1 Introduction

Shipping serves the trade patterns of the world with a mixture of short-sea shipping feeding larger vessels transiting the oceans (Fig. 1). Short-sea shipping (Lind, Michaelides, Ward, Herodotou, & Watson, 2019a; Michaelides, Herodotou, Lind,
Over the coming years, organisations involved in the maritime logistics chain will continue to look for ways to innovate their business models. These will inevitably involve digital technologies. So, for most, the next wave of innovation will come from turning their attention outward into the business ecosystem of digital communications and information exchange with customers, partners, suppliers and other actors to create new services, products and experiences. See also Lind, Ward, Bergmann, Haraldson, and Zerem (2019b).

For many ports, there is limited anchorage space outside the port, and the absence of a “port line-up” system in previous and next ports reduces the ability for terminals and carriers to increase efficiency and deliver customer satisfaction. In some ports, tanker terminals are operated by different operators, which often results in low flexibility and longer wait time, partially also due to the lack of data sharing among them. Terminals, berths, shippers and carriers tend to work in silos without either long-term, near-time, or real-time sharing of scheduling data. This often is a cause of knock-on effect delays. This inherently inefficient type of port call regime leaves the maritime network in a very difficult and unpredictable position to deliver its resources optimally.

Enhanced collaboration and instant data sharing among stakeholders within and outside the port, leading to synchronisation, coordination and harmonisation of maritime operations associated with the tanker industry, are now beginning to appear. The Port Collaborative Decision Making (PortCDM) concepts, as developed by the

\[\text{https://ec.europa.eu/eurostat/statistics-explained/index.php/Maritime_transport_statistics_-_short_sea_shipping_of_goods#Total_short_sea_shipping}\]
Research Institutes of Sweden (RISE) and tested in the Sea Traffic Management (STM) validation project\(^2\), can bring benefit to all types of trade—not just dry and liquid bulk cargo transport. Recent proposals presented to the International Maritime Organization (IMO) by the Baltic and International Maritime Council (BIMCO) relating to the easier exchange of data and just-in-time arrivals are further examples.

2 Different Types of Trade and Different Business Models

2.1 Container Traffic and Liner Services

Container traffic mostly follows a predefined pattern of scheduled and recurrent visits. It is arranged as a liner service (like a scheduled bus or an underground metro service) where different stakeholders plan their operations in relation to a fixed and repeating schedule. This schedule may be revised periodically or seasonally. This follows a similar concept to passenger traffic in aviation—with a predictable and fixed schedule and travel plan covering the present and the medium-term future. Unlike in air transport, which is mostly between two airports, containerised liner shipping services usually call at several ports during the same service.

This means that the port call actors can expect that a ship (or ships from a shipping company) will arrive at particular time intervals and can prepare for that accordingly. In reality though, maintaining punctual ship arrivals in accordance with the pre-set schedule is sometimes hard to achieve, not because ships have difficulties in making their sea passages but resulting from delays in upstream ports making it hard or impossible for a ship to make its next port call on time. This is especially the case for short-sea shipping arrivals or when ships require repositioning in a port after cargo operations in one terminal prior to further work in another.

Many of the largest container shipping companies, such as Maersk, MSC, CMA/CGM, and Hapag-Lloyd, also own terminal facilities (e.g. the Maersk-owned APM terminals) and may operate in different alliances. These alliances can then have the effect of blocking others in making optimal or desired port calls if the relevant shipping company is not part of the same alliance as the terminal operator. Chinese shipping companies, such as China Ocean Shipping Company (COSCO), are also involved in investing in seaports, including in the context of China’s Belt and Road Initiative, or more specifically the Maritime Silk Road part of this initiative\(^3\).

Recent years have seen the introduction of super large container ships carrying up to 24,000 containers. However, confronted with physical limitations in ports and access channels, combined with changes in global trading patterns, their size may

\(^2\)https://www.stmvalidation.eu

\(^3\)https://www.forbes.com/sites/wadeshepard/2017/09/06/chinas-seaport-shopping-spree-whats-happening-as-the-worlds-ports-keep-going-to-china/#1cfb78b14e9d
have peaked, as reflected by the reduction in global order books for these super large vessels.

2.2 The Dry and Liquid Bulk Industry and Irregular, Often Short-Notice Port Calls

The dry and liquid bulk sea transport sector operates most times as a tramp service (more like a taxi or charter bus than a scheduled bus or metro service) with fixed, semi-fixed or flexible routes and without a predetermined timetable. Ships may be engaged on either a voyage or a time charter basis.

A voyage charter means that the charterer pays a fixed price for the carriage of specific goods from one port to another, with the ship operator carrying the risks and expense for any delays or diversions caused by such things as weather, strikes, or variations in the cost of bunkers (fuel). For a time charter, the charterer in effect takes a lease on the operation of a ship for a certain period and, with it, the risks and costs of any late-notice variations in a number of the operating expenses. In either case, this leads to unpredictable and short-notice port visits because at least one of the charter parties is always seeking to minimise or avoid the impact of the mostly unpredictable and variable short-notice changes in voyage expenses.

The tanker industry in particular is governed by freight contracts made by traders who often decide the load date and destinations based on diverse factors and in particular fluctuating cargo-oil prices. Due to the fluctuations in prices and availability, there are often very late changes of schedule, which puts pressure on port call actors and their resources to respond on time and still preserve the financial and environmental benefits for all involved. Some of the liquid bulk cargoes are actually traded while the ship is on passage, and the new cargo owner may then reroute the ship to a new destination.

2.3 RORO Trade and the Need for Detailed Tracking and Scheduling

The so-called RORO (roll-on/roll-off) trade is the maritime part of the dual-modal transport mechanism of road-ship-road. At the port of origin, motor vehicles drive on the ship (roll-on), and in the destination, they drive off the ship again (roll-off). The RORO concept is intended to reduce cargo handling as the cargo does not leave the land carriage vehicle, and, as such, dismounting of such things as containers or other bulky items for loading and remounting at the port of arrival is not necessary. This method also avoids individual storage and rearrangement of cargo. RORO includes “unaccompanied trailer transport”. Here the trailers of a truck are positioned on a cargo vessel, but the tractor units and drivers do not travel with
the ship. With unaccompanied trailer transport, another tractor unit meets the ship on arrival, or the next modal transport could be a train, where the unaccompanied trailers are carried further on as part of a multimodal transport chain. RORO vessels normally follow the same regime as container shipping by following a fixed liner schedule.\(^4\) The complexity of this highly integrated dual or multimodal transport needs careful and detailed planning and coordination for optimal results to be achieved. This sector is also quite concentrated, with a few shipping companies including common names such as Wallenius Wilhelmsen, Stena and Grimaldi dominating the supply. RORO is also used for the bulk import and export of new motor vehicles. For larger RORO ships, dedicated parking and assembly points are required in ports to manage and synchronise vehicle loading movements.

### 2.4 The Cruise Industry and Its Long-Term Planning of Port Visits

Presently there are about 390 cruise ships in operation globally, and there are 120 more on the order books with no reported plans for taking any of the existing ships out of service,\(^5\) though this can now be expected to change in view of the Covid-19 pandemic. There are several dominant shipowners, such as Carnival Cruise Line and Royal Caribbean International, together having up to 70% of the market passenger wise.\(^6\)

Seen from a port’s point of view, a cruise (port) call is most often initiated two to three years in advance to settle everything that is related to the port visit. The proposed timetable is then used to assign different locations within the port to enable possible parallel cruise calls at the same time. In a popular cruise destination, there is a desire to manage as many cruise calls as possible during the season. A challenge, however, is coordinating a number of calls on the same day; any deviations of a cruise ship’s arrival and departure times will influence excursion options as well as passengers joining or leaving the ship.

As the cruise season approaches, contracts related to passenger excursions, linesmen, security and third-party service providers are settled and then planned precisely by the port, agent and cruise line. Cruise lines do not want anything to go wrong and thereby fail to meet the expectations of their passengers. Cruise excursions, for example, require high levels of coordination and understanding of the current situation to function well. This enables cruise ship passengers to schedule their excursions precisely.

Even though actors have an individual focus on delivering their services, there is a need for joint delivery from all actors for a successful cruise call. In order to

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\(^4\)https://www.marineinsight.com/types-of-ships/what-are-ro-ro-ships/
\(^5\)https://www.cruiseindustrynews.com/cruise-news/cruise-ship-orderbook.html
\(^6\)https://cruisemarketwatch.com/market-share/
provide a high-quality joint delivery, actors must know and understand all involved parties’ plans and outcomes and their role in making a cruise call a success for each passenger (Lind et al., 2018b).

Disruptions can happen, such as a local tour operator missing a return deadline for passengers returning to their ship. In most cases, when tours are delayed, then the departure of a cruise ship is delayed, which can then have consequences for other ships in the area, including other cruise ships. There might be several cruise ships arriving on the same day, having the same types of needs for services, physical infrastructure and sea passages. Unplanned changes can cause serious delays, bottlenecks or cancellations, which then requires replanning and execution. In the worst case, the passenger experience is inferior or non-existent.

2.5 The Need for Collaboration and Digital Data Sharing
Independent of Trade

As many ports use the container ship or other dominant trade scheduling models as their foundational base for planning, other nonrecurrent visits are then left to fit around the basic plan based on the predominating ships. This exposes an obvious need to provide a more flexible system that provides sufficient information to allow ports to plan, optimise and execute port visits, independent of the type of trade. The PortCDM concepts and the port call optimisation principles laid out by the International Taskforce on Port Call Optimization (ITPCO) have been developed specifically to address this problem.

In the future, there will be an enhanced data stream originating from many different sources, where ship-to-port collaboration becomes increasingly more synchronised. Upstream ports will provide information to downstream ports, where many more physical objects (down to the level of containers, bollards, etc.) are digitally twinned, allowing for remote data streams to be generated and kept up to date with minimal human intervention. All of this requires standards for data sharing, such as the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) standard S-211 Port Call Message standard. The Electronic Product Code Information Services (EPCIS) standard that enable data exchange and the sharing of time stamp data ship-to-port, port-to-ship, port-to-port, as well as port actor-to-port actor is another example. S-211 is part of the S-100 family of data exchange standards that underpin the IMO Common Maritime Data Structure (CMDS). The S-100 standards, in turn, are based on the ISO 19100 series of geographic information standards.7 EPCIS is a standard used for exchanging event information among supply chain partners across all modes of transport and is also an official ISO standard (ISO/IEC 19987).

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7 https://www.ipcdmc.org/standards-and-guidelines
Enhanced information sharing, especially regarding the crucial parameters of estimated time of arrival and estimated time of departure, as well as estimated time of operations commencing and completing, is necessary to enable any optimisation effort before a vessel visits a port. This is key to satisfying all port actors, including terminal operators and shipping lines, and it is also relevant to hinterland operators and the final recipient of the cargo (the consignee).

There are different types of challenges that need to be handled in relation to the different types of trade and its shipping services, for example, liner versus tramp services. Independent of trade, there is also a need for enhanced collaboration and data sharing within ports and along the maritime transport chains providing each of the participants with up-to-date real-time information.

3 The Ports of the World and the Complexity of Port Call Operations

3.1 The Ports of the World

There are close to 100,000 commercial ships [>100 gross tonnage (GT)]. The ones that are above 1000 GT conduct about 4.1 million port visits per year, and the figure for the amount of port calls made to several thousands of active ports in the world if all commercial ships are taken into consideration is very much higher. These ports are arranged in structures of feeder ports and transhipment hubs. Some of the major ports of the world desire to become the gateway into their particular region (such as the Port of Rotterdam into Europe), which both drives competition and also heavy investment in hinterland connectivity.

As physical infrastructures are costly long-term investments, it is highly essential for high-throughput ports to secure sufficient traffic to profit from their investments. For ports, this is highly sensitive because the decision for a shipping company to alter its destination is relatively easy, while relocating the physical infrastructure of a port is costly. This has driven ports to specialise in different segments, such as establishing advanced capabilities for managing containers, providing services that add value to the incoming trade, offering storage facilities or making the port an attractive cruise destination. As much of the world’s trade originates in Asia, the majority of the largest specialised ports are also in Asia. Out of the ten largest ports in the world, seven of them are in China and one each in Korea, Singapore and

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8There are 96,295 commercial ships of 100 GT and above (c.f. http://stats.unctad.org/maritime) and 51,684 commercial ships of 1000 GT and above (c.f. https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf)
9In 2018, there were 4,112,944 port calls made of ships of 1000 GT and above (c.f. http://stats.unctad.org/maritime)
10https://www.esri.com/en-us/see/stories/port-of-rotterdam/port-digitalization-article
Europe (Rotterdam).\textsuperscript{11} This list is complemented with other notable ports such as Hamburg, Houston, Dubai and Antwerp which have been singled out as growing proactively.\textsuperscript{12}

Ports are a conglomerate of actors working together. Most often the port “company” or the port authority becomes the landlord providing space for others to perform operations. This provides opportunity for the larger shipping companies to own terminals, including locating them at strategic places around the world.

There exists strong competition between ports that carefully consider their development, promoting local industry and access to the hinterland. As in other transport sectors, large transhipment hubs are becoming the first line of interaction for the larger ships to make port calls, while numerous feeder ports follow the rules of operations stipulated by those transhipment hubs. However, some ports in the world, such as the Port of Stavanger, take a stronger community approach, where the actors take a more regional approach, which builds upon the Norwegian collaborative culture. These ports become the business environment for the local industry, including supporting start-ups. PortXL,\textsuperscript{13} which was initiated in Rotterdam and now has been brought also to Singapore and Antwerp, are examples of such an approach.

### 3.2 The Complexity of Port Call Operations

Port call operations involve a substantial number of actors. Upon reaching the coastal area, the maritime authority is involved; to enter the port, the port authority needs to give its approval; often there are pilots and tug operators and other supporting nautical services required to bring a ship from the port area to berth; mooring personnel make fast the ship to the berth; terminal operators and stevedores are engaged in loading and unloading; other providers deal with such things as waste and security; and agents are there to ensure that everything goes according to plan. And the same group of organisations are needed to get the ship ready to depart from berth, leaving the port area, and back to the open sea. The complexity of port call operations and the need for collaboration and synchronisation can be seen in the generic PortCDM metro map (Fig. 2).

The diagram of the port call process indicates the wide variety of services for the ship, the crew and the movement of cargo that all have to be in place during a port call and often must take place over a short period of time. Not shown in the diagram are such things as bunkering, maintenance, repair or customs, all of which serve to further complicate the overall goal of effective coordination and synchronisation, which more often than not requires complex levels of collaboration

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\textsuperscript{11}https://www.ship-technology.com/features/feature-the-worlds-10-biggest-ports/
\textsuperscript{12}https://www.menon.no/wp-content/uploads/Maritime-cities-2019-Final.pdf
\textsuperscript{13}www.PortXL.org
and communication between the crew, owner, agent, the terminal and others, including administrative stakeholders such as border control, customs, immigration and the port authority.

Even the relatively simple metro map in Fig. 2 indicates that nothing is going to be better than the weakest link in the port call process, particularly if every actor acts on its behalf, pursuing only its interests. The risk of sub-optimisation is high. Collaboration with others in the port call chain is the key to enhanced operations and underpins the PortCDM concept and port call optimisation.

### 3.3 One Size Does Not Fit All

Most ports are also logistical environments, in other words, logistical hubs in the larger transport system that manage different types of trade and modal changes built around different requirements. Handling and other requirements in container transport are very different from those required for liquid bulk transport. As a result, there are often distinct differences in a port ecosystem with the concept of “ports within the port” being common.

Traditionally, ships are served on a first-come-first-served basis upon their arrival to a port, which often leads to “hurry and wait” behaviour for ships steaming towards...
ports. It is also evident that many ports base their organising approach on serving one predominant type of trade, leaving ships engaged in other types of trade to depend upon the same traditional approach. For many, container transport has become the dominating concept for arranging the schema within the port. Often this does not respond optimally to the needs of liquid and dry bulk or passenger traffic such as ferries or cruise ships. It is also not desirable that port call processes are completely different for each trade (and potentially conflicting with each other) because vessels, regardless of their trade, also need to share common infrastructure, such as fairways into the port.

4 New Opportunities Due to Digitalisation

4.1 Benefits for a Multitude of Stakeholders

If the multitude of actors engaged in the maritime supply chain were to join forces, there are significant beneficial effects to be shared among the different actors and stakeholders (Lind et al., 2018a) (Table 1). These benefits are relevant for ports and

| Table 1 Benefits from enhanced digital collaboration for different stakeholders |
|---------------------------------------------------------------|
| **For shipping companies/ships**                             | **For shipping agents**                                      |
| • Saved bunkers due to just-in-time arrivals                  | • Enhanced basis for planning and easier coordination of port call operations |
| • Saved bunkers due to just-in-time departures avoiding chasing the time window at the next leg | • Less time spent on chasing different actors, more time for other services to the ships |
| • Fleet optimisation and saved bunkers due to shorter turnaround times |                                |
| **For terminal operators**                                   | **For VTS operators**                                       |
| • Enhanced possibilities for berth management                 | • Possibilities to digitally log entrance and departures   |
| • Enhanced capacity utilisation (resources and infrastructure)| • Better coordination of ship movements                     |
| • Better planning horizons for approaches to be served        | • Increased capability to synchronise the traffic dependent on the status in the port |
| **For port authorities**                                     | **For port control/pilot planning, tug operators, mooring companies, and service providers** |
| • Safe and efficient port approaches                          | • Enhanced basis for planning                              |
| • A long- and short-term overview of port visits              | • Optimised capacity utilisation                           |
| **For hinterland operators**                                 | • Enhanced capacity utilisation (resources and infrastructure) |
| • Enhanced capacity utilisation (resources and infrastructure)|**For digital service providers**                           |
| • Better planning horizons for loading/offloading at ports    | • Low entry barriers to provide digital innovations        |
| • Enhanced predictability                                    | • Enhanced capabilities in existing systems by being connected to the “outside” |
maritime stakeholders in other regions, including developing countries. In addition to benefits for specific stakeholders, the international community as a whole will benefit from reduced emissions of greenhouse gases when sailing at optimal speeds and through port call optimisation.

### 4.2 The Role of Maritime Authorities in Collaborative Data Sharing

**The National Maritime Authorities**

Key shore side actors in shipping are the national maritime authorities. The national maritime authority is usually responsible for maritime safety and a range of navigational services within its waters. Maritime authorities are often responsible for VTS (Vessel Traffic Services) where established, mostly following the recommendations and standards of IALA. They organise and guide traffic through confined and congested waters, through channels or for approaches and through departures of the port limits and associated sea areas. How these and any other roles are coordinated and executed often differ from country to country, even from port to port within the same country.

Local legislation usually supplements or enacts the relevant international rules, covering such things as border control, customs clearance, immigration control and others. Besides these state duties, the maritime authority usually holds also the responsibility for Port State Control, ensuring that ships meet the requirements of IMO regulations as assigned by ships’ flag state, as well as any specific requirements of the coastal state.

**The Port Authorities**

When it comes to ports and their detailed operation, the relevance and influence of the national maritime authorities can vary greatly. There are centralised ports, where the maritime authority is also responsible for the majority of activities in a port and has decision and ordering rights on port operations. In other words, there is one centralised controlling authority. In other ports, the maritime authority focuses only on state activities, and all operations are executed by individual actors, who are free to organise their cooperation in serving a ship call as they deem appropriate. This gets more complicated in some ports, where the “port within a port” concept is in place. A classic example here is the Scheldt Ports with Antwerp as a central port.

**Maritime Governance Structures and the Role of Associations**

Most of the world’s commercial ships and particularly those engaged on international voyages are subject to regulations established by the IMO. These regulations are adopted by the flag states who together with coastal and port states enforce them which leads to all states following a global harmonised standard.

Meanwhile, shore-based infrastructures, such as the operation of ports, port services and logistical activities, are normally governed by the relevant national
regulations. This, of course, can vary from country to country and is an example of how the lack of global standards or practices makes it more complex and less efficient for the trade.

Who Watches Over the Ports and Infrastructure?
Other than for the specific requirements to conform to IMO regulations and to meet any national requirements in each country, the actors in the shipping industry have tended to operate mostly as a self-organised ecosystem where each of the actors makes decisions independently, with only limited consideration of how their decisions might affect other actors further up or down the maritime transportation chain. However, digitalisation, as well as commercial and competitive pressure from other forms of transportation, such as air and land bridges, is forcing key actors in the maritime industry to acknowledge that better coordination and synchronisation is key to improving reliability, customer satisfaction and profitability.

The maritime transportation chain comprises a multitude of actors, each performing often specific and specialised tasks as part of transporting goods from consignor to consignee. Each may be subject to different requirements, regulations and profit drivers. What tends not to be acknowledged well enough is that many if not most of the actors in the transportation chain have at least some dependency on the activities and the actions of others in the chain. This is particularly so in terms of the timing of events and ensuring the availability of appropriate supporting resources.

Just-in-Time Operations and e-Navigation
The IMO, while still considering the operation of ships as its primary focus, is now encouraging initiatives for just-in-time operations together with other regulations such as emission controls to combat environmental pollution and to promote sustainable development (IMO, 2018). One key initiative in this regard is the IMO’s e-navigation strategy, which seeks to enhance marine safety as well as efficiency by establishing open digital data exchange standards. e-Navigation is intended to provide digital information and infrastructure for the benefit of maritime safety, security and protection of the marine environment, reducing the administrative burden and increasing the efficiency of maritime trade and transport. To do this, a Common Maritime Data Structure (CMDS) has been established, based on the ISO-compliant S-100 Universal Hydrographic Data Model data exchange standard managed by the International Hydrographic Organization (IHO). e-Navigation goes hand in hand with PortCDM and other standardised digital data exchange arrangements that are now coming in to use. The IMO is also developing a reference data model where the data elements required for ship reporting and associated activities are defined. Great care is being taken to ensure that the definitions are harmonised and consistent with any similar terms being used in other data exchange regimes. The United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) is playing an important role in these endeavours.

Single-Window Data Exchange
Another digital information initiative that sits under the growing maritime digital data exchange framework is the single-window concept that allows parties involved
in trade and transport to lodge standardised information and documentation with a single entry point to fulfil all import-, export- and transit-related regulatory requirements. The European Union (EU) Reporting Formalities Directive (RFD) in force since 2015 simplifies and harmonises the administrative procedures applied to maritime transport through National Single Window for reporting formalities from ships arriving in or departing from ports. The RFD is planned to be superseded by the European Maritime Single Window environment (EMSWe) that is expected to be applied in 2025.

At the same time, the IMO member states agreed on a mandatory requirement\(^\text{14}\) for national governments to introduce electronic information exchange on 8 April 2019 to make cross-border trade simpler and the logistics chain more efficient for the more than 10 billion tons of goods traded by sea annually across the globe between ships and ports. In support of this, the IMO Facilitation Committee (FAL) is ensuring that the digital data exchange process is supported by appropriate and compatible international standards and definitions. In line with this, the EU VAT eCommerce Regulations will come into effect in 2021.

Taking their lead from the vision of intergovernmental organisations such as the IMO and the supranational organisation of EU, other intergovernmental and international organisations are also proceeding with detailed implementations to improve data sharing and effectiveness in the maritime transportation chain. This includes the IHO, the World Meteorological Organization (WMO) and IALA.

**Tackling Environmental Concerns**

The IMO, co-financed by EUR10 million from the EU, has implemented an initiative for five Maritime Technology Cooperation Centres (MTCCs), under the umbrella of the Global MTCC Network (GMN)—formally titled “Capacity Building for Climate Mitigation in the Maritime Shipping Industry” in targeted regions as part of a global network.\(^\text{15}\) Together, they are promoting technologies and operations to improve energy efficiency in the maritime sector and help move shipping into a low-carbon future.

BIMCO is an example of an industry representative organisation that is actively seeking to improve the environmental performance of shipping and the port call process. As well as submitting proposals to IMO on slow-steaming, it has also submitted proposals to IMO related to port logistic operational data (BIMCO, 2019) in support of the just-in-time concept.

**Other Complementary Initiatives**

More governmental-focused organisations working on the topic, including the earlier mentioned organisations like IHO and IALA, associations in the private sector as well as those with mixed memberships, are starting to get engaged in the

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\(^{14}\)Amendments to the Facilitation Convention were adopted in 2016 and entered into force on 1 January 2017. The FAL Convention amendments make it mandatory for ships and ports to exchange FAL data electronically from 8 April 2019.

\(^{15}\)https://gmn.imo.org
aforementioned concepts. The International Harbour Masters’ Association (IHMA) has developed the definition for IMO Maritime Service 4—Port Support Service which, in effect, places PortCDM and port call optimisation within the IMO’s e-navigation initiative.16

The International PortCDM Council (IPCDMC)17 is an example of an association that has combined both governmental and industry players to further develop PortCDM and help in its implementation. IPCDMC was initiated by RISE to provide global guidelines to be used for regional and local implementations of PortCDM.

The Port Call Message Standard S-211, which is the underpinning data exchange format for PortCDM, was created under the auspices of the IPCDMC, adopted as an international standard by IALA and registered in the IHO S-100 Geospatial Information (GI) Registry.

The principal international association for marine electronics companies18 CIRM is another industrial association supporting the development of e-navigation services, and its members are engaged in the work of the International Electrotechnical Commission (IEC) supporting the development of IALA standard S-421 for route exchange to enable interoperability with S-211.

ITPCO, the consortium consisting of a wide range of stakeholders, has been working to establish standards for port call optimisation that improves collaboration during port calls. These efforts have resulted in functional definitions (common semantics) for terms used in the Mariner’s Handbook (the comprehensive guide to seamanship and key aspects of navigation published by the UK Hydrographic Office and used worldwide by seafarers), agreed process descriptions and guidelines to help ports and port process stakeholders to coordinate and synchronise their activities through the availability of reliable master data for vessels and port infrastructure. The ITPCO published its first guidance document in 2020 (ITPCO, 2019).

These activities all show that the development of PortCDM and data sharing more generally is not only driven by authorities or research institutes but by a fast-growing community of industry players as well.

Work is also proceeding to optimise cargo flow from ports to the hinterland. Initiatives such as the EU rules on electronic freight transport information (eFTI), eCMR (electronic waybills) and the Digital Transport Logistic Forum (DTLF) subgroup on “paperless transport”, will establish uniform, predictable and trusted environments for the electronic exchange of information on goods transported within the EU.

16NCSR 6/8/2, IMO 2018
17www.ipcdmc.org
18http://cirm.org/
4.3 Roles Are Likely to Change and Evolve Under Digitalisation

Digitalisation is changing the way actors associate with port operations.\textsuperscript{19} For example, the traditional role of a ship’s master has already begun to change with an increase in remote monitoring of a ship’s position leading to others providing advice or instructions on what speed to use or what route to take to avoid such things as weather or traffic congestion or to make an optimal arrival time at a port.

Digitalisation will change some roles more than others. Overall, many activities should become easier and be more efficient which could reduce the roles for some actors. At the same time, digitalisation will provide opportunities for providing new or enhanced services. The future role of the ship agent is one example.

Ship agents provide two major types of capital (Watson, 2019) to their clients. First, because they typically have personnel physically located in the ports of call, they provide social capital in the form of a network of connections with the port’s service providers. Their specialised local social capital means they know whom to contact for routine and special services. Second, they have developed routines and procedures (organisational capital) to deal with the local laws and regulations and atypical features of their port and its environment. They have created efficient procedures to weave together the various local requirements and services needed for a successful port visit in their territory.\textsuperscript{20}

Traditionally, a ship agent, as a representative of the owner, the charterer or both, of a visiting ship, ensures that the essential requirements for a ship’s visit are arranged and met. They also guarantee that involved port actors are paid. In the absence of other information, port actors also rely heavily on the information about the port call (arrival time, planned operations, etc.) provided by a ship agent. People increasingly realise that in the future when digitalisation will generate multiple, accessible data feeds that can enable all actors to have a shared and common situational awareness, they will not need to rely on a single source of agent information. Nevertheless, the value of the ship agent will likely remain and could actually be enhanced by their access to those multiple, up-to-date data streams because it will enable them to be even better on-the-spot coordinators than they are today.

Digital data sharing and greater visibility of plans and their modification could enhance this role for ship agents willing to embrace digitalisation. They could go beyond organising the delivery of local services to ensuring that they are delivered with full satisfaction and predictably as well as validating invoices against real time data. The local agent can take on the important role of helping to ensure the fastest possible turnaround where everything is aligned instead of simply sending

\textsuperscript{19}Digitalization in Maritime Transport: Ensuring Opportunities for Development, UNCTAD Policy Brief No. 75, Geneva, 2019. \url{https://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=2479}

\textsuperscript{20}\url{https://hansa-online.de/2019/11/schifffahrt/140080/}
intermittent progress reports to its client that may be inaccurate no sooner than they have been sent.

In the redefinition of the ship agent business model, the ship agent could also be the provider of information and optimisation services to transport buyers and cargo owners by becoming the physical and informational integrator of maritime operations in the global transport chain. With the growing ability of the ship agents to collect and analyse incoming data streams, their value proposition, for both the ships and a port’s actors, opens new opportunities to change and enhance their business model.

Enhanced digitalisation and collaboration in the maritime transportation sector will change the capital creation recipe for many in the ecosystem. The ship agent is but one example. Those who want to continue to participate profitably in the ecosystem will need to reblend their social and organisational capital to match the digital connectivity and standardised digital data exchange that will dominate the execution of the future port call. Their social capital will decline in value if they do not accommodate digital data sharing for establishing the phasing of a port call and managing its execution. A phone call or email will be a costly alternative to a digital data exchange with service providers to establish when, where and what services that will be provided for the given port call. It also addresses the need for updating these as circumstances require.

5 Current Digitalisation Initiatives in the Maritime Sector

5.1 Community-Driven Standardisations and Digital Tools

Emerging

The uptake of digitalisation in the maritime sector has been increasing steadily. In 2017, the theme for the IMO’s World Maritime Day was ... connecting ships, ports and people. The IMO’s e-navigation initiative is ongoing, as is its work on digital ship reporting. At the same time, Maersk and IBM have been working on a significant collaboration to bring blockchain technology into the maritime sector to massively reduce the reliance on paper documents. In ships and ashore, increasing amounts of relevant data are being transmitted digitally, including a ship’s position and details via AIS transponders every 6 seconds, remote engine and machinery monitoring and data describing the loading and details for ship’s cargo.

Digitalisation is increasingly playing a pivotal role in ESG (environmental, social and governance) topics by accelerating sustainable initiatives and helping to monitor and mitigate emerging risks and pressures, for example, in tackling environmental pollution and climate change. Digitalisation and the ability to connect different maritime transport actors to enable greater efficiency and to reduce their collective carbon footprint are an obvious example of the benefits for the maritime sector.
In addition to the work being led by the IMO, there are numerous “community” initiatives surfacing within the maritime industry, such as the chainPORT, the Digital Container Shipping Association (DCSA), the Global Industry Alliance (GIA), the IPCDMC, the International Port Community Systems Association (IPCSA), the Maritime Connectivity Platform Consortium, the ITPCO and the Smart Maritime Network.

In parallel with these initiatives, there are numerous digital tool providers emerging to enable data sharing along the supply chain. However, many of these are or have been developed for a single port with the notion of then engaging others along their particular transportation chain. This can lead to non-standardised or proprietary solutions emerging—which is not desirable nor in keeping with the aims of the major intergovernmental and international organisations such as IMO, EU, IHO or IALA. Nonetheless, and fortunately, the tools all strive to embrace a number of common assumptions and principles and in particular that:

- Nothing substantially related to addressing environmental concerns will happen without engaging a multitude of maritime transport producers.
- There will unlikely be a single party providing a tool to the entire maritime transport industry.
- It must be possible for clusters of actors (such as a port) to choose among different solutions meeting their needs.
- The different solutions need to be based on the established standard message formats (such as the use of the S-211 data exchange format) and communication protocols that enable seamless, interoperable data sharing among the various different tools.

A future with greater access to a variety of data streams capable of being combined to provide more predictable and sustainable transport services can be expected by having various tools available and using standardised messaging systems, independent of the domain that they are addressing and connected to. This will require common definitions of data sets used for the exchange of static and dynamic information (e.g. International Taskforce on Port Call Optimization, 2019). This will cater for both enhanced collaboration and interoperability throughout the maritime supply chain and also make connected maritime operations part of the larger supply chain. Establishing and using logistic communication platforms means that information can be entered once and used by many—thereby avoiding the need for actors operating in more than one port or those dealing with multiple actors to rely on a number of dedicated single point-to-point connections.
5.2 The Use of Diverse Digital Technologies Enabling Enhanced Efficiencies

Enabling Collaboration by the Use of Timely Data Sharing
One clear development trend is an enhanced degree of collaboration to glue the different actors of the maritime transport ecosystem together. Some effects have been identified by Lind and Simha (2020) coming out of different development trends enabled by new technologies, such as:

- Port operators expanding their planning horizons
- Ship and port operations becoming seamlessly integrated
- Regions being empowered by digital collaboration among, for example, a port and its operators
- Elastic timing of operations enabling just-in-time arrivals
- Cargo owner and maritime transport providers becoming more integrated

Such initiatives that enable collaboration and digital data sharing around plans and progress improve transport chain visibility as well as create foundations for enhanced utilisation of infrastructure and capacities. This integrated performance approach would also provide foundations for optimising the use of energy, which is in line with goals of the United Nations 2030 Agenda for Sustainable Development.

6 The Importance of International Standards

The IMO and other relevant intergovernmental organisations wish to see global standards prevail for key digital information in the maritime sector. As a contemporary example, the IMO is pursuing the so-called single-window concept for the digital reporting via a single portal, without duplication, of all information required by public authorities in connection with the arrival, stay and departure of ships, people and cargo. The single-window concept joins other standardised processes already in place covering such things as obligatory navigation routes, nautical charting and safety-related information.

However, the use of universal digital data standards is much less common in the other aspects of maritime activities that are not under the jurisdiction of the IMO or other relevant authorities, such as detailed port call or cargo information. Naturally, in single window’s efforts, the national trade and customs organisations are highly involved.

As part of developing a standardised approach to digital data sharing in those areas not previously addressed at the intergovernmental level, several associations are seeking roles as leaders to establish new practices for collaboration and data sharing. One of them is the ITPCO; others include the IPCSA (Morton & De Cauwer, 2019) and the IPCDMC.
Other groups have also established themselves, such as the DCSA, which covers 9 out of the 11 largest container shipping lines in the world. This alliance is acting on behalf of its members to develop information systems and security standards that address the common challenges related to transmitting, receiving and exchanging data across the industry.

### 6.1 Important New Standards for the Maritime Transportation Chain

Several standards related to the transport of goods have been developed or enhanced recently for application in maritime contexts. One example, the GS1 standard EPCIS (also registered as ISO/IEC 19987), was developed many years ago for the purpose of communicating the status of goods throughout the supply chain, in other words, by providing the answers to what, where, when and why on the actual status of goods in transit. EPCIS has been implemented widely in the supply chain and is continuously maintained and updated based on industry input. However, EPCIS does not currently support exchanging information about intentions (things that have not actually occurred yet), which is necessary for the distributed coordination of movements and operations (Lind et al., 2018c).

The port call message format standard S-211 is a fundamentally important standard that provides the ability to communicate intentions in a standardised way. S-211 is ISO 19100 compatible and has also been aligned with GS1 EPCIS so as to enable communicating when particular goods items will arrive at particular locations, which may be done by combining data streams from both standards.

### 6.2 Resistance to Standards

A legacy of the relatively uncoordinated adoption of digitalisation and common data standards within the maritime sector means that there are several different existing and successful electronic data interchange (EDI) connections being used by the larger shipping lines and their partners. Thus, there is some reluctance to make any dramatic changes towards a standardised approach if there is a significant organisational or financial reinvestment cost involved.

The larger shipping companies have historically dominated the adoption of digital technologies by others in the industry. The leading ports would like to set the agenda for the smart and digitalised port, and at the moment, it seems that some of the larger ports are trying to sit in the front seat of the development. In this respect, care needs to be taken to maintain standardisation and the wide adoption of the principles of collaboration and data sharing in accordance with PortCDM.
Connected Maritime Operations: Smart Ports and Smart Ships

7.1 Connected Maritime Operations: A Must for an Efficient Global Transport Chain

Connected maritime operations are seen as the way to optimise the maritime transportation chain and thereby provide better services for both the cargo owner and the transport buyer. This connectivity, achieved through digitalisation, enables improved collaboration between the actors and better synchronisation of their individual contributing activities. Port call coordination is one example, which has been highlighted by the World Economic Forum.

Using the container trade as an example, Fig. 3 depicts the need for an integrated view on both the movements of goods between different transport hubs using different means of transport.

Another initiative in support of digitalisation and improved connectivity is the Maritime Connectivity Platform (MCP),\(^\text{21}\) formerly known as the Maritime Cloud. The MCP is a framework for enabling efficient, secure, reliable and seamless elec-

\(^{21}\)https://maritimeconnectivity.net
Electronic information exchange between all authorised maritime stakeholders across available communication systems. The MCP has been created to enable maritime actors to use digital services to exchange public as well as private information. It brings common Internet standards to maritime navigation and transportation systems by applying open and vendor-neutral technologies. The MCP was created initially to address the goals of the e-navigation initiative of the IMO but now has the potential to support digitalisation across a much wider maritime domain because it is an open-source solution that relies on the Internet concept of Web Services for identity management and service management and, as such, can support more than just the IMO’s Maritime Services in the context of e-navigation.

The importance of improved and up-to-date situational awareness within transportation hubs, which PortCDM has enabled, has been recognised in other industries, such as in aviation with Airport CDM and StationCDM for the railway sector.

Further, the European Commission, through the efforts of the Digital Transport and Logistics Forum (DTLF), stresses integrated corridor information systems and has recently launched two projects to demonstrate a concept for a federated network of platforms called FEDERATED and FENIX.

The integration between different modes of transport across borders is an important concern for tomorrow’s transport of people and goods.

### 7.2 Smart Ports

The use of up-to-date information technology in ships and in ports, including real-time data transmission and collection, big-data calculations, digital modelling and remote control, is expected to better guarantee navigational safety and improve operational efficiency. Ships will become more reliable, more efficient and more closely integrated into global supply chains generating cost savings and improving revenue generation.

Enhanced digital collaboration will overcome the legacy of disconnectivity in shipping. The Internet of Things (IoT) is set to play a key role in creating transparency and enhancing efficiency of the global supply chain. Players within the supply chain that can use data to improve their operations and are able to create partnerships can gain significant competitive advantage.

In this context, an increasing number of ports are now aiming at becoming **smart ports**. Expectations include being:

- The driver for sustainability by enabling just-in-time operations
- An information hub advising the use of the transport network of which the port is a hub
- Providing enhanced predictability of operations and the timing of the port visit

It is essential for the port of tomorrow to be connected to the global supply chain, in particular, by being informed about upstream progress to ensure its ability to plan its operations successfully and optimally. Through the introduction of digitalisation
and enhanced procedures of collaboration and data sharing, this can be enabled. PortCDM and port call optimisation promote the necessary cultural development of collaboration necessary to achieve environmental and efficiency gains in port call operations and to establish ports as an integrated hub in the global transport chain.

In 2018, Inmarsat carried out a research program to understand how IoT is being adopted within the supply chain. An independent market research firm, Vanson Bourne, interviewed 750 respondents across global transportation companies. The research reports:

- $2.5 million is the average shipowner investment in IoT solutions over the next 3 years. 24% are planning on investing more than $3 million and 14% less than $100,000.
- 100% of shipowners/managers surveyed will be using IoT solutions to meet emission regulations.
- 51% of the respondents said the biggest obstacle in adopting IoT is the lack of timely data. There is a time lag between obtaining the data from the ship and analysing it on the shore side.

7.3 Smart Ships

Integrated information systems capable of autonomously monitoring, recording and analysing the conditions and operations of major equipment such as engines and other shipborne systems are increasingly commonplace in new ships. The data helps to reduce the crew’s workload, improve efficiency, and avoid misjudgements.

The digital enhancement of existing ships is more complicated, but not impossible. In the current situation, the shipowner can opt to install particular aspects of digitalisation in the form of specific applications—for example, one for voyage optimisation, another for emission monitoring and another for ballast water monitoring. Then, data from these systems is sent from ship to shore. However, as a result, the shipowner will have several different IoT systems and equipment on board, which can result in some common data perhaps being sent several times from ship to shore. On the shore side, the data from each system might also be stored in different clouds and may not be interoperable if it is locked into different application providers or relies on proprietary data formats.

A truly smart ship will have an integrated IoT platform that is, in effect, one agnostic “box” on board that collects serial, analogue and digital data. Data is transferred from ship to shore through dedicated bandwidth. Data are stored in a centralised, cloud-based database providing an API and a dashboard for the shipowner, so that they can use and analyse the data. In addition, other application providers can tap into the cloud and data can be shared.

22https://research.inmarsat.com/. Accessed 4 March 2020
At present, shipborne digital transformation has not resulted in significantly smaller crew sizes because the number of sailors for each class is stipulated by regulations, but further technological and regulatory developments are likely to lead to future reductions. In particular, the development of autonomous and semi-autonomous ships, which rely heavily on digitalisation as well as some level of remote monitoring, will minimise or remove the need for permanent manning of some types of ship. This digitalisation will include autonomous route optimisation and collision avoidance. What is clear is that the large-scale application of smart technologies will enable shipowners to save costs in ship maintenance and fleet operations.

8 Concluding Remarks

Shipping companies are strongly driven by the pursuit of enhanced efficiency, and ports are driven to satisfy the needs of their clients of which the shipping companies are the most important. At the same time, emphasis is placed upon ports to deliver services of high quality and enable engaged port call actors to generate revenue. All of this requires enhanced situational awareness empowered by greater digital collaboration and data sharing.

Digitalisation of navigation and international security arrangements is reasonably well covered by internationally agreed global standards and directives under the auspices of the IMO, the EU and other organisations. However, one of the dilemmas with digitalisation, standardisation and data sharing in the port operations environment is the absence of overarching bodies, like the IMO, that can strongly influence standardisation. There is also the tension between catering for local requirements and sensitivities including existing infrastructure to overcome and at the same time enabling those involved to connect.

The challenge is for current stakeholders in the maritime sector to implement digitalisation and to adopt common, interoperable data standards or to risk losing control of the logistic chain. A question for those currently involved is whether progress in standardised digitalisation will be fast enough or whether some of the major suppliers of goods or services, and others, or even some countries will impose their own arrangements, including, in effect, the control of shipping companies and ports at strategic places in the world, by using and imposing their own systems and procedures.

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