The Future of Port Interoperability: Synergy between TIC4.0 and IPCSA

05.12.2025

Terminal Industry Committee 4.0

1. INTRODUCTION

Digitalisation has become a defining force in the transformation of global logistics, and ports, crucial crossroads between rail, road and sea, are under increasing pressure to deliver transparent, efficient, and resilient information flows. As transport chains grow more complex and the expectations of global trade evolve, the need for robust, interoperable data standards has never been more urgent. Today, modern logistics ecosystems depend on a seamless exchange of accurate, real-time information between terminals, equipment, cargo owners, carriers, port authorities, and community systems. Yet fragmentation persists. Legacy systems coexist with emerging technologies, communication still relies heavily on EDIFACT messaging developed in the 1980s, and many ports struggle to harmonise data across stakeholders. It is within this context that TIC4.0 and IPCSA bring together their complementary expertise. TIC4.0 provides a modern, semantics-driven data standard capable of representing real-time and predictive operational states, while IPCSA unites the community of Port Community Systems (PCS) and Single Windows that manage the administrative and commercial backbone of port processes worldwide.

The convergence of these frameworks—supported by research initiatives such as the Horizon Europe FOR-FREIGHT project—offers a new pathway toward true multimodal interoperability. By translating EDIFACT and PCS messages into the TIC4.0 semantic model and aligning PCS processes with granular representations of carrier and cargo operations, this collaboration demonstrates how mature, proven standards can evolve to meet the needs of a fully digital, data-driven logistics chain. This White Paper provides an integrated view of how the TIC4.0 standard, the EDIFACT message suite, and PCS platforms can be combined to improve process visibility, reduce operational uncertainty, and enable the next generation of automated, intelligence-driven port operations.

1.1. TIC4.0

The Terminal Industry Committee 4.0 (TIC4.0) was constituted in 2019 to promote the creation and adoption of digital standards in the cargo handling industry. As of February 2025, the association had a total of 65 members, with top leading actors of terminal operators and solution providers among its ranks. Inside of the association, selected experts of its members participate in working groups called “Task Forces” to create, curate and develop the new standards. These are then published quarterly for the general public to use. 14 releases have been published since TIC4.0 was established, covering areas such as Cargo Handling, Terminal Automation, Yard Inventory or, more recently, EDIFACT.

At the core of TIC4.0 lies its semantics, a common way of defining how the “language” works and based on how human languages work. The following elements constitute the “building blocks of the TIC4.0: language:

- Subject:
- Concept
- Observed Property
- Point of Measurement

- Value

Messages complying with the TIC4.0 format must be constituted by any of the five components mentioned beforehand.

1.2. International Port Community Systems Association (IPCSA)

The International Port Community Systems Association (IPCSA) is a global industry association that represents operators of Port Community Systems (PCS) and Single Windows, as well as port authorities, from around the world.

Founded to support digital trade and streamline logistics, IPCSA focuses on enabling integrated, efficient and secure information-flows among stakeholders in maritime, air and land transport chains. It provides member organisations with standards development, research, training, networking and best-practice sharing.

IPCSA's membership spans multiple regions (Africa, Asia-Pacific, Europe & North America, Latin America & Caribbean, West Asia) and includes both founding members and associate members, aligning with the regional structure of the United Nations.

2. TIC4.0 Semantics

Translating real-world scenarios into structured data is a complex challenge. TIC 4.0 proposes a semantic framework to standardize information exchange in a technology-independent manner, ensuring compatibility, competition, and future technological advancements.

This framework is based on a structured grammar that defines six key elements: HEADER, SUBJECT, CONCEPT, OBSERVED PROPERTY, POINT OF MEASUREMENT, and VALUE. These elements work together to provide a precise and scalable representation of industrial processes and data points.

- The HEADER identifies the message source, timestamp, and unique reference.
- The SUBJECT defines the entity performing or experiencing an action.
- The CONCEPT specifies the state or action of the subject.
- The OBSERVED PROPERTY quantifies the concept (e.g., speed, volume, duration).
- The POINT OF MEASUREMENT establishes the location and time of data collection.
- The VALUE represents the actual recorded measurement.

By combining these elements, TIC 4.0 ensures a structured, human-friendly approach to data representation. This model supports bottom-up aggregation, transversal process-driven analysis, and top-down conceptual interpretation, creating a flexible and standardized methodology for industrial data management.

SUBJECT

The SUBJECT defines the entity performing an action or being in a specific state, as described by the CONCEPT. It establishes the perimeter of the element being monitored and can be broken down into hierarchical components, known as nested SUBJECTS. These hierarchical relationships ensure structured data representation, where every SUBJECT is inherently part of another SUBJECT.

For example, in a terminal setting:

- Terminal → RS (Rubber-Tired Gantry) → Spreader

In this hierarchy, the RS is the primary SUBJECT, while the Spreader is a nested SUBJECT of the RS. Further breakdowns can include additional nested SUBJECTS, such as a flipper within the spreader. The HEADER of a message provides the context for this hierarchy.

Mandatory Attributes

To ensure uniqueness and consistency, each SUBJECT must have two key attributes: an Identifier (id), which is a globally unique ID typically formed using the manufacturer name and ID (e.g., serial number), and a Name (name), a human-readable identifier recommended to follow a structured format. The CONCEPT defines what a SUBJECT is, uses, consumes, or does within a system or process, representing its status, actions, or events. Each CONCEPT is linked to a specific SUBJECT, providing context to interpret the associated VALUE.

Concept Categories

The CONCEPT can be categorized into several predefined types: Is (describes static attributes or states of the subject), Used (specifies materials, parts, or components actively involved in the process), Consumed (tracks resources like energy, fuel, or other substances utilized by the system), and Does (describes actions or events related to operations). Each CONCEPT has mandatory and optional attributes. The Concept Identifier is a unique, human-readable alphanumeric reference, with actions performed by a subject named using the gerund form of the verb (e.g., driving, hoisting). Optional attributes include the Concept Name, a long-form name for clarity, and Concept Type, a classification tag that helps organize and filter similar CONCEPTs, aiding human users in locating relevant information, even though it's not used in the data model itself.

Concept Type Categories

The Concept Type Categories cover various aspects of operations and management. Activity refers to the motion related to payloads, involving structural elements like cranes and hoists, excluding auxiliary components such as engines. Status defines the current operational state of a subject, while Move specifically focuses on cargo movement processes. Metadata identifies and classifies a subject with constant values like IDs or codes. Functional describes the operational role of a subject, including whether it's in use, under maintenance, in training, or being tested. TOS relates to work instructions and planning, while IT encompasses network and hardware attributes. Asset pertains to asset management concepts, and Maintenance deals with maintenance operations. Energy covers energy flow and behaviour, and Substance refers to the materials used in processes or devices. This classification structure ensures that TIC 4.0 provides a clear, organized, and scalable way to define the behaviour and characteristics of industrial systems.

OBSERVED PROPERTY

The OBSERVED PROPERTY defines the measurable metric (physical magnitude) of a given CONCEPT. It represents how much of a specific characteristic is being quantified, using a defined scale or unit of measurement.

Each CONCEPT can have multiple associated OBSERVED PROPERTIES, covering both:

- Fundamental magnitudes (e.g., mass, time, temperature, length).
- Derived magnitudes (e.g., speed, force, power, volume, pressure).

Most OBSERVED PROPERTIES require a unit of measurement to accurately define the VALUE.

POINT OF MEASUREMENT

The POINT OF MEASUREMENT (POM) defines both the physical location and temporal context where and when an OBSERVED PROPERTY is measured within a subject or process, providing a complete picture of the observed data. The Physical Location (pom) specifies where the observation happens in the device or process, with possible attributes such as Input (IN), indicating an external command or request, Internal_Input (iinput) for internal requests from subsystems, Internal_Output (ioutput) for feedback from internal elements, and Output (OUT) for direct measurements from sensors confirming the action or status. The Temporal Context (pomt) refers to when the measurement occurs, using the ISO 8601 standard. This includes options like Scheduled, Proposal, Request, Planned, Estimated, Actual, Performed, and Historic, which represent different timeframes and stages of observation. By combining both pom and pomt, the TIC 4.0 model ensures comprehensive data representation, improving traceability and interoperability.

VALUE

The HEADER and SUBJECT, along with various CONCEPTs, OBSERVED PROPERTIES, and POINTS OF MEASUREMENT, together define the unique meaning of a VALUE within the system. By default, the unit of measurement follows the International System of Units (SI), unless otherwise specified in the observed property attribute. The TIC 4.0 standard defines specific units for each concept, such as seconds for duration, kilometers per hour for speed, degrees Celsius for temperature, and kilowatt-hour for energy. Units for Flow & Energy, Electrical Properties, Position & Time, and Percentage are also standardized in the system. Percentages represent the observed property as a percentage of a reference value, typically the maximum design performance under real conditions. If no specific reference is provided, the most restrictive limitation applies.

DATA MODEL

The TIC4.0 data model is built upon the TIC4.0 semantic framework, which is typically represented in a flat, human-readable format.

The definitions of concepts are provided by TIC4.0 separately and are not part of this document. Instead, the data model serves as a technical implementation that translates these definitions into a digital format compatible with programming languages such as Java, XML, and Python. Multiple data exchange formats can be used (JSON, XML, MQTT, etc.), and a corresponding schema will be published.

A JSON validator will be employed to ensure that the format complies with the JSON Schema. From the JSON format, data can be converted into other formats (Java, YAML, XML, etc.) or even into a flat, human-readable format through a dedicated algorithm.

To digitally format the semantic framework and dataset, two key components are required:

- A data model, which structures the data.
- A data schema, which defines details such as format validity, data types (boolean, integer, real, etc.), and whether certain data fields are mandatory or optional.

From the 2021.1 release onwards, the data model is based on the RDF (Resource Description Framework), following the subject → predicate → object structure.

In alignment with semantic web standards (subject: object), the model consists of three main components:

1. Header
2. Asset Description
3. Measurement

3. The IPCSA and PCS. What is a PCS? Role in the industry

A Port Community System (PCS) is a digital platform that facilitates the exchange of information between all stakeholders in a port environment, including terminal operators, shipping lines, customs authorities, freight forwarders, and logistics providers. By streamlining communication and automating administrative processes, PCS improves the efficiency, transparency, and security of port operations, reducing costs and delays.

Purpose of PCS

The primary goal of a PCS is to optimize cargo flow and enhance port logistics by:

- Enabling real-time data exchange between public and private entities.
- Reducing paperwork and manual interventions through digitalization.
- Improving supply chain visibility and decision-making.
- Ensuring regulatory compliance by integrating with customs and government agencies.
- Enhancing security by providing controlled access to port information.

History of PCS

The concept of PCS emerged in the late 20th century, as global trade increased and ports faced growing complexity in handling documentation and logistics. The first systems were developed in Europe in the 1980s, with ports such as Rotterdam, Hamburg, and Antwerp pioneering early digital platforms to manage vessel arrivals, cargo clearance, and hinterland transport coordination. Over time, these systems evolved with advancements in internet connectivity, cloud computing, and automation, becoming integral to Smart Ports and global trade facilitation.

Today, PCS platforms are widely adopted worldwide, often integrating with Single Window Systems to further enhance trade efficiency. Leading international organizations, such as the

International Port Community Systems Association (IPCSA), promote standardization and interoperability to ensure seamless data exchange across global supply chains.

4. Integrating New Technological Frameworks Without Abandoning the Existing Ones: The Evolution of EDI in TIC4.0

Innovation consists of the improvement, creation, or application of new ideas, methods, or technologies to generate value. This simple definition encompasses a wide variety of ways in which innovation can enhance processes, products, and business models. Technology, although intuitively one of the first sources of innovation that comes to mind, is not actually the most common one and always comes together with other forms of innovation.

If we analyze the emerging technologies being implemented in the industry, we can mention big data, AI, digital twins, blockchain, IoT, and operational technologies. However, in each case, all of them depend on existing technologies and processes, where innovation comes from their combination.

The reason behind the creation of the TIC4.0 standard is exactly that—the constraints the industry faces when applying these technologies due to the lack of a common data structure for exchanging information between systems and equipment. The effort, time, and investment required when industries attempt to innovate with these technologies make having such a solution crucial, transforming new technologies into truly innovative solutions.

IoT devices gather vast amounts of data from equipment, a big data infrastructure stores that data, data platforms clean and structure it, and a data standard harmonizes the information. AI tools optimize processes, while digital twins enable testing, validation, and adaptation, helping industries make better decisions. The interaction between all these technologies provides industries with cutting-edge tools to truly elevate efficiency to the next level.

As we have seen, we are on the brink of a major technological revolution in the port sector, for which TIC4.0 aims to be the cornerstone that structures different system architectures and enables interoperability between them. However, there is currently a standard that has been fulfilling a very similar role for several decades and remains in use today—this standard is EDIFACT messaging.

This data structure and semantics, which in a way represents an industry taking its first steps toward digitalization, serve as a valuable reference when developing new solutions adapted to modern technologies. This is why interoperability between TIC4.0 and EDIFACT is a crucial milestone for the port logistics sector, as it will allow the use of a widely adopted standard alongside a new standard that is experiencing growing adoption.

4.1 The Role of EDIFACT in Modern Port Operations

EDIFACT (Electronic Data Interchange for Administration, Commerce, and Transport) is an international standard developed by the United Nations (UN/CEFACT) for electronic data interchange (EDI) created in the 80th decade. It standardizes business transactions such as orders,

invoices, shipping notices, and payment instructions, making global trade and commerce more efficient.

EDIFACT messages are structured using a hierarchical format with segments, composite data elements, and individual data elements. Each message type is identified by a six-letter code. EDI enables seamless communication between various entities involved in port operations, ensuring smooth cargo movement and regulatory compliance. It facilitates real-time data exchange, reduces administrative overhead, and optimizes resource allocation.

Key areas where EDI has a significant impact include:

- Cargo Handling & Terminal Operations: Optimizing container loading, discharge, and storage.
- Customs & Regulatory Compliance: Enabling automated declaration processing and reducing clearance time.
- Multimodal Transport Integration: Ensuring smooth transitions between maritime, road, and rail transport.
- Port Administration & Financial Transactions: Streamlining invoicing, payment processing, and cost management.

Key Benefits of EDI in Port Logistics

- Faster and More Accurate Data Exchange: EDI replaces manual paperwork with standardized digital messages, reducing delays and human errors in data entry and transmission.
- Improved Cargo Tracking and Visibility: By using transport status messages, stakeholders gain real-time insights into cargo movements, reducing uncertainties and operational inefficiencies.
- Enhanced Customs Compliance: EDI allows direct communication with customs authorities, expediting declarations, and ensuring regulatory adherence, thereby reducing delays and potential fines.
- Cost Reduction and Process Automation: Automating documentation and communication processes lowers administrative costs, minimizes labor-intensive tasks, and improves operational efficiency.
- Reduced Port Congestion: Pre-arrival notifications and automated container release messages contribute to better traffic management within ports, improving turnaround times.

Table 1: Common EDI Messages in Port Logistics

EDI Message	Description
BAPLIE	Bayplan/stowage details of containers on a vessel
COARRI	Container discharge/loading report
COPARN	Container announcement for arrival/departure

COPINO	Container pre-notification for pickup/delivery
COREOR	Container release order
COPRAR	Container discharge/loading order
CODECO	Container gate-in/gate-out report
CUSDEC	Customs declaration
CUSRES	Customs response
CUSCAR	Customs cargo report
IFCSUM	Forwarding and consolidation summary
IFTMBF	Transport booking confirmation
IFTMIN	Transport instructions
IFTSTA	Transport status updates
INVOIC	Electronic invoice for logistics services
MOVINS	Stowage instruction message
TSEDEN	Transport equipment damage and repair notification

As can be seen, EDIFACT messages for transport and logistics cover a significant portion of port operations, from ship-port communication to customs interactions for dispatching goods to the hinterland. Their extensive use demonstrates their validity not only due to the diversity of stakeholders exchanging EDIFACT messages but also, and most importantly, because of their broad geographical adoption, as they are used globally. These facts also highlight the relevance of the standard; however, within the industry, there is growing concern that these messages may not be suitable for more advanced technological environments where cutting-edge technologies are deployed. This is precisely why TIC4.0 has recognized the need to establish interoperability between standards, adapting the data contained in EDIFACT messages to the TIC4.0 semantic framework.

Earlier in this document, we mentioned some of the technologies that are beginning to be deployed in the maritime port sector. It was also noted that these technologies should be supported by the experience of proven past technologies, whose validity remains relevant.

After more than forty years of using EDI messages, the industry has begun to complement or even replace them with more modern information exchange technologies, such as JSON and XML data formats, which are among the most widely used today. These formats have an advantage over EDIFACT as they are lightweight and feature a syntax that is easier for people to understand when reading message content.

Additionally, these formats are well-suited for integration into big data environments, artificial intelligence (AI), and, most importantly, they facilitate data analysis due to their use of human-readable languages.

4.2 Translation EDI to TIC4.0

At the beginning of 2024, TIC4.0 launched an initiative to integrate EDI (Electronic Data Interchange) data, primarily in EDIFACT format, into the TIC4.0 data standard. Currently, TIC4.0 focuses on terminal technical data, lacking operational data that EDI provides. The goal is to create a comprehensive data model that supports end-to-end operational processes by translating EDI messages into TIC4.0. This integration aims to overcome the challenge of limited integration between EDI and TIC4.0, which currently hinders the creation of valuable, automated triggers and a holistic view of terminal performance. By standardizing EDI data within TIC4.0, it becomes easier to understand and fuse with other operational data, benefiting terminal operators, global terminal operators, and agencies by improving efficiency, reducing integration efforts, and modernizing data exchange.

The methodology involves reviewing EDI messages based on the SMDG (Ship Message Design Group) standard, segment by segment, and mapping the data into existing or newly defined TIC4.0 fields. This process includes translating established EDI message types like BAPLIE, MOVINS, COPRAR, and CODECO. The first outcome of the working group responsible for the translation of EDI to TIC4.0 was a whitepaper in which detailed explanations are provided about the EDIFACT structure, including segments, tags, and code lists, and examples are offered on how to interpret and translate these elements into the TIC4.0 data model. The goal is to enable a more streamlined, automated, and integrated data flow across terminal operations, facilitating better planning, prediction, and decision-making for all stakeholders.

The initial efforts have focused on the translation of the COARRI message, one of the main EDIFACT messages, which functions to communicate the confirmation of container loading and unloading operations carried out on a ship within a port in a precise and timely manner. This message details which specific containers have been moved, providing essential information for shipowners, agents, and other stakeholders in the logistics chain.

Through the COARRI, detailed information is transmitted about each container, including its unique identification, dimensions, type, and status (full or empty). Additionally, it may include data about the container's location on the ship and the exact dates and times of the operations. This information enables accurate tracking of goods, facilitating planning and informed decision-making throughout the supply chain, and contributing to efficiency and transparency in maritime transport.

The conclusion of the translation of the COARRI message has triggered the beginning of the translation of the next message, the CODECO message. This message is primarily used in port terminals and container depots. Its main function is to confirm and communicate the entry and exit movements of containers through the terminal gates. This message provides a detailed record of when and which containers have been delivered or picked up by road, rail, or barge transporters.

In addition to recording entry and exit movements, the CODECO can also be used to inform about internal movements of containers within the terminal, excluding vessel loading and unloading operations. By providing accurate, real-time information on container movements, the CODECO message facilitates efficient terminal management, improves supply chain visibility, and contributes to the optimization of logistics operations.

With the incorporation of the COARRI and CODECO message data into the TIC4.0 standard, the TIC4.0 standard is capable of generating the correct traceability of cargo moving from the vessel to its shipment to the hinterland, while respecting the terminologies and logics behind EDIFACT. These two messages are just an example of the TIC4.0 standard's ability to interoperate with other standards, as it is flexible enough to structure data to represent a specific reality.

5. Enhancing Port Operations Planning

In a sector as inherently uncertain as maritime port logistics —where the number of potential disruptions to supply chains continues to grow alongside globalization and the increasing complexity of interconnected systems —having tools that enhance planning processes is critical. The ability to build resilience into these processes, enabling them to adapt organically to continuous operational changes, has become an undeniable necessity.

Moreover, as ports and logistics networks face challenges such as geopolitical tensions, climate-related disruptions, and rapid technological advancements, leveraging digitalization and standardized data exchange is key to mitigating risks and improving efficiency. Solutions that enable real-time visibility, predictive analytics, and automated decision-making are no longer optional but essential for ensuring the fluidity and reliability of global trade. This reality highlights the importance of platforms such as PCS, which, through the consolidation and distribution of information, enable greater coordination among the stakeholders involved in port processes.

5.1 Current Challenges

The scale of the challenge facing the industry in improving operational planning is so vast that, even with advanced solutions like PCS, significant inefficiencies persist. These inefficiencies are largely driven by data gaps —particularly in real-time information— which prevent a truly dynamic representation of reality, making it difficult to anticipate unforeseen events and disruptions.

While PCS play a crucial role in streamlining communication and coordination among stakeholders, their effectiveness is often limited by fragmented data sources, inconsistent data standards, and delays in information sharing. To overcome these barriers, the industry must move towards deeper integration of real-time data analytics, IoT-enabled tracking, and AI-driven predictive modeling. By doing so, ports and logistics networks can transition from reactive decision-making to proactive, data-driven strategies that enhance resilience, optimize resource allocation, and improve overall supply chain performance.

5.2 TIC-Based Solutions – interconnectivity with EDIFACT

Improving Information Accessibility

The core purpose of Port Community Systems is to facilitate seamless access to critical information for stakeholders in port logistics, ranging from a vessel's Estimated Time of Arrival (ETA) to the arrival of a truck at the port for container pickup. However, the nature of this information can vary significantly—it may consist of simple event notifications with low update frequency or more complex datasets that provide detailed descriptions not only of possible events but, more importantly, of the current state of processes and the various stakeholders

involved. Despite sector-specific differences, port terminals face a common challenge: the need for greater interoperability to streamline operations. The industry has recognized standardization as the key path forward, reducing the effort required to interconnect systems that must inherently interact with one another.

Just as EDIFACT once played a pivotal role in unifying different stakeholders under a common data structure and shared semantics, the TIC4.0 standard can now fulfil that role in a more advanced and adaptable manner. Designed to be compatible with the latest and most widely deployed technologies, TIC4.0 goes beyond traditional frameworks by enabling the representation of a broader range of operational realities—spanning historical, real-time, and predictive future scenarios.

One of the fundamental principles behind the development of TIC4.0 was ensuring the ability to represent the different states that an entity has been in, is in, or will be in. In the past, this requirement was constrained by technological limitations that prevented the efficient collection and communication of the necessary data. However, with the advancements in digitalization, IoT, and real-time data processing—many of which have been discussed earlier in this document—this is now a tangible reality.

The ability of the TIC4.0 standard to capture and communicate process states enhances transparency across the sector by providing a more powerful and standardized tool for information exchange. Its structured approach ensures that every data point introduced into the model carries an unambiguous, industry-agreed meaning, reducing misinterpretations and fostering interoperability. This not only streamlines communication across all stakeholders in the logistics chain but also improves efficiency, decision-making, and overall supply chain resilience.

From Event Management to Process Management: How TIC Supports PCS Evolution

We have already discussed the value of being able to transmit the main events that occur in port-call operations, including loading and unloading operations, and the dispatch or receipt of cargo to or from the hinterland. However, an informational structure based on events lacks the ability to convey the dynamics that occur in the processes and how these change throughout the operations.

To address this situation and enrich systems and personnel with information to optimize planning and decision-making, TIC4.0 has focused on standardizing the “Carrier Visit” and “Cargo Visit” processes, which are centred on carrier and cargo operations, respectively, from the perspective of terminals, considering TIC4.0 semantics.

In the case of Carrier Visit, all events and states of the process have been clearly defined, from the moment the vessel approaches the port until it leaves port waters.

For Cargo Visit, the key aspect is to distinguish the unique and unrepeatable visit of a cargo to the terminal, making it necessary to incorporate all possible data that describe this visit to handle it according to its specific requirements.

Carrier visit:

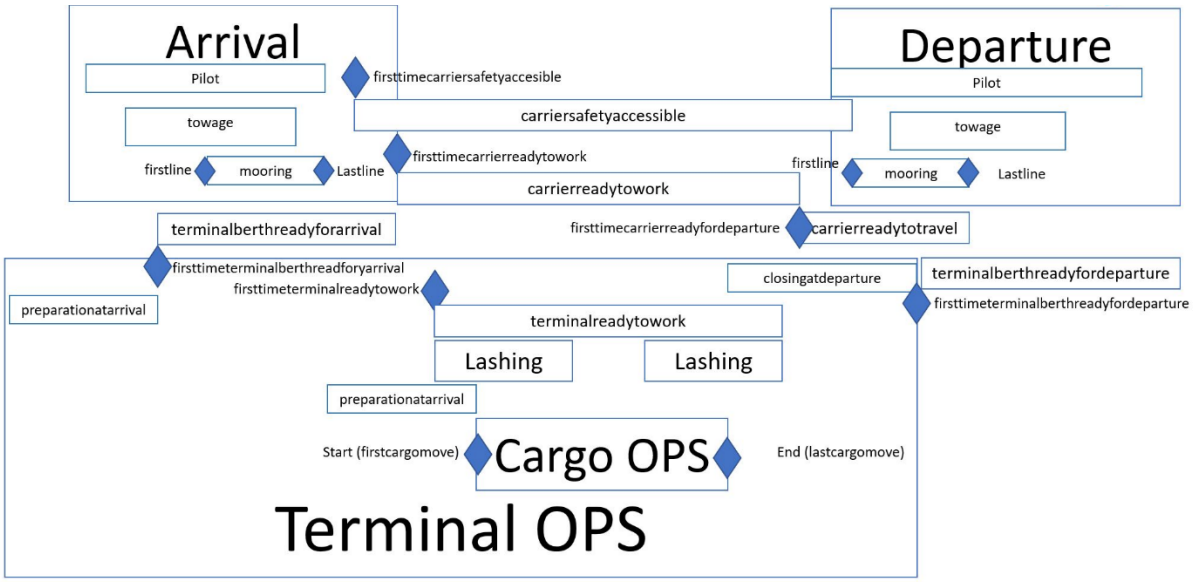
"CarrierVisit describes the process of a carrier (vessel, truck, barge, train) passing through a terminal (visiting the terminal) to load or unload cargo, or utilize other 3rd party-services (e.g. bunkering, garbage disposal, etc)".

The work done to create this detailed process was based on identifying the most relevant stakeholders who actively participate in the process, the most significant timestamps, and the possible states in which the subjects (systems, people, services, or equipment) may be or may be operating.

One of the major innovations of this work is the incorporation of multiple terminal events and states, such as "First Time Terminal Ready for Arrival," "Terminal Ready for Arrival," and "First Time Terminal Ready for Departure."

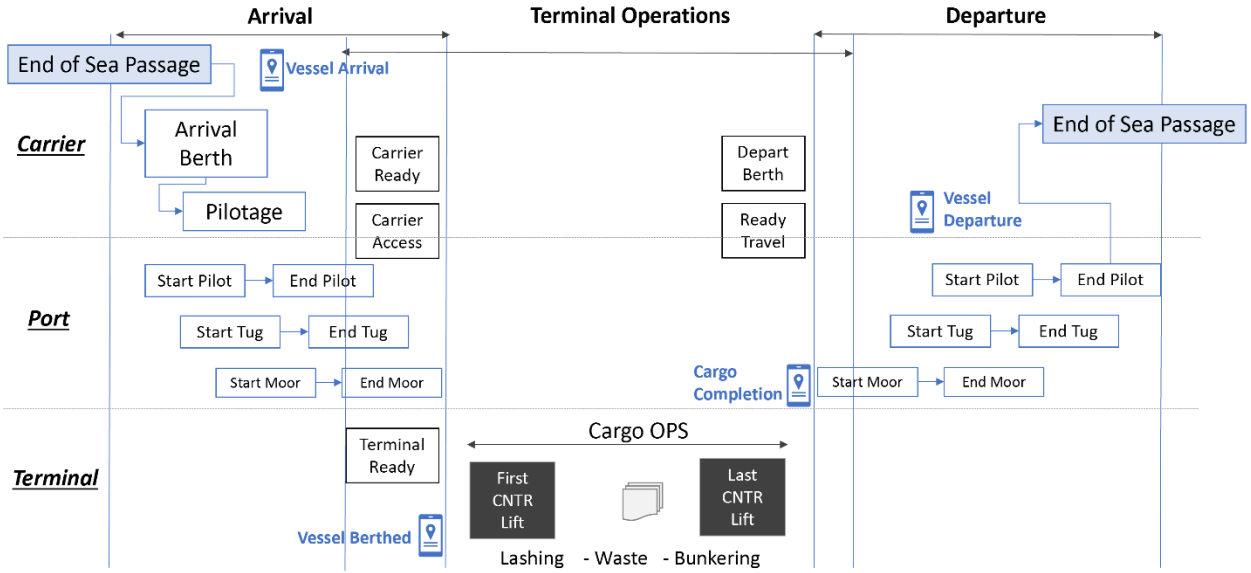
This new level of detail in the process expands the scope of digital representation, allowing information to be communicated to stakeholders automatically and unequivocally with greater agility and precision.

Figure 1. TIC4.0 Carrier visit phases definitions



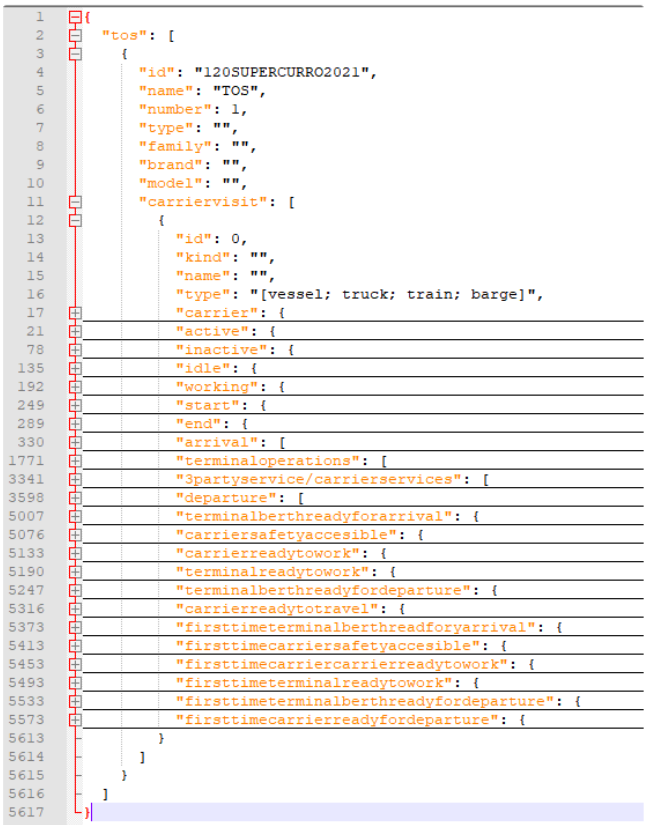
Another very important aspect to highlight is the comparative and harmonization exercise carried out with standards such as DCSA and IALA's S-211. This exercise made it possible to identify which events are compatible with the other two standards and incorporate those definitions into the TIC4.0 data model to ensure interoperability between standards. This allows stakeholders who have not yet adopted the TIC4.0 standard for information exchange to continue using their existing standards, as TIC4.0 has the capability to recognize data sent in DCSA or S-211 formats without requiring any changes.

Figure 2. Process detailed, including sub-processes



The process defined by TIC4.0 takes into account the different types of carriers that may visit the terminal. This means that the process not only considers the characteristics from the vessel's perspective but also incorporates the different parts of the process and the data associated with Carrier Visits for other types of transport, such as trucks and rail.

Figure 3. Overview of the Carrier Visit data elements in the process data model



Cargo visit:

"Lifecycle of cargo at a terminal from arrival until departure (both included)".

Just like *carrier visit*, *cargo visit* represents the journey of cargo through the terminal. This process encompasses all relevant events, both operational and administrative. On the operational side, it includes inbound movements, gate-in check-in, and real-time location tracking of the cargo. Administratively, it incorporates data derived from the translation of EDI messages, specifically the contents of the COARRI message.

Thanks to the nesting capabilities provided by TIC4.0 semantics, all data can be interconnected either through hierarchical integration or via references using the unique IDs of each entity. This allows for a complete traceability of a cargo's journey through the terminal, incorporating the efforts required to move it, identifying who handled it, and capturing both its operational and administrative status at every stage of its stay in the terminal.

Due to the concentration of information, PCS are, by nature, the most suitable system to manage port processes, as they integrate all parties involved in the operations, both suppliers and consumers of the information managed by a PCS. The logic behind the TIC4.0 semantics is an example of how increasing the level of detail in the digital representation of reality can help improve processes. This is achieved by gaining a more precise understanding of what is happening and how the different agents interact with each other in that reality.

Example: Real-time unloading notifications using EDIFACT COARRI for individual container reporting

One of the primary goals of all initiatives aimed at optimizing port operations is to reduce the dwell time of both the carrier and the cargo in the port. Achieving a higher turnover rate enhances resource utilization, lowers costs, and reduces the carbon footprint associated with cargo movement from origin to destination.

To optimize the processes that contribute to this reduction, it is essential to provide real-time information and accurate, continuously updated estimates. By doing so, stakeholders can plan and adapt operations with greater agility and precision, minimizing congestion and idle time. Additionally, enhanced data visibility fosters better coordination among port actors, leading to more efficient scheduling, improved resource allocation, and ultimately, a more sustainable and cost-effective logistics chain.

Currently, confirmations between terminals and ship consignees regarding cargo loading and unloading are carried out through the COARRI message, which includes a list of loaded and discharged containers. However, this list is not sent in real time, meaning there is no immediate and automated confirmation for stakeholders on whether a container is already in the yard (in the case of unloading) or on the vessel (in the case of loading).

To address this gap while adhering to the EDIFACT standard, TIC4.0 now enables a link between this information and the terminal's operational data. This allows for real-time, unit-level confirmation of the loading or unloading status of a specific container.

By incorporating Segment 6 of the COARRI message—which provides details such as container identification, reference sequence, and booking number—terminals can also include transport

movement details and timestamps related to the equipment, such as the actual date and/or time of loading or discharge. The following example shows how the COARRI message would appear in a TIC4.0 format. This information could be expanded into a single message that includes additional valuable details, helping inform other stakeholders in the process about the container's status and position within operations.

Example of TIC4.0 Confirmation message for the loading of an ISO container *MAEU5174506*, a full export unit. This container was part of booking reference number *ROT045683* and, as an FCL, was loaded on **November 15, 2001, at 01:04**:

DGS Segment Example: EQD+CN+MAEU5174506+4532:102:5+2+2+5'

Corresponding TIC4.0 Data Mapping:

EDI Format	TIC4.0 Format
CN	tos|@|cargo|@|type|metaelements|ouput|actual|equipmenttypecodequalifier: **CN**
MAEU5174506	tos|@|cargo|@|id: **MAEU5174506**
4532	tos|@|cargo|@|isotypecode1984|metaelements|output|actual|equipmentsizeandtypedescriptioncode: **4532**
102	tos|@|cargo|@|isotypecode1984|metaelements|output|actual|codelistidentificationcode : **102**
5	tos|@|cargo|@|isotypecode1984|metaelements|output|actual|codelistresponsibleagencycode : **5**
2	tos|@|cargovisit|@|cargosupplierrole|metaelements|output|actual|equipmentsuppliercode : **2**
2	tos|@|cargovisit|@|flowtype|metaelements|output|actual|equipmentstatuscode : **2**
5'	tos|@|cargovisit|@|full|status|output|actual|value : **TRUE (5)**

DGS Segment Example: RFF+BN:ROT045683'

Corresponding TIC4.0 Data Mapping:

EDI Format	TIC4.0 Format
BN	tos|@|cargovisit|@|bookingreferencenumber|metaelements|output|actual|referencecodequalifier : **BN**
ROT045683'	tos|@|cargovisit|@|bookingreferencenumber|metaelements|output|actual|referenceidentifier : **ROT045683**

DGS Segment Example: TMD+3++1'

Corresponding TIC4.0 Data Mapping:

EDI Format	TIC4.0 Format
3	tos|@|cargovisit|@|movetype|metaelements|output|actual|movementtypedescriptioncode : 3
1	tos|@|cargovisit|@|movetype|metaelements|output|actual|haulagearrangementscode : 1

DGS Segment Example: DTM+404:200211150104:203'

Corresponding TIC4.0 Data Mapping:

EDI Format	TIC4.0 Format
3	tos|@|cargovisit|@|checkout|time|output|actual|timestamp : 2001-11-15-XXT01:04:000|000Z (refers to the header)

Use Cases of TIC and PCS: Managing Dangerous Goods

One of the most important applications of EDI and other information exchanges is the reporting of dangerous goods. These types of goods shall be handled and positioned carefully on the yard to prevent major incidents. Furthermore, some ports might have restrictions in place regarding the storage length or positioning of containers transporting dangerous goods.

In today's SMDG EDI messaging, Dangerous Goods are handled in the following messages, which facilitate the automation of information exchange between shippers, port authorities, customs, and carriers. They facilitate the automation of data transmission, reducing errors and enhancing regulatory compliance. Key message types used for DG include:

- IFTMIN (Instruction Message) – Provides shipment instructions, including DG details.
- IFTDGN (Dangerous Goods Notification) – Conveys specific information about hazardous cargo.
- BAPLIE (Bayplan/Stowage Plan) – Details the stowage of cargo, ensuring proper DG placement.
- CUSCAR (Customs Cargo Report) – Reports DG to customs authorities for compliance checks.

Challenges and Best Practices:

The implementation of EDIFACT for DG management offers advantages but also presents challenges, such as data inconsistencies, integration complexities, and varying regulatory requirements. To overcome these, stakeholders should focus on ensuring data accuracy through validation mechanisms, standardizing message formats to avoid misinterpretations, enhancing system interoperability by integrating with port and customs systems, and adopting digitalization initiatives like TIC4.0 to improve overall efficiency.

Example of TIC4.0 handling in Dangerous Goods:

Recent work by the EDIFACT Task Force of TIC4.0 has produced the TIC4.0 version of the SMDG message "Dangerous Goods". The experts followed the SMDG guide to insert the EDIFACT messages into the TIC4.0 Data Model, ensuring compatibility and interoperability. An example of this can be found below these lines:

TIC4.0 Sample Message on Dangerous Goods

DGS Segment Example: DGS+IMD+3+2348+037=CEL+3+3-03'

Table 2: Corresponding TIC4.0 Data Mapping:

DGS Segment Example	TIC4.0 Format
DGS+IMD+3+2348+037=CEL+3+3-03'	tos|@|cargo|@|dangerousgoods|status|output|actual|value = true tos|@|cargo|@|dangerousgoods|metaelements|output|actual|codequalifier = IMD tos|@|cargo|@|dangerousgoods|metaelements|output|actual|class = 3 tos|@|cargo|@|dangerousgoods|metaelements|output|actual|classname = flammable liquids tos|@|cargo|@|dangerousgoods|metaelements|output|actual|undnumber = 2348 tos|@|cargo|@|dangerousgoods|metaelements|output|actual|#unit#celsius|flashpoint temperature = 037 tos|@|cargo|@|dangerousgoods|metaelements|output|actual|#unit#celsius|unit = celsius tos|@|cargo|@|dangerousgoods|metaelements|output|actual|codepackingdangerlevel code = 3 tos|@|cargo|@|dangerousgoods|metaelements|output|actual|codepackingdangerlevel name = minordanger tos|@|cargo|@|dangerousgoods|metaelements|output|actual|codepackingdangerdescription = Packaging Group III tos|@|cargo|@|dangerousgoods|metaelements|output|actual|dangerousgoodlabel1 = 3-03

Additional Information in TIC4.0 Format:

DGS Segment Example	TIC4.0 Format
DGS+IMD+3+2348+037=CEL+3+3-03'	tos|@|cargo|@|dangerousgoods|metaelements|output|actual|textsubjectcodequalifier = AAC tos|@|cargo|@|dangerousgoods|metaelements|output|actual|textsubjectcodequalifiername = Dangerous goods additional information tos|@|cargo|@|dangerousgoods|metaelements|output|actual|freetextvaluecode = PP tos|@|cargo|@|dangerousgoods|metaelements|output|actual|freetextvaluecodename = Severe Marine Pollutant tos|@|cargo|@|dangerousgoods|metaelements|output|actual|textsubjectcodequalifier = AAD tos|@|cargo|@|dangerousgoods|metaelements|output|actual|textsubjectcodequalifiername = Dangerous goods, technical name tos|@|cargo|@|dangerousgoods|metaelements|output|actual|freetextvalue = BUTYL ACRYLATES, STABILIZED

This TIC4.0-compliant message structure ensures accurate reporting and compliance with dangerous goods regulations in the port sector. Thanks to this, PCS and other port actors can exchange information seamlessly and even communicate important information about the cargo to Container Handling Equipment machines. For example, an automated STS crane may receive information on the dangerous goods content of a container, adjusting its movement speed accordingly. Furthermore, the port authority can be informed of the cargo movements in real time. This paves the way for a more transparent information exchange between machinery and other applications and actors.

The FOR-FREIGHT project: achieving interoperability via an electronic platform for logistics data exchange

In 2022, the European Commission, via its "Horizon Europe" programme, awarded a research grant to the project FOR-FREIGHT. Promoted by a multi-national consortium composed of 18 members, its aim is to develop novel and interoperable T&L solutions that will deliver increased operational capacity, efficiency and sustainability of multimodal and transshipment services. To strengthen the findings, three pilot projects were implemented at the Ports of Valencia (Spain), Galati (Romania) and Piraeus (Greece). All three combined different means of transportation, including innovative solutions as a last-mile distribution via Metro de Madrid.

As part of the standardisation contributions of FOR-FREIGHT to standards-developing organisations, a consultation was conducted during the creation of this White Paper to find common solutions and areas of development for PCS interoperability. Since PCS rely on EDIFACT messaging, as explained in the previous chapters, the focus was placed on its equivalences. Furthermore, in the case of the Port of Valencia, where tailor-made messages called "Documentos Únicos de Transporte" are used, more adaptations are needed.

TIC4.0 has contributed to the FOR-FREIGHT project by adapting these messages and communications to the TIC4.0 format. For this purpose, a compatibility analysis was developed with the help of Fundación Valenciaport. The documents exchanged by the customers and companies involved in the pilot project were analyzed and adapted into the TIC4.0 Data Model. By doing this, full interoperability was achieved between the legacy systems of Valenciaport and the FOR-FREIGHT platform, paving the way for future adaptations.

In conclusion, the adaptations made by the FOR-FREIGHT project are a promising showcase of what collaboration and standardisation can achieve for logistics operations. The adaptation of EDIFACT and legacy messaging, coupled with IPCSA's systems and efforts, establishes a new paradigm for the creation of truly interoperable solutions. This marks a remarkable success in the complex world of digital logistics communications and services.

6. Conclusions

The work presented in this document demonstrates that the transition toward a digitally integrated port ecosystem does not require the abandonment of existing standards but rather enhancing and interconnecting them. By establishing a rigorous methodology to translate EDIFACT messages into the TIC4.0 semantic model, and by aligning PCS processes with a

structured, technology-agnostic framework for operational data, TIC4.0 and IPCSA have shown that interoperability is both achievable and strategically beneficial. The enhanced Carrier Visit and Cargo Visit models, enriched with real-time and historical operational states, pave the way towards deeper visibility and faster decision-making across the entire logistics chain. At the same time, the FOR-FREIGHT project provides concrete proof that this interoperability can be implemented in real operational environments, including multimodal corridors and ports with complex legacy infrastructures.

Looking forward, the sector stands at a pivotal moment. Technologies such as AI, IoT, digital twins, and predictive analytics will only achieve their full potential if supported by clean, structured, and standardised data. PCS will continue to play a critical role as trusted integrators, while TIC4.0 can act as the semantic backbone that unifies how operational reality is represented and shared. The joint work of IPCSA, TIC4.0, and the FOR-FREIGHT consortium shows that collaboration across communities is essential for building the resilient, efficient, and sustainable logistics networks that Europe and the global economy demand. The next phase of innovation will depend not on new technologies alone, but on the ability of standards to evolve together, ensuring that every stakeholder, from crane to customs, speaks a common, interoperable digital language.