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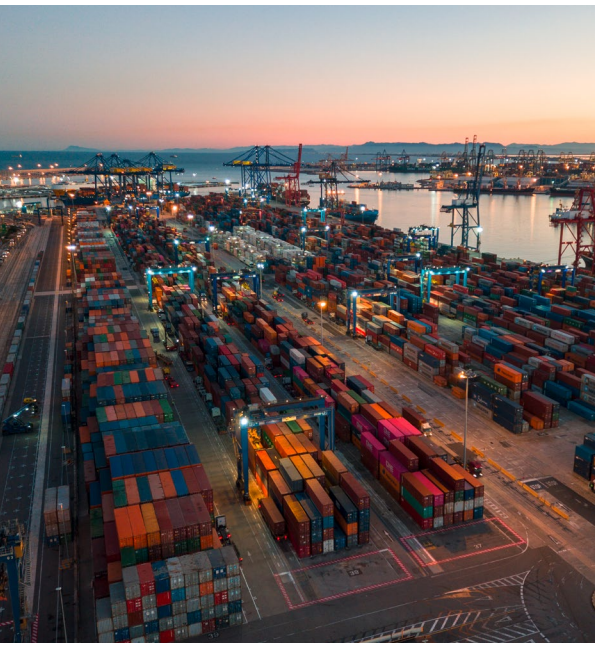

Exponential technologies for managing inland waterway transport

Background

The fourth industrial revolution is transforming the way we live and work, with implications for all productive processes. Logistics and transport, in particular, are fertile ground for the application of new technologies in planning and execution along the chain of distribution. Since the beginning of the twenty-first century, the

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This *FAL Bulletin* addresses smart navigation systems, such as smart waterway systems and port community systems. The purpose of this analysis is to explore global experience in the digitalization of logistics and transport processes for application to waterway management in South America and empower national and regional public institutions to lead the digital transformation of external trade with a view to reducing operational risks and narrowing the digital divide between Latin America and the Caribbean and other regions.

This issue was authored by Rodrigo Mariano Díaz, a consultant of the Infrastructure Services Unit of ECLAC. For further information, please contact miryam.saade@un.org.

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UNITED NATIONS

ECLAC

World Association for Waterborne Transport Infrastructure has been producing documents and developing standards to facilitate the implementation of these technologies (PIANC, 2019). Many have been successfully deployed, and a wealth of documentation and standards have helped to centralize trade processes related to navigation. The institutions involved in addressing these challenges also created the International Port Community Systems Association to support new projects based on lessons learned from past initiatives, leveraging emerging technologies to improve existing systems (IPCSA, 2015).

The aim of this study is to consider these experiences in the context of waterway management in South America with a view to preparing national and regional public institutions to lead the digitalization of external trade logistics. This would reduce operational risks and narrow the digital divide between Latin America and the Caribbean and other regions, resulting in greater competition between stakeholders, irrespective of their size.

The study is organized in four sections. The first presents an overview of concepts, together with case studies for the successful implementation of smart waterway technologies and port community systems. The second section briefly discusses the importance of port authorities as leaders in these processes and the expected benefits of implementation. The third presents a detailed analysis of the potential benefits of implementing a river community system in terms of unifying documentation and operational processes in a single national platform, and the final section presents conclusions and recommendations for optimizing the use of inland waterways.

I. Smart navigation

Recent studies by the Economic Commission for Latin America and the Caribbean (ECLAC) align with analyses of the World Economic Forum in indicating that one of the greatest risks posed by exponential technologies of the fourth industrial revolution is their widening of the divide between countries. Indeed, there is evident disparity between countries with the economic and strategic capacities to integrate and take advantage of advanced technologies —such as artificial intelligence, the Internet of things, blockchain technology and 5G communications— and countries that have not been able to adopt these innovations in a timely manner. This situation highlights a possible competitive disadvantage for Mediterranean ports, which depend on the efficient use of waterways, compared to ports that have deployed advanced technologies to optimize resources and minimize time devoted to documents management. This section provides an analysis of two models that have proven effective in resolving these issues: smart waterway systems and port community systems.

A. Smart waterway systems

Existing literature does not provide an exact definition of smart waterway systems, but there is tacit consensus that the concept refers to an advanced system for monitoring and forecasting the navigability of passenger and freight routes. Smart waterway systems may include ships with onboard echo sounders, complemented by data from marker buoys equipped with topographical measurement technology and data transmission systems, as well as any navigation-related data obtained without manual intervention.

A smart waterway system must be capable of not only acquiring and storing but also processing data. It must also be equipped for accurate hydrological modelling, including, for example, forecasting low water levels, reconstructing riverbed topography and receiving real-time information updates, as well as generating accurate navigability forecasts (Erdbrink, 2011).

The concept of river information services, spearheaded by the Directorate-General for Mobility and Transport of the European Commission, laid the foundation for the development of smart waterway systems. River information services have two fundamental components:

(i) Traffic-related services

(ii) Transport-related services.

Traffic-related services, which are the focus of this document, include:[1]

- Fairway information services. Information on fairways, including geographical, hydrological and administrative information on the infrastructure of the waterway and in the area covered by the river information system, that users require for planning, executing and monitoring transport. The flow of fairway information services is one-way: from coast to vessel or from coast to the vessel's main office.
- Strategic traffic information. Information that affects the medium- and long-term decisions of river information system users.
- Tactical traffic information. Information that affects in-the-moment navigation decisions based on the immediate traffic conditions and geographical surroundings.
- Calamity abatement. Support to limit the negative impact of a calamity, accident or incident.

Since the establishment of river information services in Europe, technical working groups have provided a platform for the international harmonization of their development and implementation. These working groups act as consultative bodies for the standardization of river information services for the European Commission, the Central Commission for the Navigation of the Rhine, the Danube Commission and the Economic Commission for Europe, among other institutions (River Information Services, 2022). The working groups have fostered the use of advanced technology to optimize inland waterway transport. In recent years, considerable advances have been made in integrating these services and making them more user-friendly, with a focus on the development of platforms offering comprehensive services in a single place. Examples include the BULRIS project on the Bulgarian segment of the Danube River; the AIRIS project on the Guadalquivir River in Seville, Spain; and the access canal to the Posorja deepwater port in Ecuador. The latter two examples are addressed below.

1. AIRIS project, Port of Seville, Spain

The objective of the AIRIS project is to develop an information system for the stretch of the Guadalquivir that runs from Sanlúcar de Barrameda to Seville, using innovative technologies to provide real-time data for improved traffic management. The Port of Seville is located inland, 89 km from the coast, and transport along the Guadalquivir is subject to the tides —in other words, vessels can pass through the canal at high tide. The availability of more precise information on the status of the waterway, following the

[1] See Schlewing (2010).

standards established for river information services, enables the waterway to be used to its full capacity and improves maritime access to Seville. Through this system, the Port Authority of Seville monitors water level and quality, currents and tides, among other parameters. With more and better information on waterway traffic (e.g. vessel characteristics and cargo, detection of possible obstacles to navigation), traffic management and resource optimization can facilitate more efficient coordination of port operations and navigation.

AIRIS currently offers the following services:[2]

- **Fairway information services**: provides geographical, hydrological and meteorological information captured by smart sensors deployed throughout the Guadalquivir River.
- **Traffic information services**: provides data for improved decision-making during transport, ensures safe navigation and optimizes the operational efficiency and management of ship traffic.
- **Traffic management services**: facilitates agile and safe coordination of ship traffic, through navigation planning and other tools, taking into account physical conditions on the river, bathymetry and existing traffic.

2. Access canal project, Port of Posorja, Ecuador

The Port Authority of Guayaquil and the Naval Institute of Oceanography of Ecuador manufactured and installed nautical markers all along the 21 miles of the access canal to the deepwater Port of Posorja. Each lighted buoy is equipped with an automatic identification system. In total, 23 buoys were installed, equipped with the same system, in addition to an LED sector light installed on Isla Puna and visible from a distance of up to 10 nautical miles. This lantern uses white light to guide vessels along the correct route. The technology transmits real-time buoy location information to ships. In the 16.5-metre-deep canal, which can accommodate Neo Panamax and Post Panamax ships, traffic is monitored 24/7 through a maritime traffic system —the first of its kind in Ecuador— which will be operated by the Port Authority of Guayaquil (Guayaquil Port Authority, 2019).

B. Port community systems

Port community systems can resolve interoperability issues to strengthen national logistics system, bringing together the various port stakeholders on a single platform.

In a study on key factors for the digital transformation of supply chains, Álvarez and Sánchez (2021) note that the region's current level of digitalization in this area is unsatisfactory, owing to a variety of contextual characteristics. At the same time, digitalization in the region is significantly more advanced among institutions that have an international presence or are international in origin than among small and medium-sized enterprises. This imbalance is even more pronounced in less advanced economies and poses a significant existential threat.

The implementation of comprehensive, centralized solutions modelled on the app economy (frequently associated with mobile applications like Uber and PedidosYa), offering services on a per-transaction basis, connects service providers with their customers. This can facilitate access to and use of services in a variety of ways, scaled and adapted according to the need of each user. For example, an occasional user of the port community system

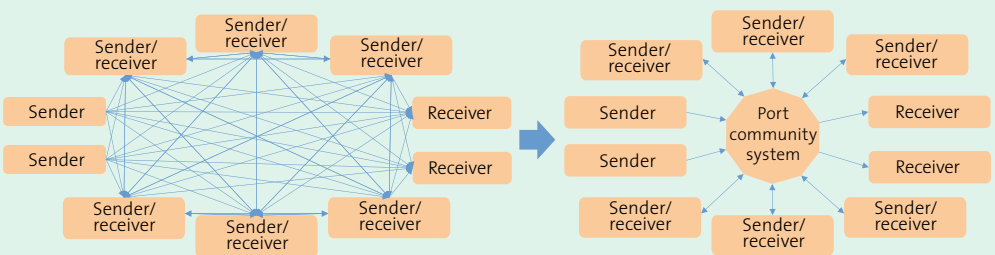
[2] See Port Authority of Seville (2021).

could access it through an online portal or mobile application. A port authority, meanwhile, which uses the system daily, could do so through a dedicated interface between its internal systems and the port community system, while also accessing information provided by all port community system users along the supply chain.

In the diverse community of inland waterway logistics stakeholders, the flow of information is a complex process; every time information is exchanged, an isolated copy of the information is created in each user's system. This means that the number of possible errors (even without human intervention) is equal to the number of systems involved in each exchange. Different versions of data representing the same physical entity can be generated at isolated points in the supply chain with no subsequent updates, making it extremely difficult to trace errors back through the transaction data . Naturally, these errors are multiplied if the exchange occurs on paper where, on top of data processing errors that may occur in digital format, there is the possibility of human error in the transcription of information.

In addition, communication channels and electronic messages may present in as many formats as there are supply chain stakeholders, creating highly complex systems and significantly increasing the effort and cost of interface development and maintenance. In a **port community system**, however, messages flow in just two directions (i.e. sending and receiving), in a uniform format for all users (see diagram 1). In addition, the port community system retains a single copy of the data, available for consultation or reference by all stakeholders.

Diagram 1
Complexity of communication processes and their simplification through a port community system



Source: Prepared by the author.

The large scale of the port community system as a technological solution is an important factor for supply chain resilience. The system has the technical capacity to ensure information availability, confidentiality and integrity, reducing the risk of service interruptions and data leaks even as its attack surface —and thus its potential exposure to cybersecurity risk— grows with the scale of the technology.

The International Port Community Systems Association has published a set of recommendations and practices for setting up a port community system that will benefit not only the community as a whole but individual users, in the following respects:[3]

- Reduced time to market, via services to manage reservations, scheduling, monitoring and documentation.
- Port-to-port track and trace.
- Simplified commercial declarations and permits, using the port community system services to facilitate cargo dispatch.
- Automated barriers for vessel clearance.
- Information to help carriers and trucking companies to better plan trips, improving overall delivery time.
- Streamlined processes and fewer documents exchanged.
- Speedier processing of high volumes of information.
- Elimination of duplicate document uploads, thanks to interfaces between systems, improving reliability of information obtained.

An Inter-American Development Bank study (Mendes Constante, 2019) identified the various business models for port community systems, which are summarized in table 1, together with the main characteristics to take into account for each model.

Table 1
Existing ownership and operational models for port community systems

Ownership model	Operational model	Characteristics
Public	Public	• Government leadership. • Strengthening of government-to-government and business-to-government integration and interoperability. • Requires financial support and governance to achieve a sustainable and attractive model that aligns with government strategies. • Difficult for public administration to act with the agility and efficiency required by the platform.
Public	Private	• Public administration takes an active role in the port community system to carry out strategy and ensure neutrality among stakeholders. • Private firm ensures sustainability from a commercial viewpoint. • Requires careful design of regulatory measures to prevent data monopolies with an eye towards neutrality and equity.
Public-private	Private Public-private	• Dynamic contracts between one or more public parties and private parties address technical, financial and operational risks.
Private	Private	• Focus on operational efficiency. • Difficult to maintain neutrality, which may lead to service fragmentation or commercial inequities. • Requires strong private stakeholder commitments to medium- and long-term public development policies.

Source: Prepared by the author on the basis of J. Mendes Constante, "Casos de estudio internacional y buenas prácticas para la implementación de Sistemas de Comunidad Portuaria", April 2019 [online] https://publications.iadb.org/publications/spanish/document/Casos_de_estudio_internacional_y_buenas_pr%C3%A1cticas_para_la_implementaci%C3%B3n_de_Sistemas_de_Comunidad_Portuaria_es_es.pdf.

[3] See IPCSA (2015).

C. Case studies of successful technological implementation in existing port community systems

1. ValenciaPort (public model)

ValenciaPort, managed by the Port Authority of Valencia, includes the ports of Valencia, Sagunto and Gandía, which account for Spain's largest commercial container shipments in the Mediterranean Sea. The Port Authority of Valencia took on all capital and operating costs as part of a strategic development plan for port modernization and digitalization. At present, the port community's members are convinced of the system's benefits and firmly committed to its continued existence. The possibility of designating a cost structure that would shift 50% of the system's costs to its users is currently under consideration (Mendes Constante, 2019).

ValenciaPort offers the following services:[4]

- Shipping
  - Departures and arrivals, scheduling
  - Cargo booking
  - Loading instructions
- Port operations
  - Port-of-call management
  - Dangerous goods handling
  - Loading and unloading lists
- Land transport
  - Management of road transport
  - Management of rail transport
  - Terminal arrivals and departures
- Customs
  - Declaration of cargo
  - Customs information
- Other services
  - Verified gross mass information
  - Cargo tracking

2. Antwerp Port Community System (public-private model)

The Antwerp Port Community System is owned by the Port Authority of Antwerp, Belgium, and Alfaport Antwerpen, and is managed by a steering committee made up of public and private sector representatives from the port community. In 2018, the system became NxtPort, an open platform that continues to offer the services provided by the Antwerp Port Community System (similar to those offered by ValenciaPort) but also incorporates a marketplace for the development of logistics solutions to expand the Antwerp Port Community System's data-sharing services, applying a concept akin to the Google Play model for Android to the port community system platform. In other words, third parties wishing to develop port solutions may do so by registering on the NxtPort platform and use the platform's business model. The community currently has 12,000 users from 4,000 institutions (C-Point, 2021).

[4] See ValenciaPort (2021).

3. Portnet, Port of Singapore (private model)

Established as a proprietary platform of the private firm Port of Singapore Authority in 1984, Portnet follows the traditional model of fully centralized information. This raises the concern of a potential information monopoly, and Portnet's ownership by a private entity with interests in the community represents a double threat, challenging operational neutrality (Portnet, 2021).

Portnet's main functions are:

- Online requests for port services
  - Service and vessel declarations
  - Mooring services
  - Stowage services
  - Yard crane operation services
  - Pilot, tug and tender boat services
  - Monitoring services for reefers (i.e. refrigerated containers)
  - Labelling, monitoring and fumigation services for dangerous goods cargo
  - Dockside warehouse facilities
- Modules for customers' work processes
  - Carrier work lists and subcontracting functions
  - Applications for government permits
  - Electronic delivery orders and delivery processing
  - Container storage and release orders
  - System support integration
- Compliance facilitation
  - Facilitates efficient and effective loading and unloading of containers during berthing
  - Guides authorization of trucks at Port of Singapore Authority's flow-through gates
  - Prevents overstowage at the planning stage
  - Proactive exception management tool
- Track and trace
  - Container status, including scheduled arrival and unloading
  - Ship status, including current location, and changes to berthing details
  - Detailed schedules: shipping, berthing and yard crane use
  - Ship planning details
  - Reefer temperature
  - Dangerous goods service consultations
- Financial functions
  - Financial electronic data interchange invoicing
  - Facilitation of shipping companies' re-invoicing processes
  - Online visualization tool for Portnet cargo

II. Key role of port authorities in implementing smart waterway systems

Port authorities have traditionally been responsible for ensuring the functioning and improvement of the port's operational area, ranging from infrastructure, development and maintenance to the commercial operation and management of port facilities. The

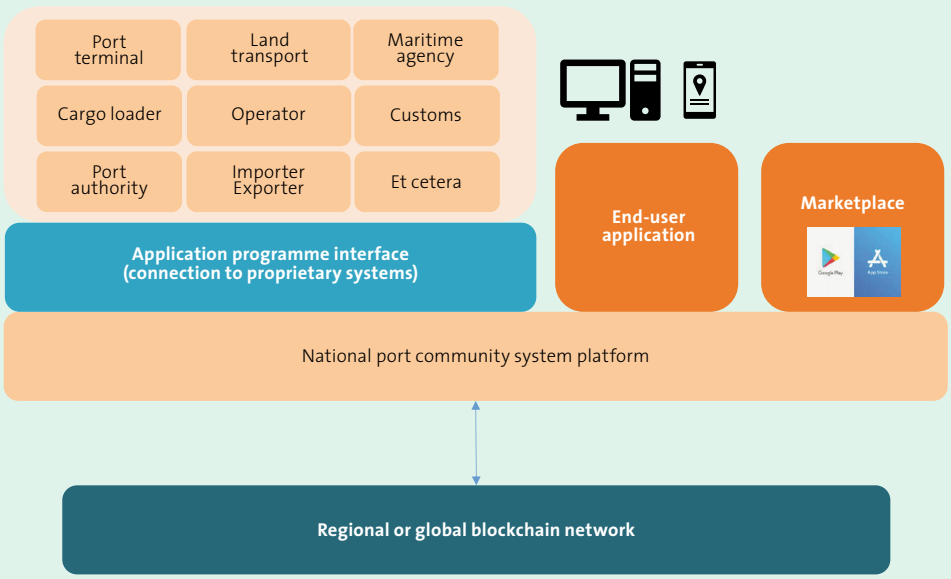
governance function of port authorities pertains to the interactions between the public and private sectors that influence the port's organizational structure, from local to global levels. This complex process has many intrinsic links, in both space and time, to different phases of history, culture and geography, as well as to different political, economic and administrative models. Port authorities, as government entities, have led the development of port information systems, subject to the availability and distribution of information technologies, the improvement of communication and the exchange of information among stakeholders, such as customs agencies, freight forwarders and shipping agents. In the past decade, ports have seen new strategic developments emerge, and port authorities are adapting their nature and functions, taking on an increasingly active role in the administration of logistics systems and, occasionally, tasks related to management and business operations (Tijan and others, 2021).

As an online platform, a port community system facilitates smart, protected data-sharing among public and private port users. Its functions may extend to a smart waterway system platform, offering one-stop information services for shipping and cargo.

Port authorities have a key role to play in improving the digital transformation of transport and the supply chain, acting as a link between all the port's coastal and inland stakeholders (Safety4Sea, 2019). Given that port authorities are responsible for the safe, sustainable and competitive development of ports, they can be of paramount importance in implementing port community systems. The use of centralized information systems can benefit port authorities, enabling them to more easily coordinate activities, monitor port operators and oversee operations. Thus, port community systems can provide port authorities with more and higher-quality information to inform better decision-making for sustainable operations (Tijan and others, 2021).

Today's technology facilitates the implementation of the conceptual model for the port community system via platforms that can integrate terminals of any size or user format. See diagram 2 for a high-level example of this concept.

Diagram 2
Concept for a port community system adapted to current possibilities and needs



Source: Prepared by the author.
Note: An application programme interface is a mechanism that enables two software components to communicate with each other through a set of definitions and protocols.

This framework envisages three types of access, each with its own business model, multiplying the number of possible uses at different economic scales. At the same time, it offers the possibility of open development for smartphone platforms, creating space for new applications, while open network blockchain communication enables its own set of functions. The potentially useful features of open networks identified by Díaz, Valdéz Figueroa and Pérez Salas (2021) are listed below.

- **Consensus**, carry out transactions, including across borders, without a central authority.
- **Origin**, transaction data can be traced back through the blocks in the chain to their point of origin.
- **Immutability**, users cannot alter transactions once entered into the general ledger.
- **Finality**, a single general ledger provides a definitive, shared source of information on asset ownership and final transactions (Ahuja, Gharehgozli and Li, 2020)

The possible incorporation of blockchain technology in a port community system platform may not only reduce paperwork (which can be managed via other platforms) but also improve oversight, reduce documentation errors and enable the use of smart contracts that are executed automatically when conditions agreed by the parties are met. In addition, such a platform could substantially reduce trade friction at border checkpoints, for simplified and lower-cost logistics (WEF, 2018).

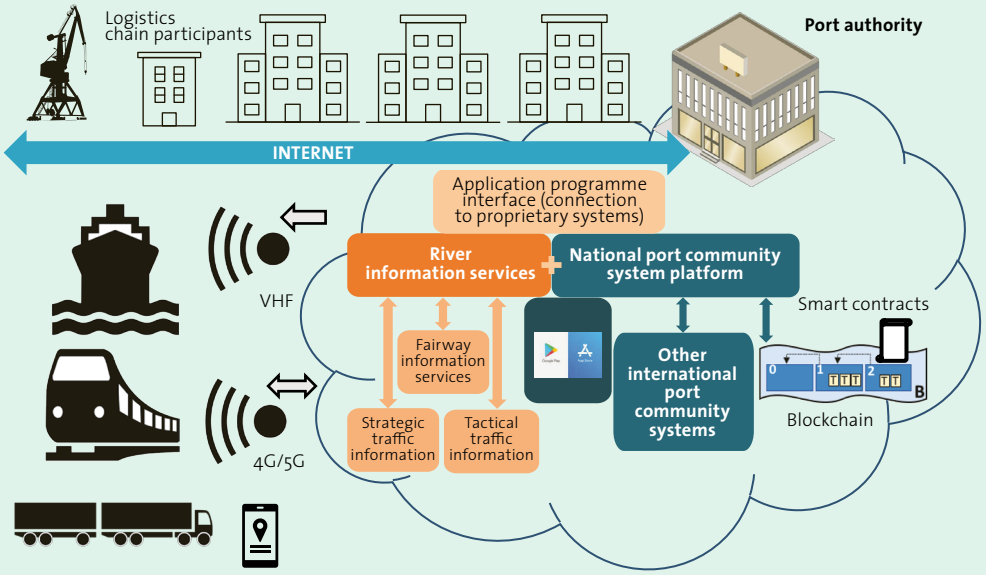
Smart contracts may also be used to pay waterway tolls, incorporating variables from the river information services system in addition to predetermined conditions, including rewards for efficient use and penalties for infractions. This would substantially improve the administrative processes of toll invoicing, incentivizing efficient use and reducing existing bottlenecks.

III. Benefits of implementing a river community system

The digitalization and modernization of waterway and port activities are a recognized need, irrespective of the scale of efforts required, as acknowledged in the conclusions of the twenty-ninth Latin American Convention of Ports of the American Association of Port Authorities (Sánchez, 2021). However, efforts are needed to reimagine existing procedures in the light of what current technology can accomplish, with a special focus on change management and the form of leadership needed post-transformation, as well as the strategic determination of the community's scope, with a comprehensive vision that prioritizes local and regional economic growth. In that regard, national and regional entities are ideally placed to lead the transformation.

There is no shortage of technology and information these days; the key factor will be the ease and speed with which individuals and institutions can access them. In that regard, smart waterway systems that emulate the characteristics described in the first section and the examples of successful systems currently in operation should be considered for comprehensive and centralized implementation alongside a traditional port community system. This type of comprehensive platform, which we refer to as a river community system, would aim to ensure the digital transfer of all information needed to facilitate the efficient transport of cargo and persons by inland waterway, reducing or eliminating problems by automating the technical and documentation processes involved (see diagram 3).

Diagram 3
Conceptual framework for a river community system



Source: Prepared by the author.

IV. Conclusions and key recommendations

- Despite the undeniably positive contribution of waterways to the competitive edge of logistics chains within the regional ecosystem of production and external trade, there remains a need to implement a modern, integrated, real-time information system, which would improve shipping efficiency, safety, oversight and support provided by authorities through the development and implementation of information and communications technology tools.[5] These tools can provide relevant variables and information on the entire process in a single place and significantly improve system governance, contributing decisively to the continued improvement of logistics performance. The integration and digitalization of shipping processes at a single point of service through the use of digital assistants or forms adapted to each activity would ensure that users are informed about documentation ahead of time and would facilitate the submission of said documentation. This could be key for operational risk reduction in a highly competitive and technologically innovative environment. The cases presented may serve as a point of reference for evaluating and emulating best practices with a view to achieving comparable results.
- Autonomous navigation via inland waterway has a promising future, according to studies on the topic presented by Working Group No. 210 of the World Association for Waterborne Transport Infrastructure (PIANC, 2022), which recognize the need to implement river information systems and warn that failure to adopt such systems will increase risks for waterways wishing to compete in this emerging market.
- The digitalization of processes carried out by international logistics chain stakeholders (e.g. ports, shipping companies, maritime agencies and cargo loaders) has reached an advanced stage among the main players involved, but these players lack the capacity for end-to-end integration, nor can any of them make progress on national or regional integration. That level of integration requires firm leadership by public entities that can reconcile the interests of all stakeholders. This constitutes a major opportunity for public port authorities to lead integration efforts, using one of the models presented, for the benefit of individuals and the community more broadly.

[5] Information and communications technology encompasses a broad range of technological tools and resources used to manage, process and share information.

- Smart contracts could be an effective tool for toll payments, enabling the automated processing of multiple complex variables to either benefit or penalize vessels depending on their conduct. Responsible use that contributes to the well-being of the community could be incentivized, while non-compliance with established standards could be penalized. This approach would make operations more efficient and transparent, optimizing the use of waterways and aligning incentives to encourage sustainable and responsible practices.
- A smart waterway system, in the form of a river community system, would offer real-time information on navigation markers and dredging to substantially improve the accurate calculation of tolls. It would not only optimize vessels' operating costs but would also increase user satisfaction, creating new opportunities for exports, imports and navigation in general. Although this information already exists, it is not shared in real time, which generates cost overruns for vessels travelling to inland ports and unnecessarily increases operating costs and delays.
- The implementation of new oversight technologies and processes for measuring gas and particulate pollution from both river and land transport should be prioritized. These technologies make it possible to manage traffic congestion at port access points, in addition to loading and unloading activities, while mitigating environmental impacts. Such steps are critical for internalizing the costs of pollution —under the polluter pays principle— rather than letting society continue to foot the bill. In addition, an incentive structure could be established to encourage the use of river transport instead of land transport, which generates more traffic congestion. This would contribute to the sustainability of one of the region's most consequential economic activities, namely river shipping (for international trade and cabotage alike), which is currently being underutilized.

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VI. Publications of interest

FAL Bulletin No. 393

Digitization in ports: Application of digital twins to complex logistics

Diogo Aita

This *FAL Bulletin* forms part of ECLAC reflections on disruptive technologies in transport. This issue explores the opportunities and challenges involved in the implementation of digital twins in logistics and port operations and the potential impact of this new technology on competitiveness.

This issue also highlights the importance of digital twins as a new key technology for the development of logistics and urban infrastructure, and the important benefits which its application could bring to Latin American and Caribbean countries. Digital twins could optimize operations in the region's ports, which are paramount to the region's participation in international trade and global value chains.

Available in: Spanish English

FAL Bulletin No. 400

Proposals to expand river connectivity in South America

Leonel Temer
Ernani Muraro
Juan Carlos Paz

This *FAL Bulletin* presents opportunities for physical river integration in South America that could mark an important step in the design of a sustainable river navigation system for the region. It also examines the opportunities that intermodal transport offers for regional logistics.

This document is part of ECLAC analyses on infrastructure and connectivity. The study was carried out with the support of the regular programme of technical cooperation of ECLAC, in the framework of the activities of the United Nations Development Account project entitled "Transport and trade connectivity in the age of pandemics: contactless, seamless and collaborative United Nations solutions".

Available in: Spanish English