Interreg

Co-funded by the European Union

Italy – Croatia

TRANSPONEXT

WP1 - Supporting greener transport options by defining cross-border strategy and action plan

Deliverable no. D.1.1.2

Best practice analysis

Summary

INTRODUCTION

This report synthesizes an analysis of best practices for enhancing the quality, safety, and environmental sustainability of the intermodal transport sector, with a particular focus on the Italy-Croatia (IT-HR) Programme Area. It emphasizes capitalizing on the results of previous projects, most notably TRANSPOGOOD and its successor, TRANSPONEXT.

Executive Summary This report presents a comprehensive analysis of best practices aimed at enhancing quality, safety, and environmental sustainability within the intermodal transport sector of the Italy-Croatia (IT-HR) programme area. Building upon the foundations laid by previous projects, particularly TRANSPOGOOD, this study identifies key strategies and innovative solutions to address current challenges such as dominant road transport, limited multimodal connections, and insufficient information sharing. The findings underscore the critical role of digitalization, interoperability, robust data governance, enhanced stakeholder collaboration, targeted technological upgrades, and sustainable technologies in achieving a more efficient, secure, and environmentally friendly intermodal transport network. The TRANSPONEXT project, with its focus on modernizing ICT tools, implementing innovative pilot solutions (such as wagon pooling in Trieste, digitalization of railway processes in Ploče, a cargo port reservation system in Zadar, and an Intermodal Transportation Unit tracking system in Abruzzo), enhancing the TRANSPOGOOD platform, and developing cross-border training schemes, directly embodies many of these best practices. Key recommendations are provided for policymakers, technological developers, operational stakeholders, and collaborative bodies to foster a resilient and future-ready transport ecosystem in the region.

This report concludes that a concerted and collaborative effort, leveraging past successes and strategically implementing identified best practices, is essential for achieving these improvements, thereby contributing to the region's economic vitality and environmental well-being.

Background and Rationale

Intermodal transport is a cornerstone of efficient and sustainable logistics within the Italy-Croatia (IT-HR) cross-border programme area, which relies heavily on such systems for economic vitality and regional connectivity due to its significant maritime dimension. The Adriatic Sea acts as a fundamental conduit for trade and transport, with ports serving as strategic gateways and crucial nodes in the broader European transport network. The development and enhancement of intermodal transport—integrating sea, rail, and road—are therefore paramount for fostering sustainable economic growth and improving access to Trans-European Transport Networks (TEN-T). The European Union, through initiatives like the European Green Deal and the EUSAIR strategy, emphasizes the need to reduce greenhouse gas (GHG) emissions in the transport sector, with a significant focus on shifting freight from road to more sustainable modes like rail and maritime transport.

Despite its importance, the intermodal transport sector in the IT-HR area faces considerable challenges. These include a predominant reliance on road transport, while multimodal connections, particularly those involving rail, remain limited in number, frequency, and geographical coverage. This imbalance strains road infrastructure, contributes to congestion, and curtails potential environmental benefits. Furthermore, the sector is hampered by a lack of comprehensive information regarding available intermodal services and by insufficient sharing of critical data related to goods movements, shipment status, and regulatory authorizations among various actors in the logistics chain. These information gaps and communication inefficiencies negatively impact overall logistic efficiency, elevate

safety and security risks, and exacerbate the environmental footprint of transport activities, notably through increased GHG emissions.

Consequently, there is a pressing need to improve the quality, safety, and environmental sustainability of intermodal transport services and nodes within the IT-HR programme area. Enhancing quality involves boosting efficiency, reliability, and the seamless flow of information. Improving safety means addressing operational risks, ensuring cargo security, and promoting best practices, particularly for sensitive goods. Advancing environmental sustainability requires concerted efforts to reduce emissions, encourage a shift towards greener transport modes, and adopt cleaner technologies. These objectives align with overarching EU strategies, including the European Green Deal and the Sustainable and Smart Mobility Strategy.

The TRANSPONEXT project directly confronts these challenges, building upon the achievements of its predecessor, TRANSPOGOOD (Italy-Croatia 2014-2020). TRANSPONEXT aims to spearhead improvements by modernizing Information and Communication Technology (ICT) tools and implementing innovative solutions tailored to the specific needs of the IT-HR intermodal sector. Given the maritime nature of the IT-HR programme area, ports are critical hubs where intermodal integration must be optimized, strengthening their connections to the hinterland via rail and road. The persistent "lack of information" highlights that digital platforms and robust data-sharing mechanisms are foundational necessities.

Project Aims and Objectives (TRANSPONEXT)

The TRANSPONEXT project is strategically designed to address identified needs within the Italy-Croatia intermodal transport sector. Its overarching objective is to support "the sustainable growth of intermodal and multimodal connections generated by maritime nodes in the Programme area through the modernization of ICT tools and innovative solutions in order to boost quality, safety, efficiency and environmental sustainability of transport services". This underscores a commitment to a more resilient, efficient, and environmentally conscious transport network.

Specific objectives include:

- Capitalizing on the main results and outputs of the preceding TRANSPOGOOD project. This involves significantly enhancing the TRANSPOGOOD Platform, notably by integrating railway lines into its routing capabilities and developing an efficient e-booking system to provide stakeholders with more comprehensive intermodal options and streamline service procurement.
- Implementing five distinct new innovative solutions across various ports and locations in Italy and Croatia to facilitate smoother freight flow, increase operational efficacy, and reduce transport costs by improving information availability and transparency. These solutions are:
    - A fully innovative solution for wagon pooling in the port of Trieste, aimed at optimizing infrastructure management and efficiency.

  - The digitalization of railway processes and procedures in the port of Ploče, expected to increase transport efficiency, information transparency, and streamline transport organization.
  - Improvement of the port infrastructure management system for cargo terminals in the port of Zadar through an ICT solution for booking and information exchange.
  - Implementation of an Intermodal Transportation Unit (ITU) Tracking system to enhance transport efficiency.
  - The comprehensive upgrade and capitalization of the TRANSPOGOOD Platform, incorporating railway lines, e-booking, and integrating data from other pilot solutions.
- Developing and delivering cross-border training schemes to facilitate the adoption and proficient use of new, efficient, and less polluting freight transport solutions developed within the project. This focus on human capital is crucial for long-term impact.
- Defining a cross-border strategy and an associated action plan for intermodal transport in the Italy-Croatia area, providing a roadmap for future developments and investments.

TRANSPONEXT's aims reflect a problem-driven methodology, informed by TRANSPOGOOD's experiences. The emphasis on specific ICT solutions and targeted pilot actions marks a strategic progression towards addressing precise weaknesses in the intermodal logistics chain. This targeted approach suggests a mature understanding of sector needs. The dual

focus on technological advancements and human capacity building indicates a holistic strategy, recognizing that successful adoption of technologies depends on the skills and awareness of personnel and stakeholders.

Scope of the Analysis

This report analyzes best practices for improving quality, safety, and environmental sustainability within the intermodal transport sector, specifically defined by TRANSPONEXT's operational context and objectives.

- **Geographical Area:** The primary focus is the Italy-Croatia (IT-HR) cross-border programme area, as delineated by the Interreg Italy-Croatia programme. This includes maritime and coastal regions, with particular attention to key ports (Trieste, Ploče, Zadar) and their hinterland transport corridors, as well as the Abruzzo region in Italy and the Istrian region in Croatia. The unique geographical characteristics of this maritime-oriented region are considered.
- **Transport Modes:** The analysis centers on intermodal transport, primarily involving the integration of maritime transport, rail transport, and road transport. While inland waterways are mentioned in broader EU strategies, the core focus remains on the sea-rail-road nexus prevalent in the IT-HR area.
- **Types of Best Practices:** The report investigates best practices categorized under quality improvement, safety improvement, environmental sustainability, and cross-cutting themes.

- **Quality Improvement:** ICT tools for advanced tracking and tracing, optimized terminal operations (e.g., Port Community Systems, Terminal Appointment Systems), efficient e-booking systems, multimodal route planners, and standardized data exchange protocols (e.g., TAF TSI, eFTI).
- **Safety Improvement:** Enhanced training and certification, advanced safety technologies (automation, sensor-based monitoring), secure data exchange, and best practices for handling dangerous goods.
- **Environmental Sustainability:** Promoting modal shift to rail and waterways, adoption of alternative fuels and greener technologies, and logistics optimization to reduce emissions and empty runs.
- **Cross-Cutting Areas:** Comprehensive digitalization, robust data governance, stakeholder collaboration platforms, and circular economy principles. The scope aligns with TRANSPONEXT's interventions and challenges within the IT-HR intermodal transport sector.

Structure of the Report

This report is structured to provide a comprehensive analysis:

- **Section 1 (Introduction):** Establishes background, rationale, project aims, objectives, scope, and report structure.
- **Section 2 (Methodology):** Details the overall approach, criteria for identifying best practices, data collection strategy, data analysis and synthesis, capitalization approach, and limitations.
- **Section 3 (Review of Previous Projects and Existing Knowledge):** Provides an overview of relevant EU funding programmes and summarizes key previous projects, focusing on lessons learned and capitalization, particularly from TRANSPOGOOD.
- **Section 4 (Analysis of Best Practices in Intermodal Transportation):** Forms the core analytical part, subdivided into best practices for quality improvement, safety improvement, environmental sustainability, and cross-cutting themes.
- **Section 5 (Capitalization Strategy):** Examines the relevance and applicability of identified best practices to the IT-HR intermodal sector, opportunities for transfer and adaptation, and potential barriers, drawing on TRANSPONEXT's approach.
- **Section 6 (Recommendations):** Translates findings into actionable recommendations categorized into policy, technological, operational/procedural, and stakeholder collaboration/capacity building, with possible prioritization.
- **Section 7 (Conclusion):** Summarizes key findings, highlights contributions to programme objectives, and offers a future outlook.

- **Appendice**

2. METHODOLOGY

2.1. Overall Approach

The methodological foundation is rooted in a comprehensive analysis of the TRANSPONEXT project, which employs a multi-faceted strategy involving preparatory actions and strategic framework definition, implementation of new solutions, and development of cross-border training schemes. This report adopts a qualitative research methodology, combining desk research, review of previous project outputs (particularly TRANSPOGOOD), and synthesis of information from relevant industry and academic sources. Core activities include document review and synthesis of existing knowledge on intermodal transport focusing on quality, safety, and environmental sustainability.

2.2. Criteria for Identifying Best Practices

Specific criteria have been defined to systematically identify and evaluate best practices across quality, safety, and environmental sustainability.

- **Criteria for Quality Improvement:** Practices contributing to more efficient, reliable, and user-oriented intermodal transport services.
    - **Efficiency:** Streamlining processes, reducing transit times, minimizing delays, optimizing resource utilization (e.g., PCS, TAS, wagon pooling).
    - **Reliability:** Enhancing predictability, consistency, and dependability (e.g., advanced tracking and tracing systems).

- **Information Transparency and Accessibility:** Improving information flow, accuracy, timeliness, and accessibility (e.g., TRANSPOGOOD platform enhancements, eFTI).
- **Interoperability:** Promoting seamless technical and semantic interoperability (e.g., common data standards like TAF TSI, federated platforms like FENIX).
- **Optimization of terminal operations and resource utilization**.
- **Increased customer satisfaction**.
- **Streamlined administrative and operational processes**.

- **Criteria for Safety Improvement:** Practices aiming to minimize risks to personnel, cargo, infrastructure, and the public.
  - **Operational Safety:** Reducing accident likelihood and severity (e.g., advanced safety technologies, automation).
  - **Cargo Security:** Ensuring integrity of goods, protecting against theft, damage, and tampering (e.g., secure ITU tracking).
  - **Staff Safety and Competence:** Focusing on personnel well-being and expertise (e.g., comprehensive training, certifications, clear protocols for dangerous goods).
  - **Compliance with national and international safety regulations and standards**.
  - **Effective risk management procedures**.
- **Criteria for Environmental Sustainability Improvement:** Practices aiming to reduce the negative ecological impact of intermodal transport.

- **Emissions Reduction (GHG and Pollutants):** Quantifiable decrease in greenhouse gases and other air pollutants (e.g., through modal shift, alternative fuels, greener technologies).
- **Energy Efficiency:** Reducing energy consumed per unit of transport work.
- **Resource Efficiency and Circularity:** Better utilization of physical resources, waste reduction, incorporating circular economy principles (e.g., minimizing empty runs, wagon pooling).
- **Minimization of noise pollution and other environmental impacts**.

These criteria are often interconnected. TRANSPONEXT's objective to simultaneously boost quality, safety, efficiency, and environmental sustainability reflects this interconnectedness.

3. Review of Previous Projects and Existing Knowledge

3.1. Overview of Relevant Programmes

Several EU funding programmes and strategic initiatives support projects enhancing intermodal transport in the IT-HR area and beyond, often sharing goals of sustainability, digitalization, and interoperability.

- **Interreg Italy-Croatia (IT-HR) Programme:** A maritime cross-border cooperation programme financing projects addressing shared challenges, including sustainable economic development, environmental protection, and cross-border mobility. Key priorities include greener, more integrated mobility solutions and strengthening institutional capacity. TRANSPONEXT is funded under Specific Objective 3.1: "Developing and enhancing sustainable, climate resilient, intelligent and intermodal national, regional and local mobility, including improved access to TEN-T and cross-border mobility". The 2021-2027 iteration emphasizes innovation, sustainability (especially in the blue economy), and capitalizing on previous experiences, synergizing with EUSAIR.
- **Connecting Europe Facility (CEF) for Transport:** A key EU instrument for strategic investments in transport, energy, and digital infrastructure to enhance connectivity

and complete TEN-T networks. CEF Transport focuses on cross-border projects, bottleneck removal, and horizontal priorities like traffic management systems and digitalization, directing significant funding to sustainable modes (rail, maritime) and infrastructure for alternative fuels and ITS. Projects like I_RAIL (TAF TSI implementation) are relevant examples.

- **Horizon Europe (Cluster 5: Climate, Energy and Mobility):** The EU's primary research and innovation funding programme (2021-2027), succeeding Horizon 2020. Cluster 5 aims to accelerate green and digital transitions in energy and transport sectors. Key intervention areas like "Clean, safe and accessible transport and mobility" and "Smart mobility" align with intermodal transport improvement objectives. Projects like LEAD (digital twins for logistics) exemplify supported research.
- **Shift2Rail Joint Undertaking (S2R JU) / Europe's Rail Joint Undertaking (EU-Rail):** A public-private partnership dedicated to rail sector research and innovation, accelerating new technology integration. Innovation Programme 5 (IP5): "Technologies for Sustainable & Attractive European Rail Freight" is highly relevant, focusing on fleet digitalization, automation, digital transport management, smart freight wagons, and new propulsion systems. Projects like OptiYard and TAF TSI initiatives align with IP5.
- **Other Relevant Interregional and Cross-Border Programmes:** TRANSPONEXT partners bring experience from Interreg ADRION, Central Europe, Mediterranean, and IPA Adriatic, supporting projects like MultiAPPRO, CONNECT2CE, SHAREMED, and INTERMODADRIA.

This landscape shows a strong strategic direction towards enhancing digitalization, sustainability, and interoperability, creating a supportive ecosystem for projects like TRANSPONEXT. The evolution across programming periods highlights a continuous commitment to building on past achievements, reinforcing the significance of capitalization.

Table 3.1.1: Overview of Key EU Funding Programmes Relevant to IT-HR Intermodal Transport

Programme Name	Key Objectives	Funding Priorities Relevant to Intermodal Transport (Quality, Safety, Sustainability, Digitalization)	Examples of Relevant Projects (from research)
Interreg Italy-Croatia (IT-HR)	Foster cross-border cooperation in the Adriatic area; address shared challenges in sustainable economic development, environment, mobility.	Greener/integrated cross-border mobility, intelligent and intermodal mobility, TEN-T access, digitalization for transport services.	TRANSPOGOOD , TRANSPONEXT , DIGSEA , SUSPORT
Connecting Europe Facility (CEF) for Transport	Support strategic investments in transport infrastructure; complete TEN-T networks; enhance EU connectivity.	TEN-T core/comprehensive network development, elimination of bottlenecks, sustainable transport modes (rail, maritime), digitalization (ITS), alternative fuel infrastructure.	I_RAIL , FENIX
Horizon Europe (Cluster 5: Climate, Energy and Mobility)	Accelerate green and digital transitions; make energy/transport sectors climate-friendly, efficient, competitive, smart, safe, resilient.	Clean, safe, accessible transport and mobility; smart mobility solutions; industrial competitiveness in transport; digitalization for transport.	(LEAD - H2020 predecessor, relevant concept for LODIT)
Shift2Rail JU / Europe's Rail JU (IP5: Technologies	Accelerate integration of new rail technologies; enhance competitiveness	Fleet digitalization & automation, digital transport management, smart freight	OptiYard , (I_RAIL aligns with TAF TSI focus)

for Sustainable & Attractive European Rail Freight)	of EU rail industry; complete Single European Railway Area.	wagon concepts, new freight propulsion, TAF TSI implementation.	
Other Interreg (ADRION, Central Europe, Med) & IPA Programmes	Address specific regional/cross-border challenges; promote territorial cooperation in various thematic areas including transport and logistics.	Varies by programme; often includes intermodal transport development, logistics efficiency, environmental protection in transport, ICT solutions.	INTERMODADRIA , MultiAPPRO , CONNECT2CE

3.2. Summary of Key Previous Projects Analyzed

This section details previous projects contributing to the knowledge base for improving intermodal transport, highlighting objectives, results, lessons, and connections to TRANSPONEXT, serving as a narrative "Capitalization Matrix". The TRANSPOGOOD project (Interreg IT-HR 2014-2020) is central. Key achievements of TRANSPOGOOD include the development of its Platform (an ICT tool for optimal transport solutions, logistics/environmental performance monitoring), promotion of intermodal solutions in the IT-HR area, and establishment of cross-border cooperation networks. TRANSPONEXT directly capitalizes by enhancing the TRANSPOGOOD Platform (adding railway lines, e-booking), integrating new pilot solutions, and building on its stakeholder network and lessons learned.

Table 3.2.1: Capitalization Matrix of Key Previous Projects

Project Name	Funding	Main Objectives Relevant to	Key Results/ Outputs	Contributions to Quality	Contribution	Contributions to	Key Lessons Learned/U	Specific Capitalization

(Acronym)	Programme	Intermodal Transport	(Relevant to Intermodal Transport)		s to Safety	Environmental Sustainability	ser Feedback	by TRANSPONEXT
TRANSPOGOOD	Interreg IT-HR	Capitalize on INTERMODADRIA; develop ICT tools for optimal transport solutions; monitor logistics/environmental performance; improve intermodality conditions.	TRANSPOGOOD Platform (maritime routing, CO2/cost calculation, e-procurement tools); training modules.	Route optimization, cost estimation, e-procurement tools.	(Indirectly through better planning)	CO2 calculation, promotion of maritime shift.	Limited info sharing is a barrier; platform improved efficiency/costs; trainings successful; rail data & e-booking needed.	Direct enhancement of TRANSPOGOOD platform (add rail, e-booking); build on training methodology; address identified information gaps.
INTERMODADRIA	IPA Adriatic	Improve integration of short sea shipping in Adriatic logistics chains.	Enhanced SSS integration frameworks/tools.	Improved SSS efficiency.		Promoted SSS as greener alternative.		Builds on knowledge for facilitating IT-HR intermodal connections.
DIGSEA	Interreg IT-HR	Consolidate ICT knowledge from	Consolidated technical knowledg	Improved efficiency through ICT	(Indirectly through better	Improved environmental	Value of clustering knowledge from	Uses available knowledge for

	(Cluster)	PROMARES, INTESA, DigLogs, TRANSPOGOOD for a unified sea-port-hinterland-logistics approach.	e on ICT for multimodal freight; single sea-port-hinterland-logistics approach.	consolidation.	information flow)	performance through efficiency.	multiple projects for a holistic view.	TRANSPOGOOD platform enhancement.
SUSPORT	Interreg IT-HR	Enhance environmental sustainability and energy efficiency of ports in IT-HR area.	Pilot actions in ports (LED lighting, EVs, renewables); common methodologies for environmental sustainability.			Direct improvements in port energy efficiency and reduced emissions.	Importance of institutional cooperation and pilot actions for port sustainability.	Partner ASVI & PPA experience informs environmental considerations.
OptiYard	Shift2Rail IP5	Improve rail yard capacity and reliability through optimized decision support for yard managers.	Decision support tool for yard managers; simulation of real-time yard operations; process optimization.	Optimized yard processes, improved punctuality/reliability.	Reduced potential for human error in complex yard movements.	(Indirectly through efficiency)	Real-time interaction with network and automated timetabling are key for yard efficiency.	Adriafer's experience informs wagon pooling and rail-related pilots.
I_RAIL	CEF	Improve interoperabi	Implementation	Improved efficiency	Enhanced	Increased rail	TAF TSI is crucial for	Adriafer's

		lity in European rail freight information exchange via TAF TSI standards and digitalizatio n.	and testing of software for digital/ha rmonized info exchange in rail freight; digitizatio n of Safety Managem ent Systems.	and quality of rail services through standardiz ed data.	safety via digitize d Safety Manag ement System s.	freight share contribu tes to sustaina bility.	cross-border rail interopera bility.	experien ce supports digitaliza tion in Ploče and rail data integrati on in TRANSP OGOOD platform .
FENIX	CEF	Develop a European federated architecture for logistics data sharing; ensure interoperabi lity between platforms.	Federated architectu re concept; pilot sites testing data sharing across TEN-T corridors.	Enhanced horizontal collaborati on and supply chain visibility.	Secure data exchan ge.	Optimiz ation of TEN-T corridor s.	Need for federated approach to overcome platform fragmentati on.	Concept ual model for data interope rability relevant to TRANSP OGOOD platform 's wider integrati on.
AEOLIX	H2020	Improve supply chains via open systems for pan-European logistics data	Integrate d European platform for logistics data (drivers, trucks, orders,	Increased visibility, real-time informatio n.	Data exchan ge for hazard ous materia ls.	CO2 calculat or.	Cloud-based collaborativ e ecosystem needed for pan-European solutions.	Provides model for compre hensive logistics data platform s.

		platform exchange.	hazardous materials, ETA, CO2); tested in Living Labs.				
RPIS 4.0	Interreg Upper Rhine	Improve multimodal transport performance via digital solutions; promote modal shift to inland navigation; extend RPIS platform to PCS for rail/bulk.	Modular extension of RPIS platform; development of new digital port services; cross-border community for sustainable logistics.	Strengthened multimodal freight management (river, rail).	Promoted inland navigation.	Value of Port Community Systems for multimodal integration.	Informs port digitalization aspects of TRANSPONEXT (Zadar, Ploče).
COMODALCE	Interreg Central Europe	Develop multimodality in CE Ports; improve hinterland intermodal connections (rail focus) via ICT.	Transnational Toolbox of ICT solutions; pilot actions for ICT-assisted freight (e.g., La Spezia-Verona rail data	Digitized information exchange for efficiency.	Promoted shift to rail.	ICT solutions are key to overcoming logistic/administrative lacks in intermodal.	Reinforces TRANSPONEXT's focus on ICT for rail integration.

			exchange).				
LEAD (LODIT concept)	H2020	Create Digital Twins of urban logistics networks for experimentation and decision-making in on-demand logistics.	Open LEAD Digital Twinning Platform; reusable models; validated value cases for low-emission logistics.	Optimized logistics operations.	Low-emission logistics solutions.	Digital Twin concept valuable for complex logistics simulation and planning.	Conceptual relevance for advanced optimization in IT-HR nodes/corridors.

Analysis reveals an evolutionary trend: early projects focused on foundational data collection and initial platforms (INTERMODADRIA, initial TRANSPOGOOD). Subsequent projects, including TRANSPONEXT, shift towards more sophisticated, integrated, specialized solutions: enhancing existing platforms (TRANSPOGOOD with rail data, e-booking), implementing targeted pilots (wagon pooling, port digitalization in TRANSPONEXT), aiming for broader interoperability (FENIX), or advanced simulation (LEAD's Digital Twin concept). This indicates a learning ecosystem where projects build on each other. Digitalization is a dominant theme, evolving from basic information provision to complex data exchange, federated systems, and advanced analytics. The trajectory is towards integrated, multimodal solutions and a holistic supply chain view (e.g., DIGSEA, FENIX). TRANSPONEXT's rail data integration into a maritime-centric platform exemplifies this move.

3.2.1. Projects Focusing on Quality Improvements

Several projects contribute to quality by enhancing digitalization, information exchange, and operational optimization. The TRANSPOGOOD platform and its TRANSPONEXT enhancements target quality with tools for route optimization, cost/CO2 calculation, and e-booking, increasing transparency and accessibility of intermodal options. I_RAIL focuses on TAF TSI implementation, standardizing rail freight data exchange for improved quality and reliability of cross-border services. FENIX and AEOLIX pioneered federated data sharing and collaborative platforms, enhancing supply chain visibility and information quality. Port Community Systems (PCS), seen in projects like RPIS 4.0 and established systems (DAKOSY, Portbase), are crucial for quality at intermodal nodes by streamlining operations and digitalizing flows. TRANSPONEXT's Zadar CPRS and Ploče railway digitalization align with this. The Digital Transport and Logistics Forum (DTLF) shapes policy for quality through digitalization, eFTI, and corridor freight information systems to promote interoperability and standardized data sharing. These projects link quality enhancement to effective digital technologies and robust data management. Examples also include projects developing Transport Management Systems.

3.2.2. Projects Focusing on Safety Enhancements

Safety is addressed through technology, procedures, and capacity building. I_RAIL contributes by digitizing manual procedures in railway Safety Management Systems. OptiYard's decision support for rail yard managers can indirectly enhance safety by

optimizing movements and reducing human error potential. AEOLIX highlighted real-time data exchange's importance for safely transporting hazardous materials. EU regulations (ADR/RID) emphasize proper handling, documentation, and specialized training for dangerous goods. TRANSPONEXT's training schemes (WP3) aim to strengthen competencies and awareness, inherently including safety aspects. Standardization efforts (e.g., TSIs) also contribute by ensuring common operational and technical requirements. Safety enhancements come from technology, regulatory adherence, staff training, and digitalization-facilitated operational control.

3.2.3. Projects Focusing on Environmental Sustainability

Numerous projects target environmental sustainability by reducing emissions, improving energy efficiency, and promoting greener logistics. The TRANSPOGOOD platform (and its TRANSPONEXT evolution) includes CO2 calculation, enabling environmentally informed route choices and promoting shifts to less carbon-intensive options. SUSPORT directly addressed port environmental sustainability and energy efficiency in the IT-HR area through pilot actions (LEDs, EVs, renewables). LEAD (conceptually similar to LODIT) emphasized Low-Emission Adaptive last-mile solutions (electric/hybrid vehicles). Shift2Rail's IP5 ("Technologies for Sustainable & Attractive European Rail Freight") includes research into new, cleaner freight propulsion concepts. COMODALCE aimed to improve Central European hinterland intermodal connections, focusing on shifting freight to rail. RPIS 4.0 sought to promote modal shift to inland navigation. Achieving environmental sustainability requires promoting modal shift, fostering technological innovation (alternative fuels, greener

vehicles), optimizing logistics (reducing empty runs), and direct environmental management in nodes like ports.

3.3. Key Lessons Learned from Previous Initiatives

Collective experience offers valuable lessons:

- **Paramount importance of digitalization and effective data sharing:** Lack of comprehensive, timely information sharing is a major impediment (TRANSPOGOOD, FENIX, AEOLIX, DTLF). Robust ICT tools, standardized protocols, and collaborative platforms are crucial.
- **Need for interoperability:** Disparate IT systems create friction. Harmonizing protocols and procedures (TAF TSI, eFTI Regulation) is essential for seamless operations. DTLF's federated network concept emphasizes this.
- **Strong stakeholder collaboration and co-creation:** Critical for success due to the multitude of public/private actors in intermodal transport.
- **User-centric approach and investment in training/capacity building:** Vital for uptake of new technologies/procedures. Solutions must meet real-world needs; training (as in TRANSPOGOOD) is necessary.
- **Building on existing knowledge through effective capitalization:** Leveraging past results (as TRANSPONEXT does with TRANSPOGOOD) is more efficient and impactful.

- **Supportive policy and regulatory environment:** Indispensable for fostering intermodal transport and innovative/sustainable practices (e.g., eFTI, Combined Transport Directive).
- **Addressing physical infrastructural bottlenecks:** Digital solutions must be complemented by investments in physical infrastructure (TEN-T network, terminal capacity, last-mile connectivity).
- **Phased implementation and pilot testing:** Advisable for complex/innovative solutions to test in real-world conditions, refine, and demonstrate benefits before wider rollout.
- **Holistic approach to environmental sustainability:** Involves modal shift, greener fuels/technologies, logistics optimization, and direct environmental management in nodes.
- **The "human factor" is crucial:** Training, collaboration, user acceptance, and governance are as important as technology for success. TRANSPONEXT's training and communication emphasis reflects this.
- **Persistent "implementation gap":** Despite many digitalization projects, widespread, interoperable adoption faces technical, organizational, financial, and regulatory hurdles. Achieving seamless digital interoperability is a long-term effort.

4. Analysis of Best Practices in Intermodal Transportation

This section analyzes specific best practices identified from previous projects and existing knowledge, categorized by their primary contribution. Many best practices offer cross-cutting benefits.

4.1. Best Practices for Quality Improvement

Improving intermodal transport quality hinges on enhancing efficiency, reliability, transparency, and interoperability, with digital technologies and collaborative approaches being central.

Table 4.1.1: Best Practices for Quality Improvement in Intermodal Transport

Best Practice	Description	Key Features/Technologies	Primary Impact on Quality	Key Enablers	Potential Barriers	Examples/Relevant Standards (Source ID)
Advanced Tracking and Tracing Systems (e.g., Real-time ITU/Shipment	Systems providing continuous, real-time visibility of Intermodal Transport Units (ITUs), containers, wagons, and	GPS, IoT sensors, AIS, RFID, telematics, data integration from carriers/terminals, AI/ML for	Enhanced operational efficiency (proactive exception management, reduced manual tracking), improved customer	IoT proliferation, cloud computing, robust API integration, advanc	Data fragmentation, lack of carrier integration/data quality, implementation costs (especially for SMEs), data security/privacy concerns, resistance to change.	TRANSPONEXT ITU Tracking, Descartes MacroPoint, Trimble Transportation, Shippeo, project44, FourKites, Smart wagon concepts (Europe's Rail),

Visibility Platforms)	shipments across multiple modes. Integrates data from GPS, RFID, IoT sensors, carrier systems.	predictive ETAs.	service (accurate ETAs, transparency), better inventory management.	ed data analytics, carrier collaboration, data sharing agreements.		RFID in Railways, GS1 EPCIS, ILU-Codes, Tive Solo 5G Tracker.
Optimized Terminal Operations through Digitalization and Automation (PCS, TAS, TOS, WMS)	Utilizing digital tools like Port Community Systems (PCS), Terminal Appointment Systems (TAS), Terminal Operating Systems (TOS), and Warehouse Management Systems (WMS) to streamline processes in ports and inland terminals. Includes automated gates, optimized yard management.	PCS: Centralized data hub, standardized messaging, customs integration, dangerous goods handling, status updates. TAS: Online booking slots, capacity management, gate automation integration.	Increased terminal throughput, reduced congestion and turnaround times for vessels/trucks, streamlined administrative/customs processes, improved resource planning/space utilization, enhanced collaboration and safety.	Strong stakeholder buy-in and collaboration, data standardization (e.g., UN/EDIFACT, ISO 28005, WCO DM), robust IT infrastructure, integration capabilities, workforce training.	Reluctance to share data, cost of development/maintenance/infrastructure, achieving critical user mass, interoperability challenges, governance complexity, complexity of implementation.	TRANSPONEXT CPRS Zadar, TRANSPONEXT Ploče Digitalization, Sinfomar (Trieste), Portbase (Rotterdam), DAKOSY (Hamburg), APCS (Antwerp), Portic (Barcelona), RPIS 4.0, CALISTA P!NG+, BEUMER Group WMS, SkuNexus WMS, Symphony WMS, OPTIYARD, NxtPort.

Efficient e-Booking and Multimodal Route Planning Systems	Platforms enabling users to plan, compare costs/emissions/transit times, and book intermodal transport services, integrating offerings from multiple carriers and modes. Considers multiple criteria and real-time data.	Online portals/APIs, integrated carrier data (schedules, rates, capacity), algorithms for route/cost/emission optimization, real-time data feeds.	Simplified booking, optimized route selection (cost, time, environment), reduced transport costs, lower emissions via informed choices, improved planning accuracy and accessibility of intermodal options.	Comprehensive and accurate carrier data, robust API integrations, advanced optimization algorithms, user-friendly interfaces, standardization of service descriptions, access to real-time data.	Lack of carrier data sharing/transparency, complexity of intermodal pricing/options, maintaining up-to-date information, integration with legacy systems, data fragmentation.	TRANSPOGOOD /TRANSPONEXT Platform, Cargoson, MercuryGate TMS, OpenTripPlanner, TAF TSI, eFTI, RailNetEurope tools (CIS, NCI), Turvo, Digitransit.
Federated Data Exchange Platforms and Interoperability	Establishing platforms and adhering to standards (e.g., FENIX, eFTI, TAF/TAP TSI) for	Common data models, standardized APIs, governance frameworks.	Enhanced end-to-end visibility, streamlined administrative processes, improved collaboratio	Trust and willingness to share data.	Data ownership and security concerns, legacy systems, cost of integration.	TRANSPOGOOD Platform Upgrade, FENIX, eFTI, TAF TAP TSI, DTLF, Shift2Rail/Europe's Rail (EU-DAC), WCO Data Model,

Standards	seamless, secure data exchange between stakeholders and systems.		n, facilitation of new value-added services.			UN/EDIFACT, AEOLIX, ILU-Code.
Wagon Pooling and Shared Asset Management	Collaborative systems where railway wagons are pooled among users to improve utilization, reduce empty runs, and ensure better asset availability.	Shared wagon fleet, IT platform for management, operational agreements.	Increased wagon utilization, reduced operational costs, lower capital investment, improved service flexibility, environmental benefits from fewer empty movements.	Trust and collaboration, robust IT system, clear rules and governance.	Concerns over asset control, complexity of coordination.	Wagon pooling in Trieste (TRANSPONEXT pilot), TTX Company, Eurowagon, WBG Pooling, DB Cargo consortium.

The convergence of these quality-enhancing best practices creates powerful synergies. For instance, advanced tracking provides data for optimizing terminal operations via TAS, which also feeds into reliable multimodal route planning. TRANSPONEXT's strategy reflects an understanding of these interdependencies. Successful implementation depends critically on stakeholder collaboration, adoption of common data standards (eFTI, TAF TSI), and data sharing through common platforms. Overcoming data silos and proprietary systems requires robust governance and demonstrated value.

4.2. Best Practices for Safety Improvement

Enhancing safety requires a comprehensive approach addressing human factors, technological systems, and data security.

Table 4.2.1: Best Practices for Safety Improvement in Intermodal Transport

Best Practice	Description	Key Features/Technologies	Primary Impact on Safety	Key Enablers	Potential Barriers	Examples/Relevant Standards (Source ID)
Enhanced Training and Certification for Staff	Comprehensive, standardized training for personnel on operational procedures, safety regulations (esp. dangerous goods), emergency response, use of new technologies. Formal certification to	Specialized curricula, simulator training, e-learning modules, practical assessments, regular refresher courses, certification frameworks.	Reduced human error, improved compliance with safety regulations (e.g., RID/ADR), better emergency preparedness, enhanced safety culture.	Management commitment, availability of standardized training materials (e.g., UIC guidelines, EU best practices), regulatory mandates for certification, collaboration with	Cost of training, operational downtime for training, lack of internationally harmonized certification, keeping training up-to-date with evolving technologies/regulations.	TRANSPONEXT WP3 Training Courses / cross-border training schemes, CFLI's role, Intermodal Freight Transport Course, EU Best Practices Cargo Securing, UIC Dangerous Goods training/RID compliance.

	validate competence.			training institutions.		
Implementation of Advanced Safety Technologies and Automation	Use of automation, sensor-based monitoring, and advanced data analytics to enhance safety in operations and infrastructure integrity. Includes automated rail coupling, ADAS, automated terminal equipment, predictive maintenance.	Automated terminal equipment (cranes, AGVs), trackside detectors (WILD, wheel profile, broken rail), on-board monitoring systems, drone inspections, collision avoidance systems, sensor-based cargo monitoring.	Reduced risk of accidents from human error, early detection of equipment/infrastructure faults, improved monitoring of dangerous goods, enhanced security.	Advances in sensor tech, AI/ML for predictive maintenance, IoT connectivity, robotics, investment in R&D and deployment.	High initial investment costs, complexity of system integration, cybersecurity vulnerabilities, need for specialized maintenance skills, regulatory approval for new automated systems, resistance to automation.	TRANSPONEXT Ploče wagon scanning / digitalization (can include safety aspects), Trieste wagon pooling GPS, Automated inspections in rail, ifm sensors for port automation, Shift2Rail IP5 freight automation / Europe's Rail projects, Automatic rail coupling (UIC), TSIs (ERA).
Secure Data Exchange and Cybersecurity for Safety-Critical	Implementing robust cybersecurity, secure communication	Strong encryption, multi-factor authentication, secure APIs, intrusion detection/prevention systems,	Prevention of unauthorized access/tampering with safety data, ensured integrity/availability of critical safety info,	Adoption of cybersecurity standards, investment in	Evolving cyber threats, cost of advanced security solutions, ensuring compliance across diverse	DTLF work on trusted/safe/secure data sharing, UK security requirements for

Information	protocols, and data integrity checks for exchanging safety-critical information (e.g., dangerous goods, equipment status).	regular security audits, data validation protocols, secure cloud infrastructure.	protection against cyber-attacks.	secure IT infrastructure, cybersecurity awareness training, clear data governance policies.	systems, balancing security with accessibility, reluctance to share sensitive info.	dangerous goods transport, eFTI emphasis on secure platforms / safety-relevant info, WCO Data Model, Electronic port clearance (EPC) ISO 28005-3.

A multi-layered approach combining human factors, advanced technologies, and robust digital security is fundamental. TRANSPONEXT's inclusion of training alongside technological pilots acknowledges this. There's a trend towards proactive safety, using sensor data with AI/ML for predictive maintenance, shifting from reactive to predictive safety management.

4.3. Best Practices for Environmental Sustainability

Addressing environmental impact is critical, focusing on emissions reduction, energy efficiency, and resource circularity.

Table 4.3.1: Best Practices for Environmental Sustainability in Intermodal Transport

Best Practice	Description	Key Mechanisms/Technologies	Primary Impact on	Key Enablers	Potential Barriers	Examples/Relevant Initiatives (Source ID)

			Sustainability			
Promotion of Modal Shift to Rail/Waterways	Implementing policies, incentives, infrastructure developments, and operational improvements to encourage shifting freight from road to more environmentally friendly modes (rail, short-sea shipping, inland waterways).	Competitive rail/waterway services (cost, reliability, frequency), efficient intermodal terminals, supportive government policies (subsidies, road pricing, infrastructure funding), digital platforms facilitating intermodal choices.	Significant reduction in GHG emissions (rail emits ~75% less CO2/tkm than trucks) and air pollutants, reduced road congestion, lower external transport costs, lower energy consumption per ton-km.	Political will, adequate investment in rail/port/IWW infrastructure, level playing field (internalization of external costs), efficient first/last mile road connections, effective marketing of intermodal services.	Higher perceived cost/complexity of intermodal, lack of flexibility compared to road, infrastructure bottlenecks, historical underinvestment in non-road modes, last-mile connectivity issues.	EU Green Deal targets, Combined Transport Directive, National grants/subsidies, TRANSPOGOOD/TRANSPONEXT platform promoting intermodal, COMODALCE, RPIS 4.0, RNE, Shift2Rail/Europe's Rail, Ports in European Rail System, Rail Port Hamburg, Port of Rotterdam rail transport.
Use of Alternative Fuels and Greener Vessels/Vehicles/Rolling Stock	Adoption of cleaner energy sources (e.g., HVO, LNG/bio-	Advanced engine technologies, battery-electric systems, fuel cells, alternative fuel bunkering/charg	Reduced GHG emissions (depending on fuel pathway	Technological advancements, availability and cost-competitiveness of	High upfront cost of new fuels/technologies, limited infrastruct	EU Fit for 55 package, AFIR, Girteka using HVO, SUSPORT pilots (renewable energy in ports), Shift2Rail IP5 (new propulsion) /

	LNG, electricity, hydrogen, methanol, ammonia) and deployment of vehicles/ vessels with lower environmental impact (electric trucks/trains, hydrogen fuel-cell vehicles, greener ships with shore power, energy-efficient engines).	ing infrastructure, lightweight materials, aerodynamic designs, shore power facilities in ports.	), improved air quality (lower NOx, SOx, PM), decreased reliance on fossil fuels, noise reduction (for electric).	alternative fuels, development of extensive refueling/recharging infrastructure (AFIR), regulatory incentives/ mandates (Fit for 55), R&D funding.	ure availability, range/payload limitations for some technologies, uncertainty about optimal long-term solutions, sustainable sourcing of biofuels/hydrogen.	Europe's Rail (smart wagon concepts for energy efficiency), LEAD (low-emission vehicles).
Logistics Optimization for Reduced Environmental Impact	Implementing strategies and digital tools to improve logistics	Advanced TMS with route optimization, load consolidation algorithms, backhauling strategies, real-	Reduced fuel consumption and emissions, lower	Accurate real-time data, advanced analytics and AI for optimization,	Difficulty in finding consistent backhauls, lack of trust for data/capacity sharing,	TRANSPONEXT Wagon Pooling (Trieste), TRANSPOGOOD route optimization, Einride (reducing empty miles),

	efficiency, reducing unnecessary mileage, fuel consumption, and associated emissions.	time visibility platforms for dynamic adjustments, collaborative resource sharing (e.g., wagon pooling, shared warehousing).	operational costs, improved asset utilization (less empty running), decreased road wear and congestion.	collaborative platforms and trust among partners, flexible operational models.	complexity of dynamic optimization, integration of diverse IT systems.	Research on collaborative logistics, TTX Wagon Pooling model, Agieren intermodal solutions.
Paperless Transport and Digitalization of Documents	Transitioning from paper-based freight documentation to electronic formats for all transport-related information (consignment notes, customs declarations, etc.), key to eFTI	Digital platforms, standardized data formats, secure communication channels.	Reduced paper consumption, faster administrative processes, lower costs, improved data accuracy, enhanced transparency, better environmental footprint.	Legal recognition of electronic documents, interoperable IT systems, data security/privacy standards.	Resistance to change, initial investment, need for cross-border harmonization.	eFTI Regulation, DTLF.

	regulation.

Achieving environmental sustainability requires a combined strategy of macro-level policy interventions (driving modal shift, supporting alternative fuel infrastructure) and micro-level operational efficiencies/technological adoption by companies. TRANSPONEXT, by enhancing CO2 calculation in its platform and piloting wagon pooling, addresses several facets. Collaboration (public-private partnerships, inter-company cooperation for freight consolidation/wagon pooling) is vital. SUSPORT's success highlights the importance of institutional cooperation for port sustainability.

4.4. Cross-Cutting Best Practices

Certain practices have a foundational role, benefiting quality, safety, and environmental sustainability simultaneously, often revolving around digitalization, governance, and systemic resource management. Integrated digital platforms (enhanced TRANSPOGOOD, FENIX) improve efficiency (quality), incorporate safety alerts (safety), and enable emissions reduction optimization (environment). Improved intermodal terminal efficiency reduces idle times/congestion (quality, environment) and can lead to safer operations (safety). Standardization (TAF TSI, eFTI, EPCIS, ILU-Code) enhances interoperability (quality), provides common frameworks for safety info (safety), and facilitates smoother processes (environment). Real-time data and analytics allow better planning (quality, environment), proactive maintenance (safety, quality), and improved incident response (safety).

Table 4.4.1: Cross-Cutting Best Practices in Intermodal Transport

Best Practice	Description	Impact on Quality	Impact on Safety	Impact on Sustainability	Key Enablers	Potential Barriers	Examples/ Relevant Initiatives (Source ID)
Comprehensive Digitalization and Data-Driven Decision Making	End-to-end digitalization of transport/logistics processes, integration of disparate systems, systematic use of data analytics, AI, and ML to optimize operations, enhance visibility, predict disruptions, improve decision-making.	Improved operational efficiency, enhanced reliability through predictive insights, greater transparency in the supply chain.	Enhanced situational awareness, predictive maintenance reducing equipment failures, optimized routing potentially reducing hazardous exposures.	Optimized resource utilization (fuel, assets), reduced emissions through efficient routing and modal choice, better demand forecasting reducing waste.	Proliferation of IoT devices, Big Data analytics capabilities, AI/ML algorithms, cloud computing infrastructure, open APIs, common data standards.	Data silos and lack of interoperability, cybersecurity risks, high implementation costs, digital skills gap among workforce, data quality issues.	DTLF (promoting digital interoperability), eFTI Regulation (paperless transport), Shift2Rail IP5 (fleet digitalization), LEAD project (Digital Twins), TRANSPONEXT (core focus).
Robust Data Governance and Stakeholder Collaboration	Establishment of clear rules, roles, responsibilities, and legal frameworks for data	Facilitates seamless information flow leading to better coordination and reliability,	Enables timely sharing of safety-critical information, coordin	Supports transparent monitoring of environmental performance, data	Clear legal/regulatory frameworks (data privacy, competition law), agreed data sharing	Trust issues among competing stakeholders, concerns over data ownership/commercial sensitivity,	FENIX (federated architecture), DTLF Subgroup 2 (Corridor Freight Info Systems), Port

Platforms	sharing/usage. Implementation of collaborative digital platforms for trusted, secure, neutral data exchange among diverse stakeholders.	standardized reporting.	ated emergency response, secure access to compliance data.	for sustainability reporting, coordinated efforts for green logistics.	protocols/standards, neutral/trusted governance bodies, secure/interoperable technology platforms.	lack of universally accepted governance models, technical complexity of federated systems.	Community Systems (as collaborative hubs), TRANSPOGOOD platform (aims for collaboration).
Application of Circular Economy Principles in Logistics	Designing and managing logistics systems/processes to minimize waste, maximize resource utilization, promote reuse/repair, and extend asset/material lifecycle.	Increased asset utilization, reduced need for new materials/equipment leading to cost savings, development of new service models (e.g., leasing, sharing).	Safer handling and disposal of end-of-life assets, reduced risks associated with waste.	Significant reduction in resource depletion/waste generation, lower carbon footprint from manufacturing new assets, promotion of sustainable consumption.	Systemic approach to product/process design (design for circularity), collaboration across value chain, supportive policies/incentives, reverse logistics infrastructure.	Complexity of implementing reverse logistics, initial investment costs, changing consumer/business behavior, need for new business models.	EU Circular Economy Action Plan, Wagon Pooling (e.g., TRANSPONEXT Trieste pilot, TTX model), Reusable transport packaging systems.

Comprehensive digitalization is the bedrock for advanced tracking, safety monitoring, and route optimization. Robust data governance and collaborative platforms are essential for effective digitalization across multiple stakeholders. Initiatives like FENIX and DTLF's work address the need for trust, clear rules, and neutral governance for widespread data exchange. Effective data governance, or the 'soft infrastructure,' is becoming as critical as technological infrastructure for unlocking collaborative potential. Circular economy principles, like wagon pooling in TRANSPONEXT, offer systemic resource efficiency.

5. Capitalization Strategy: Building on Existing Knowledge for the Programme Area

TRANSPONEXT is explicitly designed to build upon existing knowledge and outcomes of previous initiatives, particularly within the IT-HR Programme Area, to ensure efficiency, avoid duplication, and leverage proven successes.

5.1. Relevance and Applicability of Identified Best Practices to the Italy-Croatia Intermodal Transport Sector

The IT-HR programme area's context—maritime nature, road transport dominance, limited multimodal connections, significant information gaps—shapes the relevance of best practices.

- **Quality Improvement Practices:**
  - *Advanced Tracking and Tracing Systems:* Highly relevant to address information gaps on goods movements. Real-time visibility improves coordination in port-centric supply chains. TRANSPONEXT's ITU Tracking pilot directly applies this.
  - *Optimized Terminal Operations (PCS/TAS):* Paramount as IT-HR intermodal connections are "generated by maritime nodes". PCS/TAS streamline operations and improve sea-land information flow. TRANSPONEXT pilots in Zadar (CPRS) and Ploče (rail digitalization) are direct implementations.

- *Efficient e-Booking and Multimodal Route Planners:* Crucial for making intermodal options (especially with new rail data) more accessible and attractive versus road-only. TRANSPOGOOD platform enhancement is a core TRANSPONEXT element, tackling "lack of information on intermodal services".

- **Safety Improvement Practices:**
  - *Enhanced Training and Certification:* Universally applicable and vital for improving operational safety and compliance in cross-border operations. TRANSPONEXT's WP3 training addresses this.
  - *Advanced Safety Technologies:* Strategic deployment at key nodes (ports, rail corridors) can mitigate specific risks. Ploče pilot's sensor-based monitoring is an example.
  - *Secure Data Exchange:* Essential for cross-border transport involving multiple authorities, ensuring integrity of safety-critical information.
- **Environmental Sustainability Practices:**
  - *Promotion of Modal Shift:* Highly relevant due to road transport dominance. TRANSPOGOOD platform enhancement to include rail and facilitate intermodal booking supports this.
  - *Use of Alternative Fuels and Greener Technologies:* Longer-term for widespread IT-HR adoption, but pilot projects in key ports/corridors (as in SUSPORT) can demonstrate feasibility.

- *Logistics Optimization (e.g., Wagon Pooling):* Directly addresses inefficiencies and reduces empty runs. TRANSPONEXT's Trieste wagon pooling pilot is a specific application.

TRANSPONEXT's design reflects a strong understanding of pertinent best practices for IT-HR challenges, with pilot actions targeting identified weaknesses. The challenges of data silos, interoperability gaps, and the need for greener solutions are common across the Programme Area.

5.2. Opportunities for Transfer and Adaptation

Capitalization involves transferring and adapting successful solutions and lessons from a broader range of initiatives. Many best practices, especially in digitalization, standardization, and collaborative platforms, offer significant transfer/adaptation opportunities.

- **From Previous Projects to the IT-HR Area:**
  - *TRANSPOGOOD:* Direct transfer via platform evolution and training methodology refinement in TRANSPONEXT. Lessons on user engagement and platform functionality inform enhancements. The TRANSPOGOOD platform itself is a prime example of a tool developed for the region that can be further enhanced and its usage expanded.
  - *DIGSEA and INTERMODADRIA:* Knowledge on ICT consolidation (DIGSEA) and short-sea shipping integration (INTERMODADRIA) provides strategic underpinning for TRANSPONEXT's seamless intermodal chain efforts.

- *Shift2Rail IP5, OptiYard, I_RAIL:* Insights on rail freight innovation, yard optimization, and TAF TSI standards are valuable for TRANSPONEXT's rail components (Ploče digitalization, Trieste wagon pooling, TRANSPOGOOD rail data integration).
- *FENIX and AEOLIX:* Concepts of federated data sharing and collaborative logistics platforms offer models for greater interoperability, informing TRANSPOGOOD ecosystem's long-term evolution.

- **Within the IT-HR Programme Area (Replication of TRANSPONEXT Pilots):** Replication of successful TRANSPONEXT pilots (Zadar CPRS, Ploče digitalization, Trieste wagon pooling) can serve as blueprints for other IT-HR ports and nodes. The enhanced TRANSPOGOOD platform is designed for wide accessibility.
- **Adaptation Needs:** Successful transfer requires careful consideration of local context (infrastructure, digital maturity, regulatory environments, socio-economic conditions). Assessing institutional capacity, stakeholder readiness, and necessary modifications is crucial. TRANSPONEXT's emphasis on stakeholder engagement and training is vital. Adopting EU-wide standards like eFTI and TAF TSI is increasingly a necessity. Collaborative models like wagon pooling are based on transferable principles.

7. Conclusion

Summary of Key Findings

This analysis of best practices for the IT-HR intermodal transport sector, focusing on capitalizing on TRANSPOGOOD, yielded key findings. The IT-HR area faces challenges like road transport dominance, limited multimodal connectivity, and information gaps, necessitating targeted interventions. Review of EU projects shows a strategic push towards digitalization, interoperability, and sustainability. Capitalization, as by TRANSPONEXT on TRANSPOGOOD, is critical.

- **Quality improvement** hinges on advanced ICT (real-time tracking, optimized terminal operations via PCS/TAS, efficient e-booking/multimodal route planners like enhanced TRANSPOGOOD), data standardization (TAF TSI, eFTI), stakeholder data sharing, and innovative asset management (wagon pooling).
- **Safety enhancement** requires a multi-layered approach: enhanced staff training (TRANSPONEXT WP3), advanced safety technologies (automation, sensors), robust cybersecurity, and standardized safety protocols with effective information sharing.
- **Environmental sustainability** improvements are driven by promoting modal shift (road to rail/waterways), adopting alternative fuels/greener technologies, streamlining processes (paperless transport), and logistics optimization (wagon pooling).
- **Cross-cutting best practices** (comprehensive digitalization, robust data governance, stakeholder collaboration, circular economy principles) are fundamental enablers.

TRANSPONEXT's integrated approach (ICT tools, pilot solutions, strategic frameworks, training) aligns with these best practices and is poised for significant improvements.

Future Outlook and Areas for Further Research/Action

The future of IT-HR intermodal transport will be shaped by technological advancements (AI, IoT, automation), evolving regulations (European Green Deal), and the imperative for resilience and sustainability. Further research/action areas include:

- **Full-Scale Implementation and Impact Assessment of Digital Platforms:** Continued monitoring/evaluation of enhanced TRANSPOGOOD and similar solutions to quantify long-term impacts (modal split, efficiency, emissions).
- **Development of Interoperable Data Spaces:** Research into establishing a federated, interoperable Adriatic logistics data space (building on FENIX, DTLF), addressing data governance, security, and business models.
- **Advancing Alternative Fuels Infrastructure and Uptake:** Focused research/pilots on feasibility and deployment of alternative fuel infrastructure (hydrogen, electric charging for HDVs, shore power) tailored to IT-HR needs.
- **Integration of Circular Economy Principles:** Deeper exploration of integrating circular economy models (beyond asset pooling) into intermodal logistics (packaging, waste management, reverse logistics).
- **Strengthening Rail Freight Competitiveness:** Continuous efforts to improve rail freight cost-competitiveness, reliability, flexibility (addressing last-mile, terminal efficiency).

- **Cybersecurity in Intermodal Transport:** Dedicated research/capacity building in cybersecurity for transport/logistics systems as digitalization advances.
- **Long-Term Sustainability of Cooperation Mechanisms:** Investigating models for long-term financial/institutional sustainability of cross-border cooperation beyond EU project lifespans.
- **Impact Assessment of Digital Twins:** Exploring Digital Twin technology benefits for optimizing intermodal operations and infrastructure management.
- **Advanced Data Analytics and AI:** Leveraging AI/ML for predictive analytics, demand forecasting, and real-time optimization of intermodal flows.
- **Cross-Border Governance Models:** Developing effective governance models for shared digital infrastructures and collaborative platforms in a cross-border context.

Continuous monitoring, adaptation, and innovation investment are crucial for long-term success and sustainability in the IT-HR intermodal transport sector.

Appendice

List of Reviewed Projects

- TRANSPOGOOD (Interreg IT-HR)
- TRANSPONEXT (Interreg IT-HR)
- INTERMODADRIA (IPA Adriatic)
- DIGSEA (Interreg IT-HR Cluster)
- SUSPORT (Interreg IT-HR)
- OptiYard (Shift2Rail IP5)
- I_RAIL (CEF)
- FENIX (CEF)
- AEOLIX (H2020)
- RPIS 4.0 (Interreg Upper Rhine)
- COMODALCE (Interreg Central Europe)
- LEAD (H2020)

Glossary of Terms

- **CEF:** Connecting Europe Facility
- **CPRS:** Cargo Port Reservation System
- **DTLF:** Digital Transport and Logistics Forum
- **eFTI:** Electronic Freight Transport Information

- **EPCIS:** Electronic Product Code Information Services
- **EUSAIR:** EU Strategy for the Adriatic and Ionian Region
- **FENIX:** A European FEderated Network of Information eXchange in Logistics
- **GHG:** Greenhouse Gas
- **ICT:** Information and Communication Technology
- **ILU-Code:** Intermodal Loading Unit Code
- **Interreg IT-HR:** Interreg Italy-Croatia Programme
- **IoT:** Internet of Things
- **IP5:** Innovation Programme 5 (of Shift2Rail)
- **ITU:** Intermodal Transportation Unit
- **KIP:** Klaster intermodalnog prijevoza (Intermodal Transport Cluster)
- **LSP:** Logistics Service Provider
- **MTO:** Multimodal Transport Operator
- **PCS:** Port Community System
- **RNE:** RailNetEurope
- **RU:** Railway Undertaking
- **SME:** Small and Medium-sized Enterprise
- **SSS:** Short Sea Shipping
- **TAF TSI:** Technical Specifications for Interoperability - Telematics Applications for Freight services
- **TAP TSI:** Technical Specification for Interoperability for Telematics Applications for Passenger services

- **TAS:** Terminal Appointment System
- **TEN-T:** Trans-European Transport Network
- **TMS:** Transport Management System
- **TOS:** Terminal Operating System
- **WMS:** Wagon Management System