDIFACT for interoperability. **Securing resources** • Allocate budget for system upgrades, including PCS, TOS, environmental monitoring platforms, and other platforms. • Investigate funding options, public, private or public-private partnerships to fund advanced tools and demonstration and training programmes.

Source: Consortium

5.4.2 Core actions and tools

Collaboration at Level 4 is enabled through the expansion of PCS functionalities, as well as by integration of other systems like TOS for real-time data sharing and operational planning. These systems work together to improve operations, facilitating the exchange of, and access to, critical information to all authorised stakeholders. As they provide real-time updates on the status and location of cargo, berth schedules, and transport flows, the integrated systems can help in bottleneck avoidance and improved decision-making. This interconnected ecosystem allows inland ports to optimise resource allocation and organise operations in such way to meet stakeholders' expectations more efficiently.

Key actions in deployment of more advanced collaborative platforms of are listed in the following table:

Table 5-17: Elements of the core actions and tools in Level 4 – Expanding digital platforms for collaboration

Core actions and tools – Expanding the capabilities of digital collaborative platforms
Key actions **Enhancing capabilities for data sharing** • Integrate PCS with operators' TOS and external systems (e.g., customs authorities and transport operators). • Enable real-time updates for cargo status, berth schedules, and transport flows (managing the scheduling and real-time tracking of cargo transfers between vessels, trucks, trains, and storage facilities). **Introducing predictive analytics** • Use AI-driven analytics integrated with PCS to forecast cargo volumes, identify delays (deviations from schedules, alerts when vessel arrival or cargo transfer exceeds planned or expected duration, congestion risks, etc.), and recommend operational adjustments. • Provide stakeholders with useful information into relevant processes in order to facilitate their proactive decision-making. **Enabling collaborative planning tools** • Develop shared scheduling tools for cargo handling, transport arrivals, and equipment use within PCS. • Integrate TOS data to facilitate unhindered terminal-level coordination.

Core actions and tools – Expanding the capabilities of digital collaborative platforms
• Deploy digital twins for dynamic modelling of port operations, simulation of cargo flows, or optimisation of equipment scheduling based on real-time data from PCS and IoT systems. **Implementing blockchain for data security** • Use blockchain technology to secure data transactions and have transparency in shared records. • Apply blockchain to manage cargo documentation and compliance (relevant legal, regulatory, and contractual requirements) tracking.

Source: Consortium

Expanded PCS and improved IoT functionalities can also improve supply chain visibility which then becomes comprehensive, and data driven. The integration of these tools enables real-time tracking of cargo, vehicles, and resources throughout the supply chain, providing important information for stakeholders, based on which they can take informed and coordinated decisions. This improved visibility makes sure that inefficiencies are identified and tackled soon after they occur, improving overall operational efficiency and collaboration between relevant stakeholders.[18]

Key actions in this element of the guidelines are listed in the following table:

Table 5-18: Elements of the core actions and tools in Level 4 – Improving supply chain visibility

Core actions and tools – Improving supply chain visibility
Key actions **Providing end-to-end cargo tacking (part that is in ports' "hands")** • Integrate RFID, GPS, and IoT systems with PCS to track cargo from origin to destination. • Include real-time updates on cargo status, location, estimated delivery times, and conditions. **Enabling interactive dashboards** • Develop user-specific dashboards within PCS for different stakeholders (e.g., port operators, customs authorities, and logistics providers). • Use dashboards to display KPIs such as cargo throughput, waiting times, and emissions. **Generating detailed reports** • Use PCS to produce automated reports on operational, financial, and environmental performance. • Share these reports with stakeholders to harmonise efforts and improve transparency.

Source: Consortium.

5.4.3 Stakeholder engagement and employees training

Even building initial trust and collaboration between different stakeholders is by no means an easy task, let alone further deepening these aspects of stakeholder engagement. However, strong trust and thorough collaboration between stakeholders is of crucial importance for maximisation of the benefits that can be achieved using advanced digital tools. This requires continuous promotion of open communication and transparency to ensure that all parties feel valued and included in the digitalisation process. Sharing planning sessions and joint working on data-sharing agreements are collaborative efforts that can help harmonise sometimes conflicting goals of different stakeholders, and thus establish a common approach to operational efficiency and increases sustainability.

[18] https://griegconnect.com/port-improved-port-call-handling-with-key-figures-in-a-modern-dashboard/

Key actions in this element of the guidelines are listed in the following table:

Table 5-19: Elements of the stakeholder engagement and employees training in Level 4 – Deepening stakeholder engagement

Stakeholder engagement and employees training – Deepening stakeholder engagement
Key actions **Expanding training programs** • Train stakeholders on advanced PCS features, predictive analytics, and collaborative planning tools. • Organise workshops on best practices for data sharing, privacy, and security. **Formalising data-sharing agreements** • Develop a model of data-sharing agreement together with relevant stakeholders, that is open to modifications for specific cases. • Establish concrete agreements that govern how data is shared, stored, and used among involved stakeholders. • Ensure compliance with data protection regulations. **Promoting cross-sectoral collaboration** • Use PCS to facilitate joint planning sessions with stakeholders from different sectors. • Showcase successful collaborations to build trust and confidence in shared systems.

Source: Consortium.

The expanded capabilities and functionalities of PCS and related systems require a skilled and well-trained workforce, open-minded and willing to embrace dynamic changes. In this respect, employees must be trained to effectively use advanced digital tools such as predictive analytics and real-time decision-making systems integrated into PCS and operational platforms such as TOS. Moreover, employees need to develop the ability to interpret complex data, as proper interpretation of data will enable them to make informed decisions in order to improve operational efficiency and sustainability. This high-level understanding of use of digital tools and data they provide requires continuous training and high learning culture developed among the employees so that they can keep up with evolving digital technologies and operational practices. This is exactly where the need for well-educated and highly skilled workforce is most emphasised.

Key actions in this element of the guidelines are listed in the following table:

Table 5-20: Elements of the stakeholder engagement and employees training in Level 4 – Expanding workforce capacity

Stakeholder engagement and employees training – Expanding workforce capacity
Key actions **Expanding the skill levels of employees** • Train employees on using AI and predictive analytics within PCS and operational platforms such as TOS. • Offer advanced certifications in digital collaboration and data-driven decision-making, possibly in cooperation with various educational centres, schools and/or universities. **Promotion of digital literacy among stakeholders** • In order to prevent large gaps in skills between own workforce and that of stakeholders, provide tailored training for external stakeholders on PCS and synchromodal tools. • Use additional case studies to demonstrate further benefits of collaboration between stakeholders.

Stakeholder engagement and employees training – Expanding workforce capacity
Feedback encouragement • Collect regular feedback from users to improve and fine-tune PCS and other systems. • Use insights to improve user experience and operational performance.

Source: Consortium

5.4.4 Sustainability integration

Optimisation of environmental performance of port operations in Level 4 involves the use of advanced analytics and monitoring tools integrated with PCS and IoT systems. These tools enable real-time tracking of emissions, energy consumption, and use of resources, providing important information about the parameters that are used as inputs for decision-making necessary to reduce inefficiencies. Automated compliance reporting help ports in identification of opportunities for greener operations and to align their environmental performance targets with operational efficiency and stakeholder expectations.

Key actions necessary to strengthen environmental sustainability are listed in the table below:

Table 5-21: Elements of the sustainability integration in Level 4 – Strengthening environmental sustainability

Sustainability integration – Strengthening environmental sustainability
Key actions **Deployment of advanced environmental analytics** • Use AI-driven analytics to identify sources of emissions and inefficiencies. • Recommend prevention or mitigation measures to reduce environmental impact. **Automation of environmental compliance control** • Enable PCS to generate automated compliance reports for emissions and energy use. • Set up real-time alerts for regulatory deviations. **Promotion of sustainable logistics** • Promote low-emission transport options by highlighting their cost and environmental benefits within PCS dashboards. • Optimise cargo flows to minimise fuel consumption and idle times. **Sharing of environmental data** • Make eKPI data available to stakeholders to encourage greener practices. • Use transparency to harmonise joint sustainability goals throughout the supply chain.

Source: Consortium.

At Level 4, inland ports start using digital tools to provide coordination between different transport modes in real time. Integrating PCS with synchromodal tools, IoT, and AI allows inland ports to monitor and manage cargo transfers between transport modes in real-time. This coordination optimises resource use, minimises delays, and improves the efficiency of multimodal logistics for all stakeholders.

Key actions concerning advanced synchromodality are detailed in the table below:

Table 5-22: Elements of the sustainability integration in Level 4 – Bringing advanced synchromodality into the game

Sustainability integration – Introducing advanced synchromodality
Key actions **Enabling real-time synchromodal management** • In cooperation with other stakeholders, integrate PCS with IoT systems to track cargo across road, rail, and waterways. • Use synchromodal optimisation tools and AI to recommend mode switching based on cost, time, and environmental impact. • Use digital twins to support operational modelling and decision-making during the enhancement of synchromodal platforms. **Optimisation of transport flows** • Use PCS and TOS to dynamically schedule transport modes, avoiding bottlenecks and minimising delays. • Provide stakeholders with real-time visibility to monitor and adjust schedules. **Expanding stakeholder access** • Grant transport operators access to PCS features for dynamic scheduling and cargo updates. • Provide unhindered communication between all parties involved in multimodal logistics.

Source: Consortium

5.4.5 Monitoring and evaluation

Even at higher levels of digital maturity, continuous evaluation maintains its importance. It ensures that advanced systems deliver tangible and expected values, aligned with strategic objectives. Regular monitoring of determined KPIs and analysis of system performance helps ports to identify weak spots and areas for improvement. This iterative process allows ports to make informed adjustments to digital tools and strategies, making sure they remain not only effective but also responsive to changing operational demands.

Key actions related to the monitoring and evaluation are listed in the following table:

Table 5-23: Elements of monitoring and evaluation in Level 4 – Continuous evaluation

Monitoring and evaluation – Iterative procedures
Key actions **Tracking advanced KPIs** • Define and monitor additional KPIs like data-sharing frequency, cargo throughput improvements, environmental improvements, and predictive accuracy. **Performing regular audits** • Evaluate the effectiveness of new systems and identify areas for improvement or fine-tuning. • Use results to update the digitalisation strategy. **Preparing for Level 5** • Identify critical gaps that need to be resolved before introducing fully integrated systems and introduction of new business models. • Plan for innovative services such as predictive maintenance and digital freight marketplaces.

Monitoring and evaluation – Iterative procedures

Source: Consortium.

Summary of expected outcomes

Following the completion of all key activities detailed in all elements of the Level 4 digital maturity inland ports can achieve the following benefits:

- Use of advanced PCS, TOS, and IoT tools for the purposes of providing unhindered collaboration with involved stakeholders, as well as real-time decision making based on the data collected by deployed digital tools and systems.
- Providing stakeholders with comprehensive supply chain visibility and improved planning and coordination tools.
- Optimised environmental performance through data-driven analytics and automated compliance reporting.
- Building a highly skilled and well-trained workforce and nurturing collaborative digital culture.

5.5 Guidelines for Level 5 digital maturity level

Level 5 represents the highest end of digital maturity for inland ports, where port operations are highly integrated into wider digital ecosystems, beyond port limits. At this level, ports fully use advanced digital technologies, including artificial intelligence, blockchain, and the Internet of Things, for optimisation of operations. In addition, ports adopt innovative digital services and deploy new business models, seeking to create additional revenue streams from the use of digital technologies. The focus of activities shifts toward offering new revenue-generating services, such as subscription-based platforms, outcome-based pricing models, and revenue-sharing partnerships, to list the most typical ones. Furthermore, another goal is to align port operations with the physical internet concept through digital enablers, achieve dynamic and predictive operational capabilities with the help of digital technologies, and pursue improved sustainability because of the use of digital tools and systems. Connection of inland ports to wider supply chains through advanced digital platforms would increase competitiveness of ports and create new values for ports' stakeholders.

5.5.1 Strategic focus

The digitalisation strategy at Level 5 grows to a strategic foundation of future growth in digital transformation where the activities become focused on innovation, continuous improvement, and integration into wider digital ecosystems, beyond own supply chains (e.g. multiport community system of RPIS[19]). At this stage, the strategy update involves the use of advanced technologies such as AI, blockchain, and IoT to create hi-tech digital services and align operations with wider supply chain ecosystems. Encompassing continuous improvement, the strategy ensures adaptability to emerging trends in digital technologies, as well as continuous stakeholder feedback for improved efficiency. Stakeholder feedback at this level evolved to be used not just for operational refinements but for the refinement of strategic goals and development of scalable and market oriented digital services. This is achieved using input from the broad network of stakeholders to fine-tune services like predictive maintenance[20] or digital freight platforms. This advanced approach raises the stakes of collaboration with stakeholders and makes sure the competitive advantage of ports in a dynamic digital landscape which evolves at stunning speed.

19 https://rpis.eu
20 https://hhla.de/en/media/news/detail-view/ai-assisted-status-monitoring-of-port-vehicles-optimizes-logistics-processes

Key actions related to the update of the strategy are listed in the following table:

Table 5-24: Elements of the strategic focus in Level 5 – Update and expansion of the strategy

Strategic focus – Refining and expanding the strategy
Key actions **Setting ambitious goals** • Prioritise service innovation, sustainable practices, and customer-centric solutions. • Emphasise integration with international platforms or initiate activities on creating such platform(s). **Promoting continuous innovation** • Set up a process for regular updates updating the strategy to incorporate emerging technologies. • Foster a culture of experimentation and improvement across the organisation. **Focusing on monetisation and scalability** • Outline plans for monetising digital services through various business models such as subscription-based, pay-per-use, freemium, or outcome-based models. • Make sure that new services are scalable, for adoption by (or licensing to) other ports and logistics stakeholders. **Enabling the digital support for the physical internet** • Focus on digital enablers such as IoT-based tracking, interoperable data systems, and universal data exchange standards. • Promote open data-sharing frameworks that align with international best practices.

Source: Consortium

5.5.2 Core actions and tools

Reaching the highest digital maturity level requires inland ports to transform themselves into providers of digitalisation-enabled services of high value. This includes the use of advanced digital tools to create additional business lines, beyond the traditional port operations and lease of assets. Use of digital technologies such as IoT, AI, blockchain, big data analytics, etc., ports can offer new services such as cargo tracking in real time, predictive and prescriptive analytics, and secure transaction platforms. These services have dual benefits – on the one hand they improve operational efficiency, and on the other hand, they facilitate opportunities to create new revenues streams and provide additional competitive advantages to inland ports.

Key actions in the domain of core actions and tools are listed in the following tables:

Table 5-25: Elements of the core actions and tools in Level 5 – new business services

Core actions and tools – Development of new digital services
Key actions **Creating digital freight market places** • Launch port-centric platforms that connect shippers, freight forwarders, and carriers to match cargo with transport capacity in real-time. • Create revenue flows from these platforms through subscription fees or transaction-based commissions. **Predictive maintenance as a service (PMaaS)**

Core actions and tools – Development of new digital services
• Use IoT sensors and digital twins to monitor the condition of infrastructure and equipment of operators, concessionaires and/or tenants. • Provide predictive maintenance insights to users on a subscription or pay-per-use basis. **Introducing smart energy management service**[21] • Deploy digital systems to track, optimise, and monetise energy usage for tenants and operators. • Use analytics tools to monitor emissions and recommend improvements. **Developing blockchain based services** • Use blockchain for secure and transparent transactions, such as electronic bills of lading and customs clearance. • Make revenues from these services by offering subscription-based access to secure data repositories. **AI-assisted logistics optimisation** • Use AI to analyse operational data and recommend efficiency improvements in cargo handling, route optimisation, and workforce allocation. • License AI tools to other ports or logistics providers.

Source: Consortium.

Key actions related to the introduction of the innovative business models are listed in the table below:

Table 5-26: Elements of the core actions and tools in Level 5 – Adopting innovative business models

Core actions and tools – Innovative business models
Key actions **Introducing subscription-based models** • Charge users for access to advanced digital services like predictive analytics or cargo tracking platforms. **Introducing outcome-based models** • Introduce pricing structures that are in function of performance metrics, such as reduced emissions or improved cargo handling efficiency. **Offering revenue-sharing partnerships** • Collaborate with technology providers, logistics companies, and start-ups to develop joint digital solutions. • Share revenues generated from co-developed services. **Introducing freemium-based models** • Offer basic services for free (e.g., simple data analytics or limited access to a digital platform). • Charge for premium features like advanced analytics, integration capabilities, or expanded functionality. **Expanding wider presence** • Use digital platforms to integrate with global (wider) ecosystems and attract international logistics providers.

Source: Consortium.

21 Issa Zadeh, S. B., Esteban Perez, M. D., López-Gutiérrez, J. -S., & Fernández-Sánchez, G. (2023). Optimizing Smart Energy Infrastructure in Smart Ports: A Systematic Scoping Review of Carbon Footprint Reduction. *Journal of Marine Science and Engineering*, 11(10), 1921. Available at: https://doi.org/10.3390/jmse11101921

Key actions related to the integration into Physical Internet are listed in the table below:

Table 5-27: Elements of the core actions and tools in Level 5 – Integration into Physical Internet

Core actions and tools – Physical Internet
Key actions **Benefitting from IoT-equipped infrastructure** • Equip port infrastructure with IoT sensors to enable dynamic tracking and management of assets and cargo. • Ensure data integration across global (wider) platforms for useful operational insights. **Participation in wider platforms** • Integrate PCS with multiport, multimodal or international platforms for seamless data sharing and collaboration. • Enable cross-border tracking and transparency in international logistics. **Using cloud-based collaboration tools** • Employ cloud platforms for real-time coordination across global supply chains. • Ensure relevant data is accessible to authorised stakeholders in real-time, regardless of their location. **Facilitating dynamic routing and scheduling** • Implement systems capable of adapting schedules and routes dynamically, based on real-time data.

Source: Consortium

5.5.3 Stakeholder engagement and employees training

Since in competent and competitive industries learning never ends, Level 5 also requires ongoing innovation and refinement of digital tools and services. Inland ports should continuously evaluate and upgrade their digital technologies to maintain their competitive edge and be on par with evolving global standards. This involves continuous stakeholder feedback, exploring emerging trends like next generation AI (such as explainable AI - XAI) and blockchain advancements, as well as ensuring that systems are regularly optimised for performance and scalability.

Table 5-28: Elements of the stakeholder engagement and employees training in Level 5 – Culture of continuous improvement

Stakeholder engagement and employees training – Mentality of continuous improvement
Key actions **Encouraging stakeholder feedback** • Use PCS, TOS and other digital platforms to collect input on service performance and user satisfaction. • Include feedback into regular updates of digital tools. **Investing in research and development (R&D)** • Establish research partnerships with universities and technology providers to explore emerging technologies together. • Organise or assist pilots for new solutions in collaboration with partners and stakeholders. **Cultivating the culture of collaboration** • Promote open communication and sharing of ideas among employees, stakeholders, and partners.

Stakeholder engagement and employees training – Mentality of continuous improvement
• Organise "hackathons"[22] on targeted topics and challenges. • Encourage and reward innovation and experimentation within the organisation. **Regular updating of systems** • Ensure that all digital tools and systems are properly and regularly maintained and upgraded to keep pace with technological advancements.

Source: Consortium

5.5.4 Sustainability integration

It has been discussed earlier that synchromodality as a practice contributes to sustainability by enabling more efficient cargo routing with lower fuel consumption and related emissions, minimising resource waste across transport modes, reduction of idle voyages and congestion, thereby contributing to the reduction of environmental footprint of port operations. For this reason, activities related to synchromodality are assigned to the element of sustainability integration.

Table 5-29: Elements of the sustainability integration in Level 5 – Synchromodality in "warp drive"

Sustainability integration – Full implementation of synchromodality
Key actions **Improving synchromodal platforms** • Use AI and advanced analytics for dynamic cargo allocation to the most efficient transport mode based on real-time conditions. **Focusing on digital integration for the physical internet** • Ensure systems like PCS and IoT networks are fully compatible with global physical internet standards. • Develop predictive algorithms to anticipate disruptions and dynamically reroute cargo. **Enabling predictive synchromodal logistics** • Use AI tools to optimise resource allocation across all transport modes, reducing idle times and costs. **Promoting schedule alignments among stakeholders** • Strengthen partnerships with rail, road, and barge operators to ensure alignment in schedules and operations.

Source: Consortium

Sustainability is a core focus at Level 5, realised through the use of advanced digital tools to monitor and minimise environmental impact of various activities in the domain of port operations. Ports employ IoT sensors and AI-driven analytics to track emissions, energy consumption, and waste generation in real time. These tools provide necessary information that enable ports to optimise resource use, reduce inefficiencies, and comply with environmental regulations or own eKPI targets. The use of these digital technologies allows ports to integrate sustainability into daily operations while supporting broader zero-emission goals within the limits of their own possibilities.

Contribution to zero-emission port operations can be realised through the activities listed in the following table:

22 For example: https://alternativefuelshackathon.eu/smart-energy-management-in-ports/

Table 5-30: Elements of the sustainability integration in Level 5 – Contribution to zero-emission operation

Sustainability integration – Commitment to digitalisation-enabled zero-emission operations
Key actions **Deployment of smart environmental monitoring systems** • Use IoT and AI to track emissions, energy use, and waste generation in real time. • Provide analytics to identify inefficiencies and recommend improvements. **Automation of environmental compliance** • Use digital tools and systems to generate real-time compliance reports for emissions and energy use. • Send alerts for any deviations from sustainability benchmarks or targets. **Promotion of digital tools for greener operations** • Use digital freight marketplaces to prioritise transport options with lower total emissions. • Use AI to optimise cargo flows, reducing fuel and or battery consumption and emissions. **Offering environmental analytics services** • Grant access to detailed environmental performance data to relevant stakeholders • Monetise these services through subscription-based models or offer them for free in package with other commercial digital services.

Source: Consortium

5.5.5 Monitoring and evaluation

Continuous monitoring guarantees that Level 5 systems deliver and maintain maximum value and align with port's strategic goals. Regular tracking advanced KPIs permits ports to evaluate the performance of digital tools and services, and to identify areas for improvement and further fine-tuning. This process involves using real-time data analytics to ensure that systems remain optimised, adaptable to dynamic requirements, and responsive to evolving operational demands. Regular evaluations and feedback integration can also help in maintaining alignment with both strategic objectives and global industry trends.

Key actions for monitoring and evaluation in Level 5 are listed in the table below.

Table 5-31: Elements of monitoring and evaluation in Level 5 – Continuous evaluation

Sustainability integration – Commitment to digitalisation-enabled zero-emission operations
Key actions **Tracking advanced KPIs** • Define and monitor metrics like service adoption rates, revenue from new business models, environmental impact, and customer satisfaction. **Performing regular evaluations** • Evaluate the performance of new services and business models. • Use insights to refine strategies and identify growth opportunities. **Alignment with global trends** • Regularly assess global (wider) logistics trends and adjust systems and services accordingly. • Ensure alignment with international regulatory standards and best practices. Use digital freight marketplaces to prioritise transport options with lower total emissions.

Sustainability integration – Commitment to digitalisation-enabled zero-emission operations

Source: Consortium

Summary of expected outcomes

Finally, by achieving Level 5, ports will be enabled to realise the following benefits:

- Offering new, innovative, revenue-generating digital services that can improve operational efficiency even more.
- Complete integrate with global (wider) digital ecosystems, aligning with physical internet principles through digital enablers (IoT, interoperable data systems, AI, blockchain, digital twins, synchromodal tools, etc.).
- Achieve dynamic, real-time synchromodal coordination between different transport modes.
- Achieve leading position in sustainability through digitalisation-enabled green logistics initiatives.
- Create and cultivate a culture of continuous innovation, ensuring long-term competitiveness.

6 Conclusions

The Digitalisation masterplan for inland ports and terminals represents an important initiative in addressing the digital transformation of the European inland ports sector with two main goals: increase of operational efficiency and reduced environmental footprint of port operations through the application of digital tools and systems. This masterplan combines advanced technologies, fosters interoperability and aligns digital transformation with sustainability goals with the aim of providing a comprehensive framework for modernising inland ports into smart, sustainable, and interconnected hubs. This chapter synthesises the insights, outcomes, and recommendations from the masterplan to highlight its overarching goals and future implications.

6.1 Lessons learned

Several key lessons can be learned from this masterplan. The first one is that the inclusivity drives the digitalisation progress. Recognising the fact that inland ports across Europe are in different levels of digital maturity, the masterplan guarantees that all inland ports, regardless of their “take off” point are treated appropriately to embark on the journey of digital transformation. The Digital Maturity Self-Assessment Tool (DMAT) and tailored Digitalisation guidelines are crucial in achieving this inclusivity.

It has also been demonstrated that collaboration between involved stakeholders is essential, as it directly influences effective implementation. Collaborative platforms that can be used by port authorities, operators, government bodies, and various private entities are fundamental for the breaking down of data silos and for ensuring interoperability.

From the environmental point of view, the masterplan demonstrated that the integration of advanced digital technologies such as IoT, AI, blockchain, predictive analytics offer substantial potential to increase inland ports’ sustainability through implementation of digital innovation.

Finally, the masterplan offers insights into the effectiveness of the phased implementation. The structured roadmap’s step-by-step approach facilitates ports to gradually adopt digital tools, matching the technological advancements with resource availability and stakeholder engagement.

6.2 Addressing challenges

Digitalisation masterplan, as well as the work on the entire Task 3, has successfully proven that the potential of digitalisation for the increase of operational efficiency and decrease of negative environmental impact is tremendous. Nevertheless, there are significant challenges that must be addressed. For example, financial constraints may be a serious issue for some ports. Smaller ports may have difficult time with providing sufficient budget or large-scale digital investments. Phased implementation, public-private partnerships and EU funding mechanisms are critical to overcoming these constraints. In addition, the harmonisation of legal frameworks across regions is essential to facilitate data-sharing, cybersecurity and liability issues. Last, but not least, it has been seen throughout the masterplan that a digital skilled workforce is of crucial importance, and that tailored training programs and continuous learning opportunities must be places high on a priority list.

6.3 Strategic recommendations

For the successful implementation of the masterplan a set of strategic recommendations for four key action areas is elaborated. Strategic recommendations provide guidance on how inland ports can strategically use digital technologies to improve operational efficiency, collaboration, sustainability, connectivity with other modes of transport and synchro modality. They are focused on strengthening standardisation efforts in terms of digital frameworks and protocols to enable system interoperability and to encourage collaboration between relevant stakeholders. Moreover, they provide insights on how targeted training programs should be developed and implemented to educated port employees, ensuring that they can effectively manage and operate advanced digital systems. Another direction for successful digital transformation is the integration of sustainability aspects, meaning that inland ports should prioritise environmental performance as one of the key drivers for digitalisation initiatives.

6.4 Implementing the Roadmap and Action plan

The five-step roadmap, from building foundational systems to achieving full integration with supply chains, provides a practical and scalable pathway for digital transformation. Each step of the way is supported by actionable elements in the Action Plan, which details specific activities, timelines, stakeholder roles, estimated efforts (work and finances), as well as key performance indicators to track the progress of implementation. The Action plan's use of scalable effort and financial estimates ensures that implementation is tailored to the unique needs and capacities of individual ports. The alignment of short-term victories with long-term goals should have steady progress towards achieving the vision.

6.5 The role of Digitalisation guidelines

The Digitalisation guidelines complement the Roadmap and Action plan as they provide tiered recommendations based on a port's digital maturity level. Ports that are on the very beginning of the digitalisation journey (lower maturity levels) can focus on foundational digital tools like fee calculating software, digital billing and invoicing, as well as simpler Port Community Systems, while more digitally mature ports can explore AI, IoT integration and blockchain for secure and transparent operations. This approach of the guidelines ensures a cohesive and inclusive digitalisation journey for the widest possible variety of inland ports.

6.6 Final reflections

The Digitalisation masterplan for inland ports and terminals is much more than a blueprint – it represents a call for action. Adhering to this vision, inland ports can transform themselves from ordinary transport hubs into critical drivers of economic, environmental and technological progress. The successful implementation of this masterplan required continuous and sustained commitment, adaptive strategies and, never enough emphasised, collaboration of all involved stakeholders. This masterplan positions inland ports at the forefront of Europe's green and digital transition. Through shared vision, strategic implementation, and innovation, inland ports can lead the way toward a smarter, greener, and more interconnected future.

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