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A New Architectural Framework for Digitalization of Maritime Intelligent Transport Systems

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ABSTRACT: Digitization in international shipping is an increasingly important topic, but for many years, the lack of accepted international standards and the usage of many different regional solutions, especially for communication between ships and ports, has made the introduction of digitalized solutions difficult. Since 2020, important work has been done in IMO to harmonize international standards supporting ship-port interactions, and this work has now been supported by both shipping, ports, and international standardizations organizations. IMO, through its facilitation committee (FAL) and EGDH (Expert Group on Data Harmonization) is developing the IMO Reference Data Model that covers mandatory reporting requirements related to port calls. This conceptual data model is mapped to three technical data models in three different domains, namely, UNECE (trade), WCO (customs) and ISO 28005 (maritime) to ensure the interoperability between the different ICT systems participating in the data exchange. The IMO Reference Data Model has also been extended with operational data to handle Just-In-Time arrival and departure and also nautical information to ensure that the specification of the locations in ports (berths, pilot boarding places, bollards etc) are the same for different usages. Several international organizations as BIMCO (the largest ship owners' organization) and international port organisations as IAPH, IPCSA and IHMA are strongly involved in this work. This paper summarizes work done by IMO and others to clarify the roles, functionalities and ICT-systems (Information and Communications Technology) that are needed to support the various processes needed to be performed during a port call. These definitions will form the basis for defining a Maritime ITS (Intelligent Transport System) Architecture which will also need to be related to road ITS and also to e-Navigation functionalities. The Maritime ITS Architecture described in this paper contains three levels, namely the Domain Definition (generalized roles that represent people, organizations and equipment in the system), the Processes (definitions of processes and functions that need to be supported to make the domain work), and the Information model (a generalized information model covering the information elements that are required by the functions and processes). In addition to this comes the layers to describe the physical implementation architecture, and the layers to describe the service implementation (e.g. APIs) and the protocols.

1 INTRODUCTION

1.1 *Background*

The shipping industry currently goes through a rapid development in terms of digitalization and process automation. This applies to onboard systems as well as data collection on the ship for operational efficiency or environmental monitoring purposes. Today, this is sometimes referred to as Shipping 4.0, or the adoption of Industry 4.0 technologies to the shipping sector, and this is explored with great interest by many large companies in the sector [1].

However, these developments also include more conventional digitalization and automation of administrative and other work processes. This has a history back to the 1970s when computers started to be introduced on ships and in offices. This corresponds to what one can look at as the third industrial revolution [2]. This includes digitalization of the information exchanges between ships and ports where port clearance to national authorities, port approach navigation, just in time arrival negotiation, cargo handling and ship supplies are among the processes that are changing.

A characteristic of ship and port operations is that several very different domains overlap. This includes nautical operations and e-navigation, authority reporting, general ship and port operations, trade related data exchanges as well as cargo logistics. This has made it difficult to coordinate developments of data communication standards, but an initiative from IMO has started to resolve some of the differences: This is the IMO Compendium and the IMO Reference Data Model (IRDM) that harmonize standards from ship operations (ISO), authority reporting (World Customs Organization) and international trade and transport (UN/ECE). The IMO Compendium has also been extended into more operational areas, such as just in time arrivals in port, waste delivery and more. We refer the interested reader to an earlier paper for a more detailed discussion of the IRDM and the IMO Compendium [3].

To make the harmonized ship-shore information exchange useful in practise, it is also necessary to have a clear view of the typical ICT landscape in seaports as well as the processes that make use of the ICT systems. Work to identify this has now been completed by a correspondence group in IMO [4]. This group has developed a first taxonomy for the most common systems seen in the port: PCS (Port Community System), TOS (Terminal Operating Systems), VTIS (Vessel Traffic Information System), PMIS (Port Management Information Systems), and MSW (Maritime Single Window). However, the actual configuration and the capabilities of each system type differs between ports and particularly between large and small ports.

Another issue of concern is the integration of the general geospatial information with operational information. It is important that the identification codes, for instance for bollards and other quay-side infrastructure, are harmonized between the operational and geospatial standards. For instance, when a ship master plans a berth arrival based on operational instructions received for instance through an ISO 28005 XML message [5], the locations should be specified in the same was as in ECDIS chart overlays, provided in the IHO S-131 format [6].

The geospatial overlap continues into the terminal area where cargo and cargo transport locations are important for logistics and hinterland transport. This brings the ship operations into the intelligent transport system (ITS) domain. Initiatives are also under way to see if it possible to define a maritime ITS architecture that further links ship operations into the overall transport chain [7].

1.2 *A Maritime ITS Architecture*

There are several ITS architectures that has been proposed over the years. These architectures attempt to create an overall structure for development of compatible digitalization standards in the selected domain. Also, an ITS architecture is a special case of the more general information technology (IT) architecture [8]. We have previously suggested a structure for a maritime ITS architecture as illustrated in Figure 1 [9]. This has been updated with a physical architecture layer since first published.

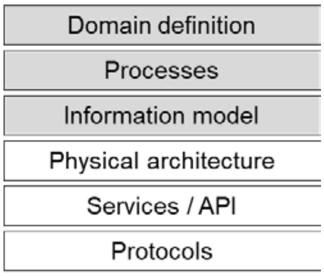

Figure 1. A Suggested Maritime ITS Architecture [9]

The grey rectangles represent the actual ITS architecture and are respectively:

- *Domain definition:* This is the definition of the domain and its delimitation, including the generalized roles that represent people, organizations and equipment in the system.
- *Processes:* This layer contains the definition of the processes and functions that need to be supported to make the domain work.
- *Information model:* This is a generalized information model covering the information elements that are required by the functions and processes.

The white rectangles represent the services, e.g. as application programming interfaces (API), used to connect processes together, and the protocols that are used in a distributed implementation of the system. We have also added a physical architecture layer above these layers as that is needed to define how functions are distributed in the actual system. The physical architecture will normally be different in different implementations of the system, e.g. in different ports or countries.

The purpose of the ITS architecture is that the physical architecture, the services and protocols can be developed independently to suit specific functional requirements, but that the overall architecture ensures a minimum interoperability between them.

As one may already have guessed, the IMO Reference Data Model is already a start on the information layer in the architecture. The rest of this paper will give an introduction to the other parts of the architecture as well as to some concrete parts of the physical implementation.

1.3 *Paper Structure*

This paper gives an overview of the levels *Domain Definition*, *Processes* and *Information Model* in the Maritime ITS Architecture. It also describes some relevant technical standards to be used for ship-shore interactions, and it also describes some ICT systems relevant to support the processes.

2 DOMAIN DEFINITION

2.1 *Domain delimitation*

The domain of Maritime ITS is not fully defined yet, but the preliminary definition is that it at least should include the ship and the entities that are directly interacting with the ship as exemplified by Figure 2.

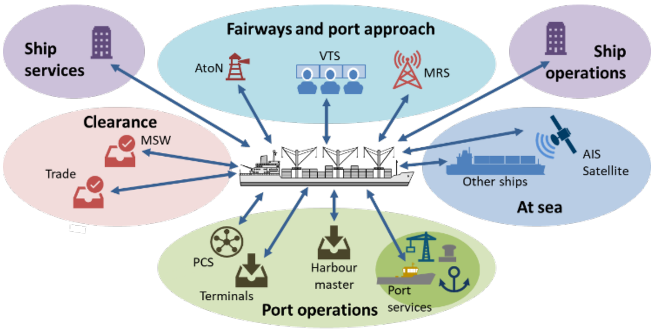

Figure 2. The Proposed Maritime ITS Domain [from [17]]

In addition to this definition, it may also be necessary to define the delimitation of the shore side extension of the domain. This delimitation is most relevant for the port and ship operations as these have significant interaction also with other shore side functions such as international trade and transport. This model is also preliminary as it may be extended, e.g. to ship building, repair and decommissioning.

2.2 *Maritime ITS Roles*

From the IMO FAL correspondence group on developing Guidelines on Electronic Signature Systems and Operational Port Data [1], we have the parties defined as described in Table 1. Each party represents a group of stakeholders fulfilling a certain role before, during and after the port call.

3 PROCESSES

Table 2 gives an overview of the tasks and processes needed to be performed by each role during a port call. The tasks are divided into the phases Marketing/Contracting, Planning, and Execution. This table is based on work done by the IMO FAL correspondence group on developing Guidelines on Electronic Signature Systems and Operational Port Data [1] and also on work done in the AEGIS project.

The Marketing/Contracting phase includes creating the contact between the stakeholders that have a need for transport or a service, and those who can offer transport and services that fulfil the demand. It consists of publishing the needs or offered services, establishing contact between the parties, agreeing on the terms of the service and the sale of the service. For container transport, this will take the form of a booking (carriage contract), meaning that information about the container handling must be agreed with the vessel and cargo service providers in the terminal. For bulk, this will involve chartering of a ship and deciding on which ports to call at for this type of bulk and the chosen ship (sale of goods contract). If there is no fixed contract with the terminal, this must be arranged with the vessel and cargo service providers in the terminal.

In the Planning phase, the transport and services are planned and managed based on actual and foreseen demands and information about the infrastructure and the traffic conditions. The planning includes decisions about

- Voyage/Passage planning
- Berth arrival planning, including VTS (Vessel Traffic Service)/pilotage area planning
- Port arrival planning, including VTS/pilotage area planning
- Vessel and cargo service planning
- Nautical service planning
- Request clearance
- Berth departure planning, including VTS/pilotage area planning
- Port departure planning, including VTS/pilotage area planning

Voyage/Passage Planning: According to SOLAS Chapter V Regulation 34, the master shall ensure that the intended voyage has been planned by using appropriate nautical charts and nautical publications. This is done based on nautical charts and publications from the hydrographic service provider, port information from the port planner, and berth information from the berth planner.

Berth planning arrival: The ETA Berth (Estimated Time of Arrival) is normally sent by the ship master to the ship agent by e-mail, which then forwards this to all parties ashore on behalf of the vessel [3]. More generally, the party having the role of the ship manager provides the ETA Berth to the berth planner, which decides on the RTA Berth (Requested Time of Arrival), and provides this back to the ship manager. If the ship manager accepts the RTA Berth, this becomes the PTA Berth (Planned Time of Arrival).

Port arrival planning: The vessel (via the ship manager role) advises the port planner on the ETA pilot boarding place based on the PTA berth. The port planner provides back a RTA pilot boarding place to the ship manager, which becomes the PTA pilot boarding place, if accepted.

Vessel and Cargo service planning: The timing and location of vessel and cargo services during the ship visit to a berth is very important to be able to complete all necessary services on time, before departure from the berth.

Nautical service planning: The ship manager role (eg. vessel or agent) orders nautical services from nautical service providers, like pilots, tugs and linesmen at a certain time before they are needed, to avoid financial consequences or unavailability at the time when the services are required.

Request clearance: The ship manager (e.g. ship agent on behalf of the ship master) requests clearance to enter the port, and the port authorities give clearance to a ship to call at a specific berth in the port. The port authorities forward the clearances to other authorities, as customs, immigration, and health. The timing of clearance is important; some are given prior to the port call (e.g. pre-arrival notification and health), while others are needed prior to the start of the operations (e.g. customs). Certain services also need to be reported to the authorities, for instance waste (due to MARPOL (The International Convention for the Prevention of Pollution from Ships (IMO))), bunkers, and vessel repairs (e.g. main engines).

Berth and Port Departure Planning: This involves similar information exchanges as for arrival planning.

Execution: The exchange of operational data during the port call includes times for actual arrivals and departures to and from port (pilot boarding place, VTS area) and berth, and the actual start time and completion time for vessel and cargo services performed during the port call.

Based on Table 2, relevant ICT functionalities related to nautical, operational, and administrative data are summarized in Table 3. The left-most columns list the typical functionalities that need ICT support, while the right-most column lists typical systems that cover the various functionalities.

Table 1 Port Call Parties from IMO FAL guideline on Electronic Signature Systems and Operational Port Data

Logical Party/Role	Description	Stakeholders (examples)
Authorities	Party that receives information related to the port call and provides clearance to the ship's arrival and departure	Harbour master, Customs, Immigration, Port health, Port VTIS, Coastguard
Berth planner	Party that plans the berth call	Terminal operator, Berth operator, Port authority, VTIS
Hydrographic service provider	Party that provides hydrographic data and all nautical information necessary for safe navigation during passage and berthing of the vessel	National hydrographic office, Regional charting agency
Nautical service provide	Party that provides nautical services to the ship	Pilots, Tugs, Linesmen, Boatmen, VTIS
Port planner	Party that plans the port call port	Port authority, Harbour master, Terminal operator, VTIS, Pilots, Coast guard
Ship agent	Party that represents the interests of the ship owner and/or charterer while the ship is at any port	Ship agent
Ship charterer	Person or company who hires a ship from a shipowner for a period of time	Ship charterer
Ship manager	Party responsible for the day-to-day management, operation and maintenance of the ship, handles authorities' reporting requirements, or other information requested by other parties	Shore side ship manager, or other party acting on behalf of the shore side ship manager: Port captain, Ship master or Ship agent
Ship operator	Party that decides how the ship is employed and where a vessel is to call	Ship charterer, Shipowner, Cargo owner/trader, Ship manager, Carrier, Parties representing/acting on behalf of before mentioned parties
Vessel or cargo service providers	Party that provides vessel services to the ship (bunkers, lube oil, potable water, provisions, stores, waste per IMO/MARPOL Class, repairs vetting, flag survey, periodic maintenance etc) or cargo services (cargo handling, cargo lashing, cargo survey etc).	Vessel or Cargo service providers

Table 2 Port Call Tasks for relevant parties

Party/Role	Marketing/Contracting	Planning	Execution
Authorities		Handle requests for clearance to port call, Forward notifications and declarations to other authorities, Forward declarations needed regarding certain services.	
Berth planner	Provide berth information to ship charterer	Provide berth information for voyage/passage planning, berth planning of arrivals, provide RTA Berth to ship manager during berth planning,	
Hydrographic service provider		Provide nautical charts and nautical publications for voyage/passage planning	
Nautical service providers		Plan safe and efficient port approach and port call	
Port planner	Provide port information to ship charterer	Provide port information for voyage/passage planning, Provide RTA pilot boarding place to ship manager, Provide RTD berth to ship manager	
Ship charterer	Contract for chartering ships		
Ship manager		Voyage/Passage Planning (IMO Res893(A21)), Provide ISPS information to berth planner and port planner. Provide ETD Berth from previous port for berth planning at the next port, Provide ETA Berth for berth planning, Accept RTA Berth (confirm PTA Berth), Provide ETA pilot boarding place to port planner, Accept RTA pilot boarding place (confirm PTA pilot boarding place),	Ship master notes ATA pilot boarding place in log book, ATA given by AIS, Provide ATA Berth, Provide ATD Berth, Provide ATD pilot boarding place.

		Request clearance for port call, Report on certain services, Order nautical services, Order vessel and cargo services, Set RTS of service based on ETS, Set RTC service based on ETC service, Provide ETD from current berth, Confirm PTD berth	
Ship operator	Carriage contract, Sale of goods contract	Contract for hiring terminal services,	Ship owner sends notice of readiness to ship charterer to confirm ATA pilot boarding place (for tramp shipping)
Vessel or cargo service providers		Provide ETS for vessel or cargo services, Confirm PTS for service, Provide ETC service to ship manager, Confirm PTC service.	Provide ATS service, Provide ATC service

Table 3. ICT Functions for Port Calls

ICT Functions	Systems
Nautical functions	
Provide nautical charts and nautical publications for voyage/passage planning	ECDIS
Plan safe and efficient port approach and port call	ECDIS, VTIS
Booking of nautical services (e.g. pilots, tugs, linesmen, boatmen)	VTIS, PMIS,MSW
Operational functions	
Provide berth information for voyage/ passage planning,	PCS, TOS
Provide port information for voyage/ passage planning,	PCS, PMIS
Port planning at arrival (exchange ETA, RTA, PTA for pilot boarding place)	PCS, PMIS
Berth planning at arrival (exchange ETA, RTA, PTA for berth)	PCS, TOS
Berth planning at departure (exchange ETD, RTD, PTD for berth)	PCS, TOS
Port planning at departure (exchange ETD, RTD, PTD for pilot boarding place)	PCS, PMIS
Booking of vessel and cargo services	PCS, TOS, PMIS
Cargo manifest: Generate import & export cargo manifest	PCS, TOS
Hazardous cargo declaration	PCS, TOS
Payments and invoices	PCS, PMIS
Administrative functions	
Handle requests for ship clearance to port call,	PCS, PMIS, MSW
Report on certain vessel/cargo services	PCS, PMIS, MSW
Forward notifications and declarations to relevant authorities,	PCS, PMIS, MSW
Forward declarations needed regarding certain services.	PCS, PMIS, MSW
Port state reporting/reporting to MSW	PCS, PMIS, MSW
Crew/passenger reporting	PCS, PMIS, MSW
Handle ISPS information	PCS, PMIS, MSW

4 INFORMATION MODEL

The data that is needed for the planning and execution of a port call can be divided into Nautical data, Administrative Data, and Operational Data [1].

4.1 *Nautical Data*

Nautical data is data that is provided by Hydrographic Offices in electronic navigational charts (ENC), nautical publications (sailing directions), coast pilots, and tide tables [1]. They are used for safe navigation during the port approach and also in port basins and waterways. The challenge with nautical data in ports is that different data sources use different datums, which make them difficult to compare. Also, the vessel and cargo service providers may not use the same geographical information to describe the location of their services, meaning that the navigation in the port area may be unclear. [2] gives testimonials from operational people regarding this: In most ports the berth is not identified in the nautical chart. Frequently, the berth is not displayed at all, and sometimes even the port is not displayed. Often the identification of the terminals and berths in the ENC is different from the sailing directions or other publications.

4.2 *Administrative Data*

Administrative data is data that is submitted by ships or other non-authority parties to authorities in notifications and declarations [1]. Administrative data is based on legislation or regulations. This data can normally be shared between the authorities covered by the relevant regulations, but normally not with others. Administrative data is typically provided by the ship manager role to the authority role, Table 1. A good overview of administrative data is given in the IMO Reference Data model, based on the IMO FAL Compendium (see Section 4.1). This reference data model contains harmonized data elements required to be exchanged during arrival, stay, and departure of the ship, and includes information about crew, passengers and cargo. This means that IMO reference data model is an important starting point for the implementation of the digital data exchange done through the national single windows that will be mandatory from January 1st 2024 as decided by IMO FAL 46.

4.3 *Operational Data*

Operational data is data that is submitted to non-authority parties as part of planning and execution of certain operations during a port call [1]. Operational data can normally not be shared with other parties. This data is typically provided by the ship manager role in collaboration with the port planner, berth planner and vessel and cargo service providers. To be able to cover the overlap between administrative and operational data, the IMO reference data model has been extended with data sets for operational data, that goes beyond the IMO FAL regulations. The most important data set is the one for just in time port calls, covering definitions of arrival and departure times to pilot boarding places and berths, and the starting and completion times for vessel and cargo services. Also, the IMO Reference data model covers the concepts of locations in ports, namely the description of the location for berths, terminals, pilot boarding places, ISPS facilities, and vessel and cargo services. In this regard, the IMO Reference model is closely related to the IHO standard S-131, and work has begun through the IMO group EGDH (Expert Group on Data Harmonization) to harmonize these data elements.

5 STANDARDS FOR PORT CALL DATA EXCHANGE

5.1 *IMO Reference Model*

At their 43rd Plenary meeting in April 2019, the IMO FAL Committee approved the revised and updated IMO Compendium on Facilitation and Electronic Business, to support harmonization and standardization of electronic messages for exchange of information when ships arrive at and depart from ports. This covers mandatory reporting formalities for ships, cargo and persons as defined by the following by IMO:

- All FAL standard declarations (FAL 1 to 7) as defined in the IMO FAL Convention:
  - General Declaration;
  - Cargo Declaration;
  - Ship's Stores Declaration;
  - Crew's Effects Declaration;
  - Crew List;
  - Passenger List;
  - Dangerous Goods Manifest;
- Security-related information as required under SOLAS regulation XI-2/9.2.2 (ISPS)
- Advance Notification for Waste Delivery to Port Reception Facilities; and
- WHO Maritime Declaration of Health (FAL 43/INF.3)

This is related to the mandatory requirement in the FAL Convention saying that national governments must introduce electronic information exchange between ships and ports, from April 2019. In the revised Compendium , an updated IMO Data Set identifies and defines all data elements related to this reporting information requirements, and the underlying hierarchical data structure is described in the IMO Reference Data Model.

The IMO Reference Data Model (RDM) and the IMO Data Set give a conceptual model of the ship-shore authority reporting requirements. This model supports the semantic harmonization between the various reporting requirements and relevant international standards from various domains related to ship-shore reporting. The IMO Data Set is mapped to three different technical standards, namely to the customs domain (the World Customs Organization (WCO) data model), the trade domain (the United Nations Economic Commission for Europe (UNECE/UNCEFACT) Core Component library) and the standard for electronic port clearance (ISO TC8's 28005 standard). This harmonized list of data elements and the related reference data model, together with the mapping to the technical standards (WCO, UNECE and ISO 28005), support the interoperability among maritime single window systems.

The IMO Reference data model and data set are maintained by IMO through EGDH . The current compendium was approved by IMO FAL 47 March 2023 and the following data sets has been added after the initial version:

- Port logistic operational data related to just-in-time concept (FAL 43/INF.3).
- Stowaways according to the FAL Convention, Recommended Practice 4.6.2
- Ship and Company certificates according to FAL.2/circ.131 covering requirements from IACS Rec.75
- Acknowledgement receipts (FAL 44/7)
- Maritime Services
- Ship Registry and Company Details
- Inspections
- PCS Inspection History Data
- Maritime Reporting Scheme (MRS): All general ship reporting requirements as defined in IMO Resolution A.851.
- Ballast water arrival reporting
- Waste delivery receipt
- Advanced Passenger Information
- Verified Gross Mass

The just in time data set is especially important when it comes to covering operational data and to ensure a clear overlap between administrative, operational and nautical data. This is needed for the IMO RDM to be a conceptual model that can be used across several reporting schemes and domains to ensure interoperability among systems and improved information exchange in addition to reduced administrative burden for maritime transport stakeholders. More data sets are to be included, for instance for ship particulars (IMO Safety information), for noon reporting, and others. Note that the IMO RDM is not a new standard but rather a tool to harmonize existing standards across various domains and systems.

5.2 *ISO 28005 on Electronic Port Clearance*

The ISO 28005-series of standards maintained by ISO/TC8/SC11/WG2 Maritime operational data model contains data elements to cover the requirements for ship-to-shore and shore-to-ship reporting of authority information as defined in the following:

- Most required information sets as defined in the FAL Convention to be sent at arrival or departure:
  - General Declaration (FAL Form 1)
  - Cargo Declaration (FAL Form 2)
  - Ship’s Stores Declaration (FAL Form 3)
  - Crew’s Effects Declaration (FAL Form 4)

  - Crew List (FAL Form 5)
  - Passenger List (FAL Form 6)
  - Dangerous Goods Manifest (FAL Form 7)
- The document required under the Universal Postal Convention for mail (a reference to the physical or electronic document)
- Maritime Declaration of Health as based on the Maritime Declaration of Health (MDH) from WHO, 58th World Health Assembly, WHA58.3.
- Security-related information as required under SOLAS regulation XI-2/9.2.2 (ISPS code).
- Advanced electronic cargo information for customs risk assessment purposes
- Advanced Notification Form for Waste Delivery to Port Reception Facilities, based on the recommended reporting on ship-generated waste as defined in MEPC 644, which is mandatory within the European Union, as described in EU/2000/59.
- Required reporting as defined in the bulk loading and unloading code IMO Resolution A.862.
- Mandatory ship reporting system (MRS) requirements as defined in IMO Resolution A.851.
- ETA reporting to pilot station as defined in IMO Resolution A.960.
- All data sets contained in the IMO Reference Data Model

The information is described as XML types in an XSD and also as classes in UML diagrams. The ISO 28005 standard (Part 1) describes messages and the protocol for how to exchange these different messages, including clearance, update, cancellation, receipt and acknowledgement messages. The ISO 28005 series of standards was first defined in 2011 with a second version in 2021. This version contains a mapping to the IMO Reference Data Model and cover all data elements as approved by IMO in FAL 44 in Sept/Oct 2020 . An updated version of Part 1 plus a new Part 3 covering the remaining data sets contained in the IMO Reference Data Model up till FAL47 are due in 2023.

5.3 *IHO S-131 Standard*

IHO is developing the S-131 Marine Harbour Infrastructure product specification together with the International Harbour Master Association (IHMA). Some of the data elements for berth, berth position and terminal have commonalities with the IMO FAL Compendium:
- Berth: terminal ID and port facility Number and port facility LOCODE (for ISPS) are common.
- Berth Position is described by: Port facility number and port facility LOCODE (for ISPS)
- Terminal is described by: Port Facility Number, Port Facility LOCODE, Terminal ID.

6 PORT CALL ICT SYSTEMS

The IMO FAL correspondence group on developing Guidelines on Electronic Signature Systems and Operational Port Data for the Purpose of Digital Information Exchange [1] mentions the following ICT systems as playing an important role during a port call, see Figure 3. This section will further describe these systems.

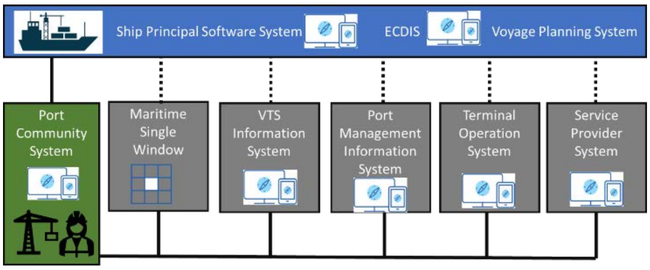

Figure 3. ICT Systems Overview for Port Calls [from [4]]

Table 4 lists typical users for various port ICT systems.

Table 4. Users for Port ICT Systems

ICT System	Users
Port Community Systems (PCS)	Ship Manager, Other systems (TOS, VTIS, PMIS, MSW, SPS, SPSWS)
Terminal Operating Systems (TOS)	Berth planner
VTS Information Systems (VTIS)	Nautical service provider, VTS Operators, Coast state authorities
Electronic Chart Display Information System (ECDIS)	Ship crew, Hydrographic service provider
Port Management Information Systems (PMIS)	Port planner, Port Authority, Vessel and cargo service provider, Harbour master, MSW, berth planner
Voyage Planning Systems	Ship manager, Ship crew
Maritime Single Window (MSW)	Port State Authorities
Service Provider Systems (SPS)	Vessel and cargo service provider
Ship Principal Software Systems (SPSWS)	Ship Manager

6.1 *Port Community Systems (PCS)*

A Port Community System (PCS) is an ICT system used to facilitate communication, coordination, and collaboration among all parties involved in port and logistics operations during a port call, typically with the following functionalities:
- Provide real-time data on vessel movements and cargo status,
- Automate administrative processes, such as document processing, invoicing, and payment,
- Track cargo movements,
- Ensure regulatory compliance.

Figure 3 shows that a PCS can be viewed as the portal to all the different ICT systems in the port. The user of the PCS is then the ship manager role. For ports that do not have a PCS, the port users will access each of the different ICT systems in the port directly. To generalise this, the term "PCS" can be used as a generic name for an ICT system in the port [1].

Several different types of PCSs exist, from small to large systems, from systems covering only port operation to systems also operating as a national MSW. The IMO FAL committee (FAL 48 in 2024) is working on guidance for PCS especially to be able to draw the line and responsibilities between PCSs and

MSWs, and at the same time ensure the reporting only once principle related to the port call. In the IMO MSW guidelines, it is opened up for MSWs to extend beyond authority reporting: MSW should be considered as a technology neutral and trustworthy platform for public private data collaboration to expand its scope beyond regulatory framework to include nautical and operational information and data as a best practice for trade agnostic port call automation [4].

IPCSA (International Port Community Systems Association) defines PCS as follows [5]: A Port Community System Is a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders in order to improve the efficiency and competitive position of the sea and airports' communities. A PCS optimises, manages and automates smooth port and logistics processes through a single submission of data and by connecting transport and logistics chains.

[6] describes PCS as "an electronic platform that connects the multiple systems operated by a variety of organisations that make up a seaport or airport community. It is shared in the sense that it is set up, organised and used by firms in the same sector – in this case, a port community. A good collaboration between all the parties involved is one of the success factors of a PCS. Distinctive for all PCSs is the link to Customs and port authorities and other institutions such as veterinary offices or coastguard, for example." The most important users of a PCS are typically shipping lines and freight forwarders, but cargo importers and exporters in general, and customs and shipping agents are important users. Typical functionalities of PCSs are [6]:

- Customs declarations
- Electronic handling of all information regarding import and export of containerised, general and bulk cargo
- Status information and control, tracking and tracing through the whole logistics chain
- Processing of dangerous goods
- Processing of maritime and other statistics

[7] also recognizes the role that a PCS can have as being a National Single Window (MSW) or as a system that are integrated into a National Single Window, for instance as a Safe Sea Net-node .

[6] recognizes that (national) single window systems cover the information flow G2G and G2B, while business to business data flow is covered by the PCS.

[6] describes the relation between a PCS and a national Single Window system as the following: A PCS can work as a portal or gateway to a national single window or can be an integral part of a single window. Other possibilities are a simple information flow from the national single window to the PCS, for instance regarding notification of port calls. As the port calls may often be known to the PCS before it is known to the national single window, this information flow may also be the other way, from PCS to the NSW. Further, PCSs can support B2B information exchange as well as being a portal for B2G information exchange.

6.2 *Terminal Operating Systems (TOS)*

A Terminal Operating System (TOS) is an ICT system that manages and controls the operations of a maritime terminal to optimize the use of resources (berths, cranes, yard equipment) to ensure that vessels are loaded and unloaded efficiently, including:

- Vessel planning and scheduling, including berth and crane allocations,
- Coordinating the movement of containers, cargo, and equipment,
- Create discharge and loading lists, often based on EDI messages received from third party stakeholders, that is, from cargo owners or forwarders or cargo agents,
- Yard space and equipment (cranes, trucks etc) planning,
- Real-time data on cargo, containers, and equipment,
- Manage container inventories,
- Tracking the movement of containers.

Several ICT systems are used to support the operations of a terminal. One of the most important is a Terminal Operation System (TOS). The TOS provides visibility, control, optimization, scheduling, planning, analytics, and automated handling of maritime containers, rail containers, and break bulk for terminal operations. The terminal is a trans-shipment point for the cargo, meaning that the cargo will switch to a different transport mode or will be consolidated. A TOS should support the main transactions in the trans-shipment between sea and hinterland transport, namely loading and discharge of cargo to and from a ship and gate-in/gate-out to/from land-based transport. Keeping track of carrier equipment, e.g. multimodal containers, and cargo is essential for efficient processing of cargo. A TOS typically enables management and operators to administrate containers and cargo positions on the terminal yard.

An example of a TOS is Terminal by Grieg Connect, which enables the operation manager to create discharge and loading lists based on EDIs received from third party stakeholders, that is, from cargo owners or forwarders or cargo agents. Further, the yard state is managed in Terminal through internal cargo transactions, termed as moves within the system. An internal move transaction represents a positional change from one position in the yard to another. There may be multiple ways of modelling positions within a yard, either by modelling a position in a grid-like system where each cell denotes a stack of containers of a certain size or by exact positioning through geo-spatial data.

There are also other relevant internal transactions that may be managed in a TOS, such as stuffing and stripping carrier equipment. Stuffing involves filling the container with cargo and stripping the reverse operation, taking cargo out.

A TOS typically enables external stakeholders, such as the container owner or the container leaser, to order actions on a container through EDI interchange. This may be ordering the terminal to release an empty container from a terminal depot to be picked up by transport or ordering stuffing of a certain container.

6.2.1 *Plan cargo operations*

The terminal needs to plan and execute operations related to cargo transactions, for instance planning a discharge or loading operation from/to a ship to/from the terminal yard. This involves exchanging data with the ship manager regarding how the cargo is stowed (bay plan/stowage plan), instructions on equipment needed to do the discharging/loading, and instructions on the discharge/loading order.

6.2.2 *Users*

The main user groups for the core TOS functionality related to cargo movements, cargo management and cargo operations are the terminal management fulfilling the Cargo service provider role.

6.2.3 *Integration with and interfaces to other systems*

In general, integration with third party systems from stakeholders such as the shipping company or customs is done either through EDI interchange or public API-based interaction. The synchronisation of data related to container transactions are mainly based on EDI messages according to UN/EDIFACT container message standards maintained and issued by International Transport Implementation Guidelines Group (ITIGG).

6.2.4 *Customs*

Although the UN/EDIFACT container messages support EDI interchange of customs-related information through the CUSCAR format, some governments also provide self-service systems and/or service-oriented solutions/integration points for usage in the customs clearance process. An example from Norway is the TVINN self-service system.

6.2.5 *General purpose container transaction and tracking systems*

In 2018, Maersk partnered with IBM to create TradeLens, a platform for sharing and streamlining shipping information across shipping partners, businesses, and different authorities . TradeLens is an example of a system developed by two major global corporations as a tool to support and centralise data related to global sea freight cargo supply chain transactions. By 2019, the platform covered nearly half of the world's shipments of cargo containers.

6.3 *VTS Information Systems (VTIS)*

A VTS (Vessel Traffic Service) Information System is an ICT system used to monitor and manage vessel traffic in a specific area, such as a port, harbour, or waterway, including the following tasks:

– provide real-time information on vessel positions, movements, and headings.
– Providing navigational assistance to vessels, including information on hazards, and weather
– Coordinating vessel traffic, including vessel routing and allocation of anchorages and berths.
– Responding to emergency situations, such as search and rescue operations, and coordinating with other emergency services.
– Collecting and sharing data on vessel movements and incidents with other stakeholders, including port authorities, shipping companies, and government agencies.
– Managing communication between vessels, port authorities, and other stakeholders, using various communication channels, such as VHF radio, email, and satellite.

6.4 *Port Management Information Systems (PMIS)*

A Port Management Information System (PMIS) is an ICT system used to manage and optimize the operations of a port or terminal, including tasks as:

– Managing and tracking the movement of cargo, vessels, and other resources
– Managing and monitoring the use of infrastructure, such as berths, cranes, and yard equipment
– Providing real-time data on the status of cargo, vessels, and other resources
– Invoicing, billing, and resource allocation.

An example of a PMIS is Port, which is developed by Grieg Connect for efficient planning and management of port calls and the related services and cargo. During port call execution, the plan is adjusted when changes occur. The execution process consists of the different activities involved in serving the ship in port while in the completion phase, port call relevant information is collected before the port call is invoiced. The users of Port typically have the port planner role, when planning the port calls and related services, and doing invoicing afterwards, or they can also have the role of a vessel or cargo service provider both when handling service delivery and collecting data that is relevant for invoicing and documentation purposes.

6.4.1 *Planning*

In the planning phase, information about port calls is received from logistics providers and agents either through the maritime single window (MSW) or by email and telephone. SafeSeaNet Norway (SSN) is the MSW system developed by The Norwegian Coastal Administration for reporting and distribution of all relevant information regarding shipping to Norwegian authorities (https://www.kystverket.no/en/sea-transport-and-ports/safeseanet-norway/). Port has also integration with a corresponding solution (Portnet) for Finish ports. The deadline for reporting in SSN is 24 hours prior to arrival and ships less than 300 gross ton is exempted from reporting. Some port calls are therefore manually entered in the port system. Port receives port call information from the MSW including ship information, ETA, ETD, preferred quay, arrival draught, crew, passenger data, and requested services. The port planner in the port system processes the requests and check for available capacity.

6.4.2 *Berth planning*

Port contains a berth planning tool that gives the berth planner a good overview of the quay assignments both in a Gantt-view and on a map with detailed positions, which is used by the planner to check for available capacities at the quays. If there is sufficient capacity and the ship satisfies the ISPS-requirements, the berth planner approves the request in Port and an acceptance message is automatically sent back to the MSW. The planner can also propose a different quay than requested or reject the request if there is no available capacity.

6.5 *Maritime Single Window (MSW)*

6.5.1 *Background*

A Single Window (SW) system is defined in the UN/CEFACT Recommendation 33 as "a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single-entry point to fulfil all import, export, and transit-related regulatory requirements. If information is electronic, then individual data elements should only be submitted once". [6]

Usually, Single Window systems for maritime applications (MSW) cover both private and public information exchange. The other distinction between MSWs is whether they cover both nautical information and cargo/trade information. For implementation of these standards, the IMO has developed guidelines for setting up a maritime single window in FAL 5/Circ. 42, 16 May 2019.

6.5.2 *MSW Regulations from IMO*

IMO, during FAL 46 in May 2022, decided that the amendments to the IMO Facilitation (FAL) Convention should enter into force from 1st of January 2024. These amendments require signatories to the Convention to implement an electronic maritime single window for all declarations made by a ship in conjunction with international port calls. Also, FAL 45 approved the revised Guidelines for setting up a maritime single window (FAL.5/Circ.42/Rev.1) to ensure a common understanding of the machine-to-machine communication related to ship calls. The IMO Reference Model (Section 4.1) describes the information exchange related to this MSW.

6.5.3 *EMSWe*

The EMSWe (European Maritime Single Window environment) is the legal and technical framework for the electronic transmission of information about reporting obligations for ships calling at EU ports. It is a network of national MSWs using the SafeSeaNet systems and other systems. The data model is aligned with the IMO Reference Model with additional data sets for local legislations.

6.6 *Ship Side Systems*

The ship side systems include ECDIS, Voyage Planning Systems, and Ship Principal Software Systems. Onboard systems are used by the ship crew, on shore systems are used by a stakeholder having the ship manager role.

6.6.1 *ECDIS*

An Electronic Chart Display and Information System (ECDIS) is an onboard navigation system ships to display navigational information from electronic navigational charts (ENCs) and to assist in route planning and navigation. ECDIS currently follows The ECDIS performance standard states that from 2029, new ECDIS systems must follow the new S-101 standard contained in the S-100 framework, instead of the old S-57. This will also introduce the possibility to add several layers of information, including the S-421 standard for route exchange, S-131 for marine harbour infrastructure and other standards. This also highlights the importance of aligning the IMO Reference model with the S-100 framework, especially the GI (Geographical Information) concept register.

6.6.2 *Voyage Planning Systems*

A Voyage Planning System (VPS) is an ICT system used by ship operators and navigators to plan and optimize a vessel's route for a particular voyage. An example of this is the NavStation by Navtor.

7 MARITIME INTELLIGENT TRANSPORT SYSTEMS (ITS) ARCHITECTURE

7.1.1 *MITS Architecture*

A Maritime Intelligent Transport System (ITS) Architecture can be based on the definitions of roles, functions and systems as described in this paper. In addition to this comes the description of the connection between Road ITS and Maritime ITS, and also how the Maritime ITS architecture relates to e-Navigation functionalities, Figure 4.

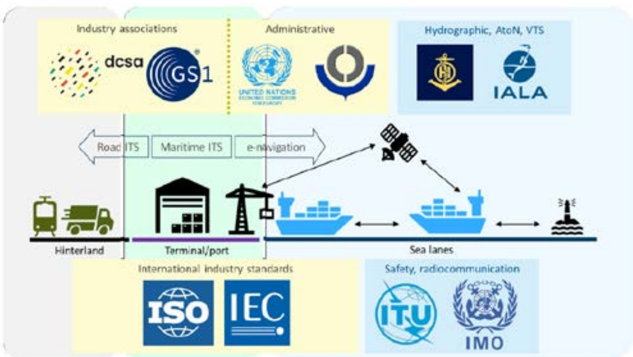

Figure 4. Maritime ITS Big Picture

7.1.2 *Players in International Standardization*

IMO is an important player in the standardization work as it maintains the IMO Reference Data Model through its Expert Group on Data Harmonization (EGDH) in the Facilitation committee (FAL). Also important is the agreement between IMO, ISO, UN/ECE and WCO on the maintenance of the IMO Reference Data Model and the updating of the mappings from the reference model to the three technical standards maintained by ISO, WCO, and UN/ECE. Further, IHO is important as they are responsible for the S-100 framework of standards, and they have also started harmonization with the IMO Reference Data Model. Also, several organizations are active in giving input on new and updated data sets to the IMO Reference Data model, for instance BIMCO, which is the world's largest direct-membership organisation for shipowners, charterers, shipbrokers and agents, IAPH (International Association of Ports and Harbours), ITPCO (International Task Force on Port Call Optimization), IPCSA (International Port Community Systems Association) and DCSA (Digital Container Shipping Association).

8 CONCLUSIONS

Harmonization of data sets are important for those parts that are overlapping between several domains, that is, between the nautical, administrative, and operational domains. As an example, when referring to arrival and departure times for a ship to a berth (in the operational domain), the same references should be used for administrative data: If the terminal plans for a ship to arrive at a berth at a certain time, that same time is equally important for both port authorities and port operational parties, for instance vessel service providers (e.g. pilots, bunker barges).

To achieve interoperability between ships and shore ICT systems, not only the introduction and usage of standards covering the data requirements are needed, but also more technical standards for the machine-to-machine interaction, for instance defining Application Programming Interfaces (API) and other common reporting protocols covering electronic data exchange. However, neither the IMO FAL Convention nor the IMO guidelines for setting up a maritime single window specify specific technical standards for the interface between ships and the MSW. This means that a technical specification of the ship-shore communication related to port call must be specified, which is what is done for instance in the ISO 28805 standard on Electronic Port Clearance.

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