FOUNDATIONS OF MARITIME INFORMATICS

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ABSTRACT

For centuries, the maritime industry has continually upgraded its information sources and processing capabilities to improve safety, efficiency, and reliability. The global positioning system and satellite communication have become essential information sources for modern navigation in the digital era. Today, shipping is a capital, energy, and information-intensive industry. This article introduces the discipline of Maritime Informatics, which studies the application of information systems to increasing the efficiency, safety, and ecological sustainability of the world's shipping industry. The shipping industry's future depends on digitisation, digital data exchange standards, collaborative decision-making, and spatial-temporal analytics.

Keywords: *Maritime Informatics, Digitization, Sustainability, Future of Shipping*

1. MARITIME INFORMATICS FOR INCREASED CONNECTIVITY

As a global self-organising ecosystem, the maritime industry has been welded together by information for over several thousand years. Traders and shippers use the information to overcome national differences and permit the many players in the world's maritime sector to request and receive the

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necessary services to transit waterways and to handle cargo and passengers in a multitude of ports of varying capabilities.

The maritime community and governments have, over the centuries, continually upgraded their information to improve resilience, safety, efficiency, and reliability. The leading naval forces of each period invested heavily in charting the oceans to improve safety and navigation. With successive improvements in precise location, charts, and the information that they contain have become ever more useful. In the first half of the 18th century, the British government fostered a national competition for a precise and sea-worthy chronometer (Sobel, 1995) to measure longitude accurately at sea for the first time. The global positioning system (GPS) and satellite connections are now essential information devices for modern and energy-efficient navigation in the digital era.

Shipping is an information-intensive industry. Apart from mapping out and following a safe path, each shipping company must record the content of its cargo and its destination and plans for future voyages and their shipments and sequence of ports. Each company needs to manage a range of issues, namely, its crew needs, shipping charges, competitive services to exporters and importers, keep its ships safe and operational. On top of these issues, it also needs to organise many other actions that generate a level of capital productivity comparable to its major market contenders. While doing all this, a shipping company needs to obey local, regional, national, and international regulations. Navigating this information *fence* is critical to business success.

Like every enterprise, shipping is a capital creation system (Watson, 2019). A shipping company primarily converts a manufacturer's products, economic capital, into higher-value economic capital by getting them to, or closer, to the end consumer. This is the age-old business of trading that emerged with the birth of agriculture thousands of years ago around the Euphrates and Tigris rivers. However, today, the same trading model is far more capital, energy, and information-intensive. Shipping companies can now combine digital data and the processing capabilities of Maritime Informatics' tools to improve their capital productivity. This new field of Maritime Informatics can enhance a shipping company's capacity to compete with other firms in its sector and with services by provided by other transport sectors. Customers seek the best combination of modes across the overall transport chain. The capital creation system does not care about history and customs. It destructively weeds out those with low capital productivity and rewards those with high capital productivity with more business.

To introduce Maritime Informatics to the shipping industry, we recently edited a book on Maritime Informatics (Mikael Lind, Michaelides, Ward, and Watson, 2020), with 79 contributors (34 scholars from universities or research institutes and 45 practitioners from industry or government) from 20 countries. In the remainder of this paper, we give a brief overview of the first section of the book, which contains nine chapters

1.1. The Origins of Maritime Informatics

The opening chapter (Ward and Bjørn-Andersen, 2020) reviews the maritime industry's history with a particular emphasis on its long search for accurate data that improves the safety and efficiency of voyaging and port visits. The need for captains to know where they are when at sea led to the development of detailed charts, accurate clocks, and other supports for navigation. Very early on, many countries realised that accurate charts and the means to reliably determine the position of a ship were a competitive advantage in war and trade. The more recent digital developments such as global navigation satellite systems, electronic charts, automatic identification system (AIS), and marine satellite communication now underpin the geolocation of most of the world's maritime data used in informatics.

1.2. A Self-Organising Ecosystem

This chapter (Watson, Lind, Delmeire, and Lieaa, 2020) introduce some key concepts for understanding the nature of the shipping industry and how it operates as a foundational worldview for maritime informatics. It describes the shipping industry as a self-organising ecosystem that uses episodic tight coupling to coordinate actions. The chapter also discusses the nature of innovation and how it follows a path of seeding, standardising, and sequencing, such as containerisation and now in the form of a digital transformation. This may be the most academic of the chapters because the concepts it discusses, such as episodic tight coupling, are important for developing a vocabulary and understanding of the maritime sector's critical characteristics that determine the nature of information systems required and the evolution of Maritime Informatics.

An important contribution of the chapter is introducing a Maritime Informatics stack (Table 1). The division of decision rights and roles across the stack enables developments in each layer to occur relatively independently provided standard communication protocols, as appropriate, are instituted across adjacent layers. In the case of a self-organising ecosystem (SOE), we might well see the structural layer's most action as it needs to adjust to changing trade patterns and environmental threats dynamically. As a result, neighbouring layers might also have to adjust to accommodate such disruptions. Thus, a maritime informatics stack should not be static, but rather be designed to support a resilient and agile ecosystem with some separation among distinct activities to confine a major change's effects to one layer and allow the others to adjust as required gradually.

Table 1: Layers of the Maritime Informatics stack

Layer		Design questions
1	Global	Industry-wide international standards for digital data exchange within the maritime sector.
2	Regional/National	Design and implementation of policies to support a digitally enhanced maritime sector and a regional/national excellence in Maritime Informatics.
3	Structural	Design of structures, such as markets, organisations and partnerships to implement efficiently frequently occurring maritime decisions in a digital era. These include shipping conferences and long-term contracts between shipping companies and terminal operators.
4	Decision support	Design of decision processes and associated actions to implement frequently occurring maritime industry decisions
5	Data stream mining	Design of techniques for dynamic identification of model parameters to support real-time decision processes in the maritime sector.
6	Data exchange	Design of message formats and content for data exchange between elements of a maritime system to support decision making
7	Data communications	Design of data communication networks to capture data for decision making at the appropriate level of granularity and frequency and transmit control commands to connected maritime equipment and devices.

Source: Watson et al. (2020)

1.3. The Necessity of Standards

This chapter (Ward and Bjørn-Andersen, 2020) reports five maritime accidents to endorse its arguments for digital data exchange standards for onboard equipment. In today's digital era, nearly all products have embedded digital capabilities and data streaming features. However, unless there are common standards, a digital babel of data streams is generated meaning that a ship's bridge can be overwhelmed by data from multiple sources without sufficient integration. A flood of data can interfere with quality decision-making and contribute to safety breaches and accidents in a crisis.

Maritime standards concerning technology innovation and informatics have a long history dating back to the invention of telegraphy and emergency protocols at sea. Solving the coordination issues related to these technologies and the related emerging opportunities (i.e., the chance to contact someone during an emergency via telegraph), led to some of the first international standards in the form of conventions and treaties like SOLAS (Safety of Life at Sea).

Today's conditions facing the maritime industry continue to indicate a strong need for standards-making as technology innovation has only accelerated and equipment on ships has increasingly become digitised with embedded sensors and communications capacity. Unfortunately, the industry itself is fragmented. Even the largest shipping operators account for only a small fraction of the total global market and capacity. As a result, standards become even more important as the many manufacturers and service providers have already created many competing solutions that do not work with each other. This has led to a situation in which five major problems need to be addressed by standards:

- Miscalculation
- Information Asymmetry
- Confusion
- Wilful Negligence
- Unintended Consequences of Computer Systems Integration

To effectively make standards, one must understand the major organisations involved in standards-making, the sorts of problems facing the industry concerning standards, and the processes standards may go through as they form. These organisations include the International Maritime Organization (IMO), the International Standards Organisation (ISO) Technical Committee (TC) 8 and others. Based on direct industry experience in standards-making, this chapter introduces all of these issues along with a developing IMO/ISO standard for ship software maintenance. Most importantly, we argue that more information systems specialists need to engage in the voluntary standards process, because it is a critical foundation for cooperation and information sharing to enable maritime informatics.

1.4. The Port as a set of Socio-Technical Systems

While we might think of a port as an organisational entity, it is a conglomerate of different organisations, a multi-organisational business, acting within a certain geographical area, such as a harbour (Haraldson et al., 2020). Due to the geographical concentration of infrastructure and capabilities for delivering services to enable transhipments and supporting inter-modal transfer, we commonly use the word port to describe this conglomerate. It is also possible that there exist ports within ports.

A multi-organisational view explores issues arising in port operations because of the myriad of organisations that need to coordinate and cooperate for a successful port visit. A port is a continually evolving collection of socio-technical systems, each subject to different levels of change induced by the digital transformation of shipping, simultaneously serving many different trades relying on different business models. The multiple organisations within a port need to collaborate to create value through a value network, and understanding this process is core to the design of systems to support port collaboration and the collection and analysis of data aimed at raising the performance of each organisation and thus the port collectively.

Thus, the port may be analysed as a set of socio-technical systems, which is particularly useful for change management. The organisations within a port, each and collectively, operate five types of systems - engagement, production, record, inquiry, and framing (Watson, 2019), ideally by and within an organisation and across organisations through virtuous interrelationships enabled by digital technology.

Ships as regular and episodic port visitors, to some extent, often need to use and share the same infrastructure, such as the waterways under the control of the port authority. Therefore, the various organisations within a port must not act in isolation. Port actors are part of the port ecosystem defined by their respective roles in the planning and realising a port's value creation process. The port ecosystem is delimited by a commonly shared object of interest, which is to enable transhipment and inter-modal transfer of cargo and /or passengers as efficiently and sustainably as possible as part of the berth-to-berth sea transport and larger multi-modal transport system. Importantly, ports are entry and exit points for worldwide trade and raw material supply linking the maritime trade dimension with other modes.

In international, regional, and local arenas, much effort is placed on integrating ports into the larger transport system, by connecting what happens at sea with that ashore. This has driven the need for ports to upgrade their capabilities to become information hubs and utilise different means for automation. The business landscape of port operations is also highly competitive. Nevertheless, we should not exclude the people factor, and we need to understand that ports are socio-technical systems (Bostrom and Heinen, 1977a, 1977b).

To cater for alignment among the various actors involved in a port's operations, Haraldson et al (2020) explore the foundations for viewing a port as a multi-organisational set of socio-technical systems. In a multi-organisational transport system, each actor should contribute to and benefit from up-to-date situational awareness for their decision-making. From a maritime informatics point of view, a socio-technical system uses digital communication to enable a common understanding of the various actors' intentions.

The well-connected port is both a data consumer and a provider to external parties. The smart port and its constituent members (Mikael Lind, Gardeitchik, Carson-Jackson, Haraldson, and Zuesongdham, 2020) should have established capabilities to make intelligent, evidence-based decisions. At the same time, there are also expectations for a connected port to be an information hub for others. The future port should provide data streams captured within the port to external parties, such as administrations, shipping companies, hinterland operators, transport buyers, cargo owners, and upstream and downstream transport hubs as their foundation for their planning.

From a socio-technical point of view, there is a need to ensure that information systems are based upon agreed message formats, interfaces, and processes. This is to enable joint coordination between the actors involved in the transport of goods. By taking a multi-organisational point of view, requirements can be stipulated as to what data are needed for ensuring coordination and synchronisation among involved actors and when these should be shared.

Digital data sharing is key to coordination and synchronisation in a multi-organisational setting. The available data contributes to the efficient utilisation of resources required to complete a port visit, including the planning and use of electrical equipment for shore-based power for ships and hinterland carriers. It may also include detailed data streams about the status of particular infrastructure (such as bollards or moving vehicles within the port) or the environmental parameters (such as current, water level and wind).

The socio-technical system perspective emphasises the interaction between structures, roles, tasks, and technologies. Mostly, people think of technology driving change, but organisations can also change structures, roles, and tasks. Maritime Informatics can facilitate change in all four components in response to industry trends and initiatives. New alliances and structural changes will typically require new information systems to support coordination. For example, the ship agent's role could be transformed when digital data exchange reduces their role as local information providers and increases their role as local service coordinators (Mikael Lind and Croston, 2020). Data analysis will become a more common task because of the greater availability and depth of data provided by standardised data exchange, a technological change.

It is important to realise that the level of change is an order of magnitude more difficult as we go from task, to role, to structural, to ecosystem. Thus, Maritime Informatics exponents must exercise skills in change management comparable to the level of change to be implemented.

High on the IMO transformation list is just-in-time shipping (Paixao and Marlow, 2003). This will likely require a technology-facilitated change at all levels. Maritime Informatics can enable such a change, but the more difficult challenge is to successfully change the social system elements, such as deeply embedded customs, practices and relationships. Developments in technology are relatively easy, but changing well-established structures and behaviours in a self-organising ecosystem can be hard. The first step on the path is to openly examine the full ramifications of digitalisation on the multiple socio-technical systems and their relationships that it is designed to change.

1.5. Digitalisation of supply chains

Digitalisation in maritime regional and global supply chains addresses the need to improve connectivity across the entire supply chain to meet each of the stakeholders' needs and in particular the needs of the beneficial cargo owner (BCO) who ultimately pay for all transport. It argues that maritime transport is a laggard in many supply networks because of its slow adoption of digital business practices. Maritime transport would ignore BCOs' needs at its peril. The solution: maritime transport adopts global standards and implements standard technology and process building blocks to ensure the smooth flow of information among systems of all stakeholders.

The chapter on "Digitalisation in maritime regional and global supply chains" (Voorspuij and Becha, 2020) identifies the growing challenges that maritime transport is poorly connected with the rest of the end-to-end supply chain. Currently, many of the stakeholders in supply chains relying on maritime transport are reviewing their stance towards their service providers in maritime transport. This chapter looks at who they are, what forces are transforming their industries and what additional requirements they are now placing on maritime transport.

It pays attention in particular to the needs of the BCO, who ultimately pay for all transport including maritime transport (even in case the BCO has no direct commercial relationship with the maritime transport service provider). A key observation is that the expectations regarding reliability, visibility, and flexibility in the business-to-consumer market are becoming the norm (maritime transport). These expectations lead to a host of new requirements on maritime transport.

These new requirements (from BCO and other supply chain stakeholders) necessitate nothing less than a transformation of maritime transport away from paper-based operations and siloed processes to paperless operations and integrated processes that interconnect seamlessly in an end-to-end supply chain. In other words, the information related to cargo should flow smoothly among all stakeholders involved to ensure the cargo can flow smoothly and reliably through the transport and logistics networks. Hence, the cargo arrives in good condition, at the right place, at the right time.

Should the incumbent stakeholders in the maritime industry fail to make the necessary transformation, various influential cargo owners will likely transform the maritime industry for them. Some of these BCO have already taken steps to take more control of their transport and logistics networks (including maritime transport). Therefore, maritime transport must start to digitalise and collaborate on a scale and level of detail much higher than maritime transport currently offers. In order to achieve this transformation quickly enough, the maritime industry must adopt common global standards and building blocks al-ready used effectively across many other supply chains.

The second part of this chapter covers those global standards and building blocks[2]. The good news is that the required standards and building blocks exist; the industry must simply be willing to collaborate to combine them.

Figure 1: GS1 framework for digitalisation of cargo movement

Source: GS1

Global standardisation organisations like ISO, UN/CEFACT, GS1 and industry initiatives like International Taskforce Port Call Optimization and DCSA have delivered and are continuing to deliver foundational building blocks. To be able to put building blocks into context, we must consider the framework below, which identifies three layers that must link together to enable digitalisation of cargo movement. The layers are as follow:

1.5.1. Identification

Information systems require the unique identification of each entity that they need to manage. The layer depicts several different kinds of entities and some examples of identifiers that may be used for them. The identifiers come from different global data standard organisations such as IMO (the IMOVN or IMO vessel number, BIC (Bureau International des Containers) BIC code for intermodal containers as well as GS1/ISO.

1.5.2. Automatic Identification and Data Capture

Each physical object must display or have embedded in it, a unique identification code that can be read automatically without error.

1.5.3. Information Sharing

Different stakeholders will handle different information systems as goods or cargo travel through the supply chain. To use unique identifiers, it is imperative that all stakeholders involved exchange

[2] https://www.porttechnology.org/technical-papers/why_standards_matter/

information regarding these entities use the standardised identifiers for each class of object, such as a container.

1.6. Sustainable Maritime Transport

Sustainable Maritime Transport and Maritime Informatics (Singh and Sengupta, 2020) is concerned with the absolute necessity to create a sustainable society. Maritime transport is the backbone of global trade and the global economy. Maritime transport accounts for the largest share of tonne-kilometres. As per the International Transport Workers Federation (ITF) study's baseline scenario[3], maritime transport is predicted to grow from 71% of total transport in 2015 to 75% by 2050. The importance of shipping in supporting and sustaining global society makes its role vital in meeting the 2030 Agenda for Sustainable Development. Even when water-borne shipping remains the most carbon-efficient and cost-effective medium of transport for long-distance trade, there is a need to reduce the associated greenhouse gases (GHG) emissions further, especially, when the share of shipping emissions in global anthropogenic emissions has increased from 2.76% in 2012 to 2.89% in 2018[4] (IMO, 2020).

Low carbon and efficient maritime transport have an essential role to play in the growth and sustainable development. The global nature of shipping and climate change mitigation requires coordinated solutions at the international level. Most people and organisations want to be environmentally responsible, but without information, many are unaware of their current and future ecological impact. Research on sustainable maritime transport is gaining ground in all aspects and sectors of the industry. Nevertheless, the ever-tightening environmental and social criteria prescribed by international regulations have called for innovative, scientific or data-driven approaches to manage maritime transport activities. Environmental sustainability has become a top priority for regulators and ship owners alike.

All maritime activities require interaction between different stakeholders such as ship owners/operators, charterers, shipping agents and ports. This interaction and integration among various stakeholders are facilitated via digitalisation and enhances environmental and economic efficiency. Decarbonisation in the maritime space is not achievable in the absence of consequential operational data. An understanding of a ship's operational output requires measurement and analysis of fuel efficiencies before it can be utilised to influence carbon reduction strategies. The number of possible interactions between a ship and its environment are significant, and harnessing this information is critical. Ships are becoming sophisticated sensor hubs and data generators, producing and transmitting data in real-time. Data is essential to understand, optimise and ensure compliance within day-to-day activities. This could reduce lead times, fuel consumption and allow related efficiencies on the shore side (and vice versa)[5]. In shipping, digitisation and the use of data is continuing to have a huge impact. Digitalisation and automation are transforming the shipping sector. In order to achieve digitalisation uniformly in the maritime world, ships and ports must be data enabled and data ready. The aim is to promote efficient and secure trade, including offering greater supply-chain visibility and use of digital data, ultimately benefitting customers who rely on shipping industry services[6].

Maritime informatics can be at the centre of such a development supporting sustainable maritime operations. Forecasting remains an inexact science, and the data it depends on can be inconsistent and

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[3] https://read.oecd-ilibrary.org/transport/itf-transport-outlook-2017/transport-demand-and-co2-emissions-to-2050_9789282108000-5-en#page21
[4] https://theicct.org/news/fourth-imo-ghg-study-finalreport-pr-20200804
[5] https://to2025.dnvgl.com/shipping/digitalization/
[6] https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

incomplete. Absence of data and trust causes lack of transparency, leading to the failure of understanding among supply chain stakeholders. However, increased transparency not only enables stakeholders to respond efficiently to disruptions but also provide the capability to anticipate them. Maritime Informatics plays a critical role in achieving the optimal environmental efficiency with the capability to proactively inform stakeholders across the entire chain as applicable, of the changing circumstances and enable them to operate in a dynamic mode. The world maritime fleet's carbon intensity trend continues to be dominated by operational drivers. Thus, the industry needs the support of Maritime Informatics to improve its sustainability so that it can identify opportunities to reduce waste, pollution, carbon emissions, and energy efficiency. There is also a need for Maritime Informatics to help raise capital productivity, so we learn to do more with fewer ships, cranes, and other maritime hardware.

1.7. Connecting cities and ports

Connecting cities and ports via Maritime Informatics details the need for ports and their associated cities to jointly develop a cooperative, smart city and port environment (Rygh, Sánchez, González, and Rudolfsson, 2020). Increasing global urbanisation is leading to many of the world's population living and working in port cities; cites and ports need to work together to deploy technology to achieve the United Nations' sustainable development goals. The need for connected cities and ports broadens Maritime Informatics' scope because it recognises that the port is a transport hub connecting multiple modes of transport, such as road and rail, that are typically integral to a city's environmental footprint and efforts to reduce it. The flow of information across transport modes can support the reduction of a supply chain's impact upon the environment, a city, and its citizens.

Ports have always been an important part of society because they connect the land across the sea, connecting many of the world's major cities. Many of the world's most thriving cities are situated within a short distance of the sea or have direct access to one or more ports. Ports, because they handle the import and export of goods and frequently are services centres, they are the economic engines of cities and the hinterland that they service. Ports are also a base for a city's identity, social structure, and interaction with global markets.

Ports, cities, and citizens are parts of an increasingly bigger global system, where the demand for better speed and quality is an ever-increasing focus. Digitalisation and smart technologies open immense possibilities for innovative solutions for connecting ports and cities. This is also crucial for achieving the United Nations (UN) 2030 Agenda for Sustainable Development, in which the cities and their ports are key players for handling the global challenges due to increased urbanisation and the unsustainable use of resources.

New technologies and methods now offer the opportunity to improve the port-city relationship in a co-creational way, with its citizens. In order to achieve a sustainable future for the world, ports and cities will have to cooperate with the quadruple helix. These "stakeholders represent key local actors from government, research and scientific institutions, companies and citizens"[7]. If done sustainably and correctly, the new socio-technical solutions, using information systems and Information Technology, will increase the demand and quality of goods and services produced and improve the maritime supply chains and be essential to the future of maritime transport.

Information systems enable the industry to get "more out of less". The strength lies in learning from each other, digitalisation, standardisation, and building solutions together. However, During the twentieth century, the port-city relationship faced serious problems that still must be resolved. Before this relationship is improved, it will be hard to pinpoint any universal quick fix or solution on how to

[7] https://www.igi-global.com/dictionary/quadruple-helix-model/66791

make sustainable maritime solutions, which supports the needs of the maritime customers in a way that can handle the increased demand and production of goods and the necessary transport caused by this. The social connection gradually faded, as ports became automated, introduced no-go areas, provided fewer jobs, and increasingly quarantined themselves from the city. Ports turned their back on their cities. The social disconnection is also visible in the unbalanced power relationship established in ports' governance (Hesse, 2018).

In the present era, cyber-physical systems are connected electronically, a complete supply and value chain can be visualised, and some systems make decisions without human intervention. This fourth industrial revolution is not just Internet of Things (IoT), computers, and robotics but also "[...] encompasses areas which are not normally classified as industry, such as smart cities for instance" [8].

Suppose we are to mitigate the environmental footprint of humankind and achieve the UN SDGs (UN, 2019). In that case, we need information systems that contribute to reducing poverty and mitigating the gap between the rich and poor nations and regions. We need to find, test and use the opportunities not used or fully exploited by using new methods and tools, like the Smart City methods used in bigger and medium-sized cities, like Barcelona (ESP), Helsinki (FI), and smaller cities and municipalities, like Stavanger (NO), Vaasa (FI) or Umeå (SWE).

Ports will be important partners in this endeavour. Cities and ports need to find the right methods and information systems for handling and using data in a 'smart' manner. The use of open data and enabling scalability will be important for ports and cities to investigate and understand. Built on transparency and trust, it is necessary a good information systems governance to ensure correct usage of data and the systems, which safeguards individuals as well as the future of the maritime industry.

By using international standards, cities and ports can have tools to predict and govern maritime operations as well as increasing the quality of the city services and products to private local, regional, and national governments, researchers, universities and schools and supporting citizens with their needs in a co-creational way "aiming for an efficient global reach" and together be "The leading maritime cities of the future"[9]. Ports and the cities will likely make mistakes in determining their future, but they should adopt decision-making processes that aim to minimise endangering life, the environment, or the economy. This needs to be a balancing act in cooperation with others, so that we can learn from each other and hopefully avoid making the same mistakes more than once.

We will need robust and resilient solutions connecting cities with ports, ports with ports, and cities with cities. Digital transformation will require an inclusive governance process that embraces many viewpoints and produces economically and socially viable outcomes. It also needs to engender trust through transparency, facilitate innovation, support the development of standards, focus on generating sound, scalable, sustainable socio-technical solutions for present and future generations. We should not build solutions that only benefit a few. Smart technologies have much potential to improve port-city relationships, and their successful implementation is dependent on extensive collaboration and citizen involvement.

1.8. Maritime Informatics for Increased Collaboration

The chapter on "Maritime Informatics for Increased Collaboration" (M. Lind, Robert Ward, Michael Bergmann, et al., 2020) identifies the principal tensions and opportunities arising that are impacting the inevitable and ongoing digitalisation process that is underway in the maritime sector, particularly

[8] https://en.wikipedia.org/wiki/Industry_4.0
[9] https://www.menon.no/wp-content/uploads/Maritime-cities-2019-Final.pdf

through the authors' experience in the development and subsequent validation of the Port Collaborative Decision Making (PortCDM) concept.

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 among the most important along with exporters and importers. At the same time, the 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.

The digital trends emerging in shipping companies, ports with its actors, authorities and associations, and movements that are being made by diverse digital solution providers, within and outside the maritime domain are also identified. The discussion is taken from the point of view of shipping as a global phenomenon enabled by ship movements creating a global network of sea transport facilitated by ports. In this global transport network, the ports are playing a key role by being nodes in the global transport system.

The following developments are identified in the chapter as occurring now and are complementary and supportive towards optimising port call operations (M. Lind, Ward, Bergmann, Haraldson, and Zerem, 2019):

- Substantial efforts are being put into reducing the administrative burden during ships' visits through the implementation of the single window initiative;
- The IMO and other intergovernmental and international bodies are strongly encouraging standardisation and supporting the concept of just-in-time shipping;
- There are now international requirements for governments to introduce electronic information exchanges to make cross-border trade simpler and the logistics chain more efficient;
- Numerous digital solution providers are now developing tools to support enhanced port call efficiency;

In order to overcome the challenges that the maritime sector is now facing, the future must embody better and more efficient levels of collaboration. This can best be achieved through digitalisation. Enhanced connectivity and the opportunity for improved situational awareness and better coordination and cooperation in the port call process enabled by digitalisation is growing fast.

In the context of global initiatives towards the decarbonisation of shipping, port call optimisation with the help of digitalisation is among the important short-term measures that can significantly reduce the CO2 emissions of maritime transport. Coordinating ship and port calls activities so that ships arrive just-in-time rather than too early will allow ships to optimise voyage speeds, which will help avoid excessive use of fuel and reduce greenhouse gas emissions.

The digitalisation of navigation and international security arrangements is reasonably well covered by internationally agreed global standards and directives under the IMO, the EU, and other organisations' auspices. However, one of the dilemmas with digitalisation, standardisation, and data sharing in the port operations environment is the absence of over-arching 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 adopt common, interoperable data standards or 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 arrangements, including the control of shipping companies and ports at strategic places in the world, by using and imposing their own systems and procedures.

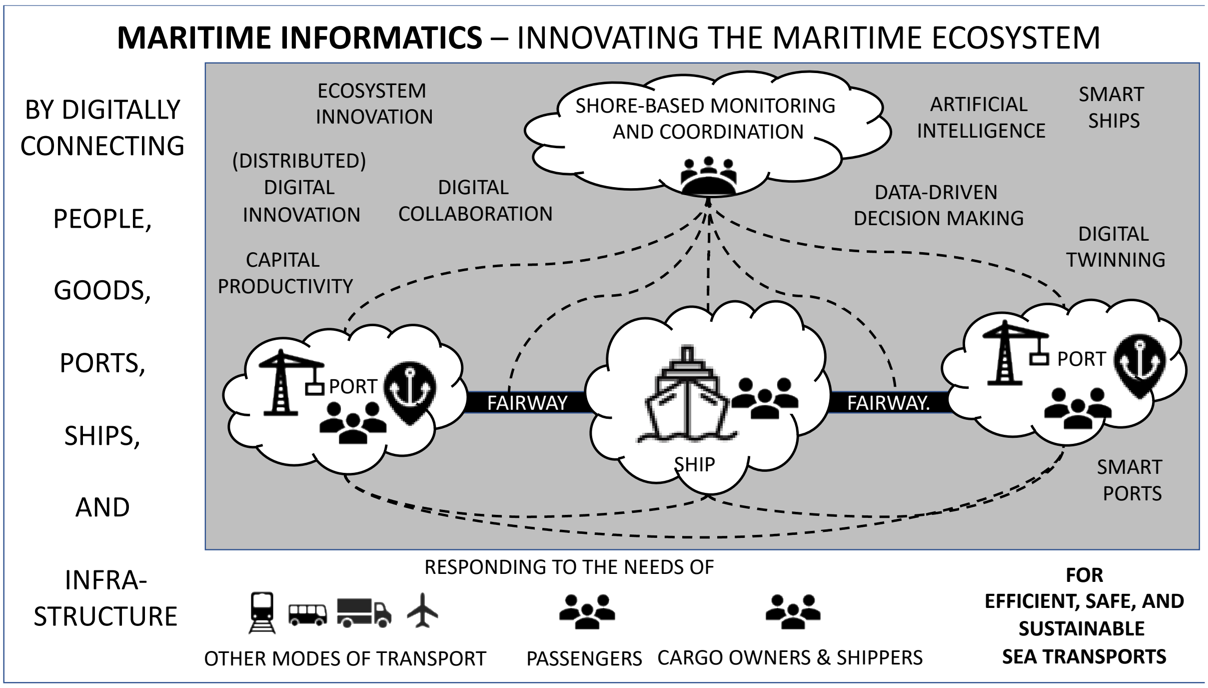
1.9.The future of shipping

The future of shipping is collaboration through digital data sharing give us an overview of lthe possible future directions concerning digital system and technology and associated changes in the shipping industry (M. Lind, Robert Ward, H. Hvid Jensen, et al., 2020). Readers will likely find particularly useful and thought-provoking the final paragraph in the chapter that lists seven expected significant transformations that flow from greater collaboration enabled by digital data sharing. For shipping executives, this is a set of waypoints for charting their enterprises' future.

Increased attention has lately been placed upon smartness and maritime operations, such as smart ships and smart ports. Operations are becoming electrified and automated. Maritime commerce's future is expected to be founded on process simplification, standardisation, connectivity, controllability, efficiency, and predictability. It is also forecasted that the volumes of data shared through digital data streams (DDSs) will expand dramatically in the coming years, and new opportunities for enhanced transparency will surface and there will be new avenues for collaboration. Such opportunities will enhance the quality of a common situational awareness along the maritime transport chain.

As addressed by the UN 2030 Agenda for Sustainable Development, there are many calls for maritime transports to be more efficient and accountable (DNV GL, 2018). In this context, Maritime Informatics is an important enabler. Maritime informatics covers many domains related to these calls (See Figure 2).

Figure 2: The concerns of Maritime Informatics



Source: Lind et al. (2020)

Maritime informatics can enable efficient, safe, and sustainable sea transport through digital connectivity between people, goods, ports, ships, and natural and physical infrastructure. It has a role to play for passengers, and cargo owners and shippers. Several emerging digitally based developments rely heavily on Maritime Informatics, smart ships and smart ports, digital twinning, artificial intelligence and machine learning, big data analytics, digital collaboration, and different innovation processes, all enabling enhanced capital productivity data-driven decision making. Maritime Informatics is a means of addressing some of the key challenges facing the maritime sector.

Maritime Informatics thus supports the integration of (maritime) (sub) practices and the supporting processes, procedures, and methods for the coordination within and among those enabled by digital collaboration and data sharing. This also means that Maritime Informatics can realise the integration goals (Hvid Jensen, 2020; Sames, 2019; Simha, 2019a, 2019b).

In the chapter focusing upon The Future of Shipping (M. Lind, Robert Ward, H. Hvid Jensen, et al., 2020), some transitions empowered by Maritime Informatics are forecasted, as, e.g.:

- From data sharing to data verification
- From disconnected to connected
- From shrouded to transparent visibility
- From semi-automatic to full automation
- From onboard to remote operations
- From static electrical grid demand to a flexible demand/supply Microgrid

The future of shipping is digitalisation, automation, and electrification empowered by maritime informatics. However, we should not forget that maritime transport operations are conducted primarily to fulfil the needs of those who are buying maritime transport services. We must, therefore, carefully ensure that any digital innovations provide value for those who pay for the services.

Standards will thus become increasingly aligned, and initiatives will be taken to continuously provide evidence of the value of digital collaboration in shipping environments. An efficient, safe, and environmentally sustainable sector needs to be developed harmoniously, in order to transform the maritime sector to compete in a digital future. The future of shipping is dependent on collaboration through digital data sharing You will likely find particularly useful and thought-provoking the following list of seven expected significant transformations that flow from greater collaboration enabled by digital data sharing:

- fragmented situational awareness ***to*** common situational awareness
- low information quality ***to*** high and reliable information quality
- vague planning horizons ***to*** predictable operations
- unstructured information exchange ***to*** standardised data exchange
- sub optimised operations ***to*** a mature collaboration culture
- unnecessary waiting times ***to*** just-in-time operations
- low information systems maturity ***to*** enhanced information systems maturity

These are exciting times for those willing to create the future of shipping.

2. CONCLUSIONS

Maritime Informatics provides the necessary foundation for a successful digital transformation of the shipping industry. As all seafarers know, setting off without a clear destination and necessary navigation tools is perilous. By collectively defining the scope of the emerging field of Maritime

Informatics, the editors and authors of this book (the first book on the topic) provide the industry with a family of linked charts that will enable this critical self-organising ecosystem to collectively design a more resilient, efficient, sustainable, and safer future.

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