Author Accepted Manuscript version of the book chapter: Cauwer, N.D. et al. (2021). The IMO Reference Data Model: One Solution Fits Most!. In: Lind, M., Michaelides, M., Ward, R., Watson, R.T. (eds) Maritime Informatics. Progress in IS. Springer, Cham. https://doi.org/10.1007/978-3-030-72785-7_4

The IMO reference data model – one solution fits most!

Nico De Cauwer, Martina Fontanet, Julian Abril Garcia, Hans Greven, Jeppe S. Juhl, Sue Probert, Mikael Renz, Ørnulf Jan Rødseth

Abstract

Digitalization is rapidly increasing in international shipping. From 2019, the International Maritime Organization (IMO) made it mandatory to allow electronic clearance of ships entering foreign ports. In preparation for this, the IMO Facilitation Committee started to develop a reference data model to harmonise the most important standards for ship clearance. The first version was published in 2020. The model is already extending into other areas of ship-port data exchanges and it is now increasingly seen as a tool to coordinate development of new electronic data exchange standards for ship operations. Lack of such coordination has, up to now, been a significant problem – this coordination will be essential in the relatively small and highly international market that shipping represents.

1.1 Digitalization of shipping and the role of IMO

Lloyd's Maritime Atlas [1] lists more than 8,000 ports around the world. In each of these ports there are different administrative and operational functions, each of them requiring information from and about the ship before the ship can enter the port. In addition, ships exchange information with other ships as well as with other shore functions. Some of these are illustrated in Figure 1.

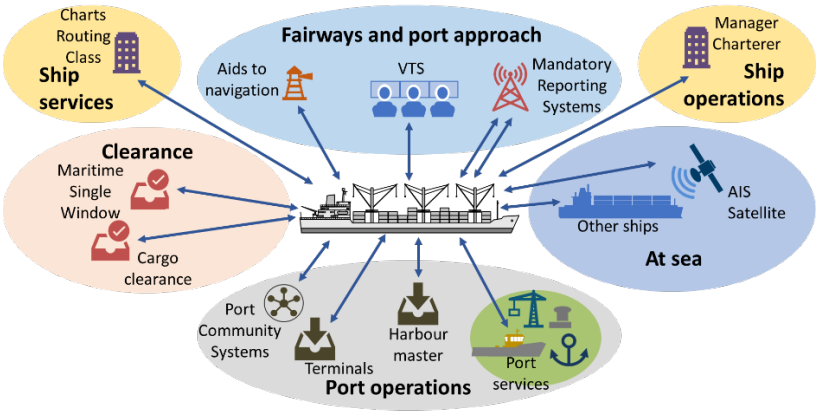

Figure 1 – Some entities the ship communicates with

These information exchanges are increasingly being digitalised. However, many different organisations are responsible for specifying these digital interfaces and most are operating on local or regional level without involving relevant international standards organisations. If this development continues, the lack of standardisation may become worse than the lack of digitalisation itself!

For internet and smartphone users, the billions of connected units create a common ecosystem that supports a natural evolution of standards. This is not likely to happen in shipping, with slightly less than hundred thousand ships in the world [2]. There is a very immediate need to focus on international standardisation, and IMO plays a central role in this.

The main purpose of IMO is to encourage and facilitate the general and international adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships. IMO is also empowered to facilitate international trade by simplifying administrative and legal matters related to these purposes. This is closely aligned with the 2030 Agenda for Sustainable Development and the associated sustainable development goals (SDG).

Ships carry 90% of world trade, including large amounts of food. Thus, shipping is vital to feeding the world (SDG 2). On the other

hand, the climate action goal (SDG 13) calls for full or almost full removal of CO_2 emissions, including from shipping. This requires new fuels and other technologies, but also a massive optimisation of operations to reduce unnecessary energy use. This is not possible without digitalisation. Digitalisation and automation will greatly improve the most important infrastructure for efficient global trade (SDG 9) – our ports and cargo ships.

In IMO, digitalisation of shipping and the ship-port interface is developed across several of its committees. The Maritime Safety Committee (MSC) is responsible for safe and efficient navigation and has developed the e-navigation concept to support this. The main aim of e-navigation is to enhance the navigational safety of ships while simultaneously reducing the burden on navigation officers.

The Facilitation Committee (FAL) is responsible for facilitation of international maritime transport. This includes international requirements for electronic port clearance. This was included as amendments to the FAL Convention in 2016 [3] which required public authorities to establish systems for electronic exchange of information by April 2019. The amendments also encouraged member states to implement a 'Single Window' environment as an effective way of delivering digitalised systems [4]. To support this, IMO also developed a new version of the Compendium on Facilitation and Electronic Business [5]. A central part of the compendium is the IMO Data Set and the IMO Reference Data Model.

1.2 The emergence of the IMO Reference Data Model

The IMO adopted the Convention of Facilitation of International Maritime Traffic, the FAL Convention, in 1965 [3]. This provided standard paper-based forms for the necessary ship reporting formalities. In 2001, the IMO FAL Committee approved the IMO Compendium' [5]. This was a description of how the paper-based forms could be digitalized, using the UN/EDIFACT data model. This served parts of the shipping community well for many years. However, by 2016 it was clear that a review of the compendium's format was required and that references to other

standards, such as those from the World Customs Organization (WCO) and the International Organization for Standardization (ISO), should be included. This developed into the idea of a specification-neutral reference data model.

WCO agreed to implement this 'eCompendium' but recognised that this mission needed a broader approach and involvement from more partners, including fellow standardisation bodies the United Nations Economic Commission for Europe (UNECE) and the ISO, maritime administrations, and trade associations. The core group of domain experts included BIMCO, representing the shipowners, and the International Port Community Systems Association (IPCSA).

An important challenge was how to deal with the existing standards and the impact on the different standard data models already in use. These data models have been implemented to reflect the specific focus of the organizations, e.g. the WCO data model representing the requirements from Customs organisations and regional authorities, or UNECE's UN/CEFACT data model focusing on trade and transport procedures and regulations. It was obvious to all parties that the impact on the existing models must be as small as possible.

The key word became 'harmonisation'. Harmonisation has nothing to do with the technology for data exchange, but everything to do with semantics and speaking the same language – that is what makes harmonisation so vital in developing interoperable technical standards. Technology represents the mechanism by which standards are implemented; as new technologies emerge and new ways of exchanging information evolve, new standard will be needed. Harmonisation, a clear data model structure and clear procedures for maintaining it, is vital for interoperability between different domains and between different technologies [10]. Thus, the focus of the eCompendium became the IMO reference data model and the corresponding IMO data set.

There are several examples of other subdomain developments similar to the IMO approach. For example, the industry group called SMDG [8] works mainly on data models for the container sector. Also, the PROTECT group [9] works for standardization of interactions between private businesses, and governments and port authorities. However, while internationally used standards have been developed and

implemented for decades, they always have been used within a specific maritime subdomain. There has never been an overarching reference model including all relevant data elements and data definitions.

Having started with the data elements from the FAL Convention and recognizing the vital importance of the reference data model, it became clear that the work to harmonise standards should continue. A consensus grew to expand the data model beyond what is required by the FAL Convention, supporting standardized and harmonized digitalization of other areas of ship transport operations. In 2019 IMO established a special Expert Group on Data Harmonisation (EGDH), under the auspices of the FAL Committee, that was tasked with expanding the range of the reference data model.

One example that should be highlighted is the harmonisation work carried out by the EGDH on the Maritime Declaration of Health (MDH). In the light of the enormous impact that COVID-19 has had on international travel, the importance of the EGDH's harmonisation efforts should be obvious. This work will be the basis for a short-term creation of a global standard for future specific MDH-messaging and worldwide reporting to authorities – a true digital transformation.

Since 2014, the FAL Committee agreed that electronic ship certificates should be treated as equivalent to traditional paper certificates [11]. All ships are required to carry certificates that establish their seaworthiness, type of ship, competency of seafarers, and so on. To facilitate the exchange of information related to certificates and access to e-certificates, the dataset on ship's certificates is also being included in the reference data model.

Rather than the divergence seen over the past years and the complexity of practical electronic information exchanges, resulting from the different data models, WCO and its partners had to find a way to streamline this process to achieve harmonization and convergence. This was done by building a new reference data model providing links to all the relevant standards and standard organizations' data models. The solution was to establish a level *above* the 'low level' architecture of these data models. And so, the IMO/IMO Reference Data Model was born.

The joint approach and co-creation model, through the IMO and involving such a broad group of stakeholders and maritime experts, is a 'first' for the industry.

1.3 Reference model design principles and resulting architecture.

The reference model was originally derived from the FAL Convention [3] and the IMO Compendium [5] by analysing the data elements that were listed in the various FAL forms. The list of data elements was reduced to one entry for each data element and assigned a number, a name, a description and detail of how to represent the data element, e.g. as a number, a code or a text string [6]. This was the basis for the IMO Data Set.

Later, the data elements were coordinated and adjusted to, as far as possible, fit into the international standards that are used to implement the relevant data transmission protocols, i.e. the WCO data model, the UN/CEFACT Core Component Library (CCL) and ISO 28005-2. The updated IMO Data Set was also structured into a common data model – the IMO Reference Data Model (IRDM). The data model and the data set were finally used to update the standards where necessary. This included providing a cross-reference between each standard's data elements and the corresponding IMO Data Set number. The process is schematically shown in Figure 2.

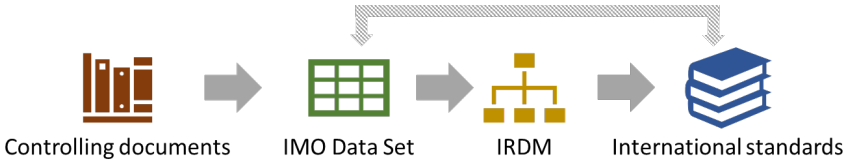

Figure 2 – The data model development process

This means that the data model has been constructed from the bottom up, based on the actual information requirements in the controlling documents, initially the FAL Convention. The data model represents the cross-section between the organizations' data models, that is defined by the controlling documents.

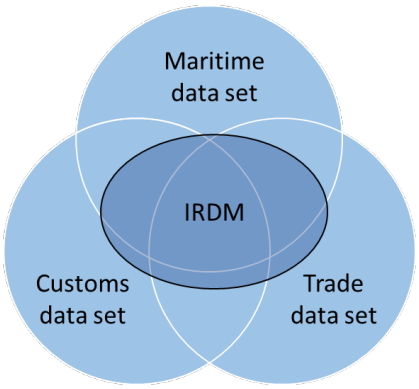

Figure 3 – IMO Reference Data Model (IRDM) represents the intersection of the standards

This provides for a semantic interoperability between the involved standards in this area. This in turn means that reports delivered in ISO 28005 or in UN/EDIFACT can easily be mapped to the correct data element in the database of the Maritime Single Window (MSW). Furthermore, the associated data model defined by the reference model can, if desired, be used as a readily available 'blue-print' for constructing the MSW's database. This is important to ensure that the national MSWs all are requesting the same type of information and in the same format.

Work is under way to extend the reference model toother reporting requirements and other ship transport operations. This includes mandatory ship reporting systems, waste delivery, port call information and more.

The eventual scope of IMRD can be said to be all information elements where a standardised semantic definition and representation helps to facilitate ship operations and port calls. This means that the IMO committees involved in the maintenance of the model should be broadened to include the Maritime Safety Committee (MSC), in particular its sub-committee on Navigation, Communication, Search and Rescue (NCSR), and the Maritime Environment Protection Committee (MEPC). Correspondingly, new standard organisations should when needed, be added to the EGDH.

There are also important benefits in extending the use of the reference model to some of the e-navigation maritime services. The inclusion of these datasets will link

the reference model to the IHO S-100 framework for e-navigation [12] and its Common Maritime Data Structure [13], [14].

1.4 Using the reference model – application cases

This section describes three use cases for IMDR where each is enabled or significantly simplified by having a harmonized reference model. This shows that the IMDR is indeed a prerequisite for a sustainable and rapid development of a digitalised maritime infrastructure and ecosystem, including further automation of administrative and operational processes on the ships and in port.

1.4.1 Harmonised and interoperable use of different standards

The starting point for IMDR was to harmonise three international standards for ship to port state reporting. A consequence of this is that any of the standards can be used where it is most suitable without any fear that data needs to be reported twice or that there are semantic misunderstandings related to some data items. This is illustrated in Figure 4.

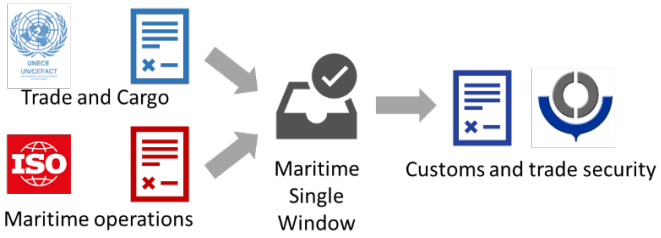

Figure 4 – Interoperability between standards

IMDR has been used as a tool to provide common semantics and representation for the data elements that are needed for the MSW. With mapping tables provided from each of the organisations between own codes for the data elements and the IMO Data Set, it is straightforward to achieve full interoperability between the standards.

As the scope of IMDR increases, e.g. with inclusion of electronic ship certificates and ship-port interfaces, it also becomes apparent that interoperability between

many new actors will become a critical factor in making shipping as an industry more efficient. IMDR will also facilitate the future smarter shipping operations.

1.4.2 Reduction of the administrative burden

The shipping industry uses significant resources at a substantial cost to comply with the administrative work imposed by standards and regulations for safety at sea, maritime security, training, certification and protection of the marine environment. Port call and pre-arrival reporting are based on national requirements, but shipping is a global business and truly international solutions are necessary to alleviate the administrative burdens imposed on seafarers [15].

On board the ship, the preparation of the port and pre-arrival documentation is one of the most cumbersome administrative tasks. As an example, feedback from ships has shown that port and pre-arrival documents, even when submitted by e-mail prior to arrival, do not exempt the ship from submitting the very same document in hard copy to the same authority on arrival. Failure to do so may result in delays, and sometimes even fines. The seafarers also highlight the differences in formats and forms used in different countries and ports when, essentially, it is the same data that is being handled.

A common international solution for a standardized reporting platform, like the IMO electronic single window, would resolve this problem. However, so far most national authorities have developed own procedures and forms and, as a result, there is no consistency or common standard. The development of IRDM and the harmonization of the main standards used in electronic ship reporting, has the potential to solve this problem by providing the national authorities with a IMO endorsed common data set and associated international standards.

1.4.3 Just-In-Time arrival

The Just-In-Time arrival (JIT) concept in the maritime industry is not new. BP Shipping and Maersk tried it out as early as 2009 [16]. While there are obstacles to the implementation [17], today's higher focus on CO_2 emissions makes it interesting to look at reductions in the range from 7% to 19% [18].

The basic concept is that the speed of a ship is adjusted to arrive only when it can proceed directly to a berth or terminal without delay. This can reduce emissions, congestion in port as well as costs.

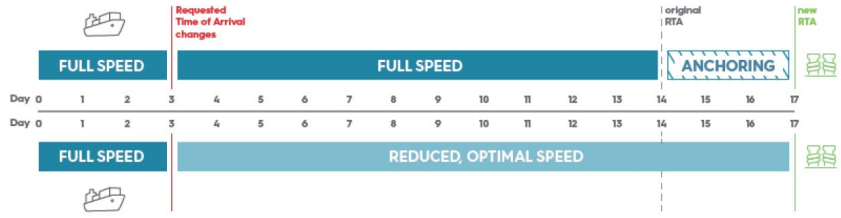

Figure 5 – JIT versus conventional full speed ahead [19]

To overcome obstacles and provide an effective implementation, clear and frequent communication between all actors in the ship-shore interface before, during and after operations is needed. Actors include ship owners and operators, charterers, ship agents, authorities, port and terminal operators, as well as many ship service providers, such as towage, pilotage, mooring and more. Harmonised communication between all actors is needed, as any gap in communication may lead to operational inefficiency or even incidents that jeopardise safety and/or protection of the environment. The ship-port interface is at time of writing being worked into the IRDM and will be standardized by ISO.

1.5 Governance and maintenance

Technology and standards are continuously changing but those changes will have no impact on the harmonised rules already agreed and recorded in IRDM.

The advance of technology and messaging brings new and better ways of sharing data and information, but this also requires the IMDR to ensure the same understanding between new and old parties, whatever new process is integrated into the emerging digital ecosystem for ports and ship operations. IRDM ensures that when parties do exchange data, they know that the systems are ‘talking’ about the same things.

It is essential to be sure that these basics are correct and understood in the same way by everybody involved in the domain of Maritime Informatics. In this regard

robust and trustworthy governance and maintenance of IRDM is of utmost importance.

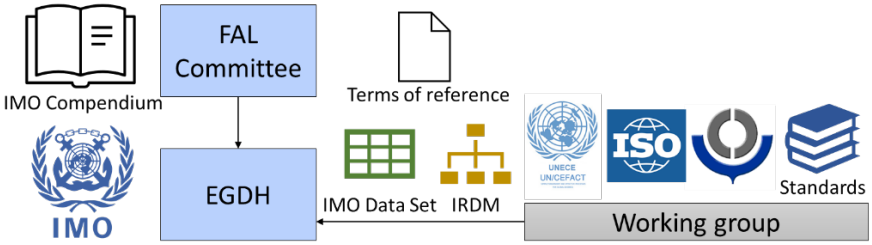

Figure 6 – Main elements in the governance and maintenance of the IMO Compendium

1.5.1 Governance of the IMO Compendium

The IMO Compendium on Facilitation and Electronic Business (IMO Compendium) is under the purview of the FAL Committee, that decides on what new datasets are to be included in IRDM, as well as when they are to be examined by the EGDH, according to the urgency.

It was foreseen that the IMO Compendium would cover areas beyond the FAL Convention and the scope of the FAL Committee, and so it is named the IMO, not FAL, Compendium. The electronic exchange of data between ship and shore is required in connection with several other IMO instruments and committees. Accordingly, the FAL Committee at its 43rd session (in 2019) invited other IMO committees and subcommittees to approach it for advice and assistance in preparing the electronic reporting and information exchange requirements for their current and future mandatory instruments. Two examples that are already included in IRDM are security-related information and the advance notification of waste to be delivered at port facilities. The respective controlling documents are maintained by the Maritime Safety Committee (MSC) and the Marine Environment Protection Committee (MEPC).

1.5.1 Maintenance of the IMO Compendium and data model

The IMO Data Reference Model and the IMO Data Set is now the main components of the new IMO Compendium. The Compendium must be kept up to date –

for instance, when the FAL Convention or any other of the other controlling documents are reviewed and updated. This will often require changes in or updates to the IMO Compendium. Likewise, if errors or omissions in the IMO Compendium are identified, maintenance is needed to correct the dataset and model. In addition, when extending IRDM with new applications, some already existing IMO data elements may need amendments, e.g. to be further generalized and reused in the new applications.

Maintenance is needed in all these cases to keep the IMO Compendium up to date over time. The EGDH is the group that at IMO level deals with the incremental development of IRDM. It consists of representatives from some of the IMO Member States, the partner standardization bodies UNECE, ISO and WCO, and of other experts from the maritime and port industry, represented through the NGOs with consultative status at the IMO. The EGDH meets twice a year and its terms of reference are reviewed annually by the FAL Committee. The terms of reference is used to update the scope of IRDM and to define the relevant controlling documents.

The EGDH follows established working procedures agreed by the FAL Committee which are continuously reviewed as the group gains experience. The EGDH examines and prepares the proposed changes to the IMO Data Set and Reference Data Model and submits them to the FAL Committee for approval.

From time to time, the partner standards organisations together with interested national or NGO experts meet outside the EGDH meetings to do preparatory work for EGDH.

1.5.2 Partnership agreement

In March 2020, to ensure maintenance of the original IRDM as well as alignment to the respective standards, the IMO, WCO, ISO and UNECE signed a partnership agreement establishing the conditions of cooperation for the maintenance of the IMO Data Reference Model. Through this agreement, WCO, UNECE and ISO agreed to cooperate to maintain the IMO Reference Data Model and use it as reference when maintaining their individual standards, in accordance with their respective policies and procedures.

1.6 Status and outlook

When the IMO Compendium was designed, a core principle was that it was not supposed to be a 'new' specification but rather a tool to harmonise other technical standards. The goal was to produce a guidance for all interested parties how to map the datasets arising from the different controlling documents, to any of the international standards. This makes it much easier to create software that can communicate no matter what technical standard they were based on. Hence, any relevant organisation responsible for a standard or a data model in the general scope of IRDM is welcome to use or contribute to the IMO Compendium.

This open approach can be described as a bow-tie concept, having the IMO reference data model in the centre. The data model side is described to the left, whereas the business opportunities leading through implementation is illustrated by the right part of the bow-tie concept as illustrated in Figure 7. This also illustrates the potential in developing new opportunities to the right, making use of the data model and corresponding harmonized technical standards to the left.

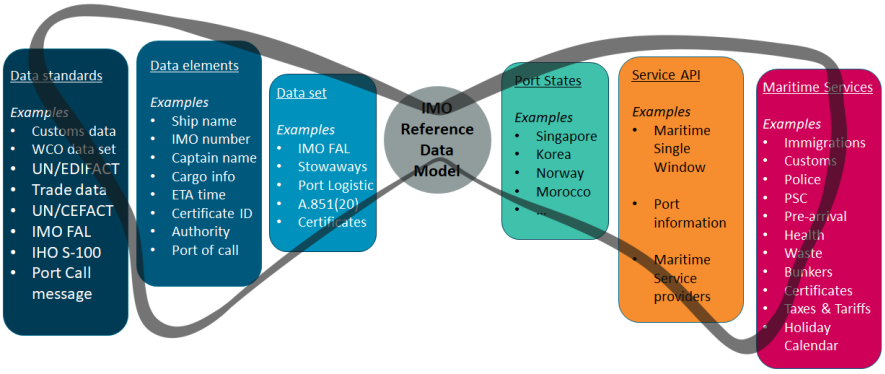

Figure 7 – Illustrating the so-called Bow-Tie Concept, having the IMO Reference Data Model in the centre.

Common definitions are a prerequisite for harmonisation, a reference data model promotes interoperability, and common definitions and code lists encourages communities to share goals. The larger the scope of IRDM, the larger communities can be created among e.g. administration agencies, ports, terminal and other regional or

international parties. This obviously also includes the ship owners, managers, and charterers. Harmonisation, interoperability, and a large enough community are crucial to the individual organisation's goals of leveraging technology, minimising administrative burdens, promoting digitalization, and helping all stakeholders meet international standards.

The IMO Compendium is currently covering the information in the seven FAL forms, waste information, health declaration and expanded information on the estimated time of arrival and berth for the just-in-time concept. During 2020, the EGDH also finalised work on stowaway reporting, as well as the ship certificates that are required to be carried onboard.

The Maritime Safety Committee (MSC) has through its e-navigation work approved 16 maritime services based on message exchange between ship and shore. The EGDH has developed or will soon develop datasets for port operational services as well as mandatory ship reporting systems, that can be used to implement some of them. It also approved data sets required to manage automated machine to machine message exchanges. It is expected that these datasets will be approved by the FAL Committee during 2021, but many new data sets are in the pipeline for being amended to the IRDM.

Looking into the future, we can see more work being done on both e-navigation and other port services that are important for ship calls. This will make it desirable to work closer with the main stakeholder organisations. This includes IMO committees such as MSC and MEPC, as well as IALA, IAPH, IPCSA and many others.

The International Hydrographic Office (IHO), which is responsible for the geographic information system, including nautical charts, is also defining some operational data in the new S-100 framework for maritime geographic information systems [12]. A link between the IMO Compendium and the product specifications for the S-100 family will be necessary. Together with developments in the VHD Data Exchange System (VDES), this gives ships another way to communicate with shore-based systems.

Figure 8 – Many new digital services will emerge

The IMO Compendium is growing, and it is the only instrument where different maritime standard organisation can cooperate to develop a common information model with unified semantics that can be mapped to their respective standards. This can be used not only to translate between the different standards but also as a tool to ensure the same vocabulary when describing flows of information, making it possible to integrate the reporting formalities of the authorities with the concepts of e-navigation and the operational needs in the port, enabling a connected and integrated world.

1.8 Conclusions

Digitalisation is a prerequisite for our modern world, including all part of shipping. Recently, the COVID-19 pandemic has also led to increased focus on the role of digitalisation in empowering maritime operations to become a part of the wider supply chain. Both require smart communication between ship and shore.

There are many examples of data-driven demands faced by the industry today. To name a few, port authorities are using real-time data from across the transportation ecosystem to improve capacity utilisation, energy efficiency and throughput.

Customers are increasingly expecting real-time updates on freight location and delivery dates. Environmental and safety concerns create new reporting requirements. With the extended use of digital data over many domains, it becomes clear that a single technical standard cannot provide the necessary coverage to support all these functions and gain the full benefits of digitalisation.

New systems and applications using onboard sensors can provide more economical operations and better predictive maintenance. For the ship operator, this leads to much better usage and management of assets, reductions in unplanned downtime and an improved carbon footprint. This has positive safety, efficiency and environmental effects that helps to meet society's expectations in relation to the sustainability of ship transport. Looking ahead, smart and autonomous ship trials are proceeding around the world, bringing even more possibilities and challenges for ship operators and others in the sector.

Hence, the maritime industry needs to be striving towards solutions that enables smart and seamless exchange of information between all involved parties. International standards are already in use around the globe – but these standards are not harmonised between the different standards organisations and the domains they represent. Some of these standards are also adapted only at a local or national level. It is commonly acknowledged that improving the quality and availability of many different real-time operational data is critical to facilitating the arrival, stay and departure of ships, persons and cargo. Hence, harmonisation of existing industry standards is required to improve the digital information exchanges.

The harmonisation work – which in fact is 'standardisation of the semantics', as opposed to standardisation of electronic messages – is needed to give the maritime world a sufficiently strong foundation for the implementation of efficient and pervasive electronic business processes. The IMO Reference Data Model (IRDM) will be a central element in this. It is a unique and very promising new development in the domain of Maritime Informatics. Digitalisation happens now: the IMO Reference Data Model is a one-off opportunity for future digital business!

Disclaimer

This disclaimer informs readers that the views, thoughts, and opinions expressed in the text belong solely to the author, and not necessarily to the author's employer, organization, committee, or other group or individual.

Acknowledgements

Part of the work reported on in this text was performed in the AEGIS project, that has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement 859992.

References

[1] Lloyd's Maritime Atlas of World Ports and Shipping Places 2020-2021, ISBN 9780367427108, 2019.

[2] UNCTAD 2020 Handbook of Statistics, United Nations, Geneva, 2020, ISBN: 978-92-1-112997-7.

[3] Convention on Facilitation of International Maritime Traffic (FAL), entry into force 1967, as amended.

[4] IMO circular FAL. 5/Circ.42 'IMO Guidelines for setting up a Maritime Single Window', May 2019.

[5] The IMO Compendium on Facilitation and Electronic Business [Online], retrieved December 2020, https://www.imo.org/en/OurWork/Facilitation/Pages/IMOCompendium.aspx

[6] The IMO Reference Data Model data set [Online], December 2020, https://svn.gefeg.com/svn/IMO-Compendium/Current/index.htm

[7] IMO Compendium on facilitation and electronic business, Annex to FAL.5/Circ.15, Electronic Data Interchange (EDI) for the Clearance of Ships, February 2001.

[8] SMDG e.V. [Online], http://www.smdg.org/, January 2021

[9] PROTECT Group [Online], http://www.protect-group.org/, January 2021.

[10] Cauwer N.D., Morton R., Why Standards Matter, Port Technology, Edition 85, 2019.

[11] IMO Guidelines for the Use of Electronic Certificates, FAL.5/Circ.39/Rev.2, April 2016

[12] S-100 Universal Hydrographic Data Model – What is the IHO S-100 Standard? [Online], retrieved December 2020, https://iho.int/en/s-100-universal-hydrographic-data-model

[13] Rødseth ØJ. Integrating IEC and ISO information models into the S-100 Common Maritime Data Structure, E-navigation Underway International 2016; Copenhagen, Denmark, February 2016.

[14] Rødseth ØJ. A maritime ITS architecture for e-navigation and e-maritime: Supporting environment friendly ship transport. In2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC) 2011 Oct 5 (pp. 1156-1161). IEEE.

[15] Danish Maritime Authority, Survey on administrative burdens among international seafarers. Final Report – International Seafarers, 2013.

[16] Maersk, Sustainability Report 2009. A.P. Moller-Maersk, Copenhagen, 2009.

[17] Poulsen RT, Sampson H. 'Swinging on the anchor': The difficulties in achieving greenhouse gas abatement in shipping via virtual arrival. Transportation Research Part D: Transport and Environment. 2019 Aug 1;73:230-44.

[18] Jia H, Adland R, Prakash V, Smith T. Energy efficiency with the application of Virtual Arrival policy. Transportation Research Part D: Transport and Environment. 2017 Jul 1;54:50-60.

[19] IMO et al., Just In Time Arrival Guide – Barriers and Potential Solutions, IMO, 2020.