User-Centric Development of International Maritime ITS

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Intelligent Ship Transport System

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Executive Summary

The Intelligent Ship Transport System (ISTS) project is focused on advancing the adoption of user-centred Intelligent Transport Systems (ITS) standards within the maritime sector. Work Package 1 (WP1) in this project is focusing on defining user requirements and understanding industry needs. WP1 employs a bottom-up approach to maritime ITS standardization, gathering insights directly from stakeholders to ensure that the resulting standards are both relevant and practical. This work package centres on analysing drivers and barriers within the industry, identifying specific user requirements, and incorporating insights from more mature ITS efforts in the road and aviation sectors. By leveraging these cross-sectoral insights, WP1 provides a foundation for maritime ITS standards that can avoid common implementation challenges and accelerate sector-wide adoption.

WP1's findings highlight the need for ITS standards that emphasize interoperability, regulatory harmonization, and adaptability to evolving technologies. Through stakeholder consultations, WP1 identifies gaps in current standards, such as limited interoperability, fragmented regulatory frameworks, and reliance on legacy systems. In response, WP1 recommends a modular approach to standardization, allowing for flexibility and enabling future adaptation. Furthermore, WP1 emphasizes the importance of collaboration among diverse maritime stakeholders—including ship operators, regulatory bodies, and technology providers—to ensure that ITS standards address real-world operational needs.

The expected impact of WP1's contributions include greater relevance and usability of standards, aligning them with the actual challenges faced by maritime operators. This alignment is anticipated to enhance operational efficiency and encourage broader adoption and compliance. By prioritizing user-centred requirements, WP1 fosters continuous feedback and encourages innovation, creating a foundation for an ITS framework that will remain responsive to technological advancements and evolving industry needs. Through these efforts, WP1 contributes to the development of a more unified and adaptable ITS framework that supports safer, more efficient, and sustainable operations within the maritime sector.

Abbreviations

ATM Air Traffic Management

CCAM Cooperative, Connected, and Automated Mobility

C-ITS Cooperative Intelligent Transport Systems

DCSA Digital Container Shipping Association

FAL Convention Convention on Facilitation of International Maritime Traffic

GHG Green House Gas

IALA International Association for Aids to Navigation and Lighthouse Authorities

ICAO International Civil Aviation Organization

ICT Information and Communication Technologies

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronics Engineers

IGO Intergovernmental Organizations

IHO International Hydrographic Organization.

IMO International Maritime Organization

ISO International Organization for Standardization

ISTS Intelligent Ship Transport System

ITS Intelligent Transport Systems

ITU International Telecommunication Union

JIT Just in Time

MSM Maritime Single Window

NextGen Next Generation Air Transportation System

NGO Non-governmental Organizations

PCS Port Community Systems

RTCM Radio Technical Commission for Maritime Services

SARPs Standards and Recommended Practices

SESAR Single European Sky ATM Research

UNECE United Nations Economic Commission for Europe

V2I Vehicle-to-Infrastructure

V2V Vehicle-to-Vehicle

WCO World Customs Organization

1 Introduction

1.1 Background

The maritime industry is facing a transformation driven by advancements in technology, particularly in the areas of automation, digitalization, and Intelligent Transport Systems (ITS). As shipping operations become increasingly complex, there is a growing need to enhance the efficiency, safety, and environmental sustainability of maritime transport. ITS offers a promising solution by enabling more informed decision-making, better coordination between stakeholders, and improved operational performance.

ITS are advanced applications that aim to provide innovative services related to different modes of transport and traffic management. They enable users to make more informed decisions, leading to enhanced safety, efficiency, and sustainability in transport operations. In the maritime sector, ITS applications can range from real-time vessel tracking and port management systems to automated navigation aids and predictive maintenance technologies. These systems, when effectively implemented, can revolutionize maritime operations by reducing human error, minimizing delays, and improving resource management, thereby contributing to safer and more sustainable maritime transport.

However, the successful deployment of ITS in the maritime sector requires a robust framework of standards and interoperability. This is essential to ensure that diverse technologies and systems can communicate and operate seamlessly with one another. Interoperability is particularly critical in the maritime domain, as vessels and port facilities often rely on a combination of legacy systems and new, cutting-edge technologies. Without standardized protocols and frameworks, integrating these systems into a cohesive ITS network is highly challenging, potentially leading to inefficiencies, increased operational costs, and heightened safety risks.

Given these challenges, a user-centric approach in the development of ITS for maritime applications is important for creating systems that are not only technologically advanced but also aligned with the actual needs and conditions. This approach could enhance the usability, adoption, and regulatory compliance of ITS, driving more efficient, safe and sustainable maritime transport.

1.2 Objectives and Expected impact

The primary goal of the ISTS project is to develop an international maritime ITS using a bottom-up approach. This approach emphasizes understanding and integrating users' needs alongside evolving and existing standards. The objectives of WP1 focus on understanding user needs and industry dynamics for maritime ITS development, including 1) Analysis of drivers and barriers from different perspectives, 2) Identification of user requirements. This deliverable will also draw on cross-sectoral insights, particularly from the road and aviation sectors, where ITS standardization efforts have been more successful. By leveraging these insights, the maritime sector can avoid common challenges and accelerate the development of effective, user-centred ITS frameworks.

The expected impact includes enhanced relevance and usability of standards, which are anticipated to be more closely aligned with the actual needs and challenges faced by maritime operators. This alignment is expected to lead to efficiency and satisfaction among users. Additionally, by addressing user needs, the ISTS project is likely to see improved adoption and compliance with the new standards. Furthermore, a focus on user requirements encourages continuous feedback and innovation, which

will facilitate ongoing improvements to the ITS framework and ensure it keeps up with technological advancements.

1.3 Scope and Structure of this report

This report focuses on the development of a user-centric framework for maritime ITS standards, with the objective of creating a cohesive, adaptable, and interoperable architecture that supports diverse maritime stakeholders. While setting technical standards is essential for developing and deploying ITS, non-technical factors also play a key role in successful adoption. These include regulatory frameworks, stakeholder collaboration, training and certification, and support from the public and policymakers. By examining user requirements, regulatory frameworks, and technological innovations, the report identifies both the drivers and the barriers for ITS standardization in the maritime sector. The findings presented here are based on insights from cross-sectoral ITS applications and specific stakeholder feedback gathered throughout the project.

The structure of this report is as follows:

- **Chapter 2** provides cross-sectoral insights from ITS applications in road and aviation sectors, exploring how regulatory frameworks, stakeholder collaboration, and training have contributed to their success. These insights offer valuable lessons for advancing ITS in the maritime context.
- **Chapter 3** offers an overview of current maritime ITS standardization efforts, discussing key initiatives, frameworks, and the primary domains where standardization efforts are underway.
- **Chapter 4** analyses the drivers and barriers influencing maritime ITS standardization. It examines how factors such as regulatory alignment, technological advancements, and resource limitations impact the development and adoption of standards.
- **Chapter 5** outlines the establishment of user requirements, drawing on expert interviews and stakeholder input to capture the needs and expectations of maritime users.
- **Chapter 6** bridges identified gaps in current standards with user requirements, providing specific recommendations for standards evolution to ensure they meet practical and operational needs.
- **Chapter 7** concludes the report with a summary of findings, emphasizing the importance of a collaborative, user-centred approach in advancing maritime ITS standardization.

This structure aims to guide stakeholders in understanding the critical factors influencing ITS standardization, while also providing actionable recommendations to drive global alignment and adoption.

2 Cross-Sectoral Insights on ITS Standardization

ITS refers to the application of information and Communication Technologies (ICT) in transportation. The concept of ITS emerged in the latter part of the 20th century, driven by technological advancements and a growing need for more efficient, safe, and sustainable road transportation solutions. A key focus was traffic centers developed to manage capacity and safety on roads, tunnels, bridges, and mountain passes[1]. This concept extended to the aviation sector, which has seen advancements in ITS applications. These advancements have enhanced navigation, scheduling, and overall traffic management in the air. The maritime sector could benefit from the road and aviation sectors' experiences and best practices. By examining their standardization practices, the maritime industry can adopt strategies to overcome its unique challenges and develop more integrated ITS solutions.

2.1 Regulatory Frameworks

One of the foundational aspects of successful ITS deployment in the road and aviation sectors is the establishment of clear and harmonized regulatory frameworks. For example, WP.29[2] develops international standards and regulations focused on vehicle safety, environmental performance, and energy efficiency. By coordinating these regulations globally, WP.29 helps ensure that vehicles meet uniform safety and performance standards, facilitating trade, enhancing interoperability, and supporting the seamless integration of intelligent transportation systems across different countries. WP.29 supports the advancement of road ITS by providing a unified set of regulations that help standardize vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication protocols, which are critical for the effective functioning of ITS technologies. These standardized protocols ensure that vehicles from different manufacturers can interact seamlessly within intelligent transportation systems, enabling safer, more efficient, and reliable road networks. Additionally, WP.29's regulations on automated and autonomous vehicle technologies help pave the way for consistent safety and performance benchmarks, fostering innovation while maintaining public trust in these new technologies.

Similarly, the International Civil Aviation Organization (ICAO) has developed Standards and Recommended Practices (SARPs) that are applied consistently across countries, facilitating high safety standards and interoperability within aviation networks. By ensuring consistent procedures across countries, SARPs enable interoperable and intelligent systems that enhance air traffic control, optimize route planning, and improve communication and data exchange between aircraft and ground systems, advancing the goals of ITS in the aviation sector.

2.2 Stakeholder Collaboration

Effective stakeholder collaboration has proven essential for successful ITS implementation in the road and aviation sectors. In the road sector, the European Commission established the C-ITS Platform[3] to support the interoperable deployment of Cooperative Intelligent Transport Systems (C-ITS) across the

[1] https://its-norway.no/en/about-its-norway/what-is-its/
[2] https://unece.org/wp29-introduction
[3] https://transport.ec.europa.eu/transport-themes/smart-mobility/cooperative-connected-and-automated-mobility-ccam_en

EU. The C-ITS Platform played a vital role by bringing together national authorities, private sector stakeholders, and the European Commission to develop a shared vision for the interoperable deployment of C-ITS. This collaborative framework fostered public-private partnerships that facilitated policy alignment, helped address cross-cutting challenges like data security, and supported the coordinated rollout of real-life pilot projects, which tested C-ITS technologies and laid the groundwork for Cooperative, Connected, and Automated Mobility (CCAM) in the EU.

In the aviation sector, programs like SESAR (Single European Sky ATM Research)[4] and NextGen (Next Generation Air Transportation System) [5] are key initiatives aimed at modernizing air traffic management (ATM) systems in Europe and the United States, respectively. SESAR focuses on developing and implementing advanced ATM solutions across Europe to optimize airspace usage, reduce delays, and enhance environmental sustainability. In the U.S., NextGen aims to transform ATM by integrating satellite-based systems and digital communications to improve efficiency and safety. Both SESAR and NextGen bring together airlines, airports, air traffic control, and regulatory authorities. This collaborative effort aligns diverse stakeholder interests, facilitates joint decision-making, and drives coordinated advancements in ATM technology. Through these partnerships, the programs ensure that new technologies are seamlessly integrated, fostering interoperability and achieving shared safety and efficiency goals.

2.3 Training and Certification

In both the road and aviation sectors, standardized training and certification are important for ensuring safety and operational consistency. These processes play a fundamental role in ITS standardization efforts, as they ensure that personnel can effectively handle advanced technologies.

Currently, training and certification programs specifically aimed at enhancing cross-border interoperability in road traffic systems are limited. However, standards like ISO 39001, which establish a foundational framework for road traffic safety management, could serve as a strong basis for developing such programs. ISO 39001 provides a universal framework for managing and improving road safety at the organizational level, though it doesn't explicitly address international interoperability. Still, its guidelines for creating consistent safety practices that could be adapted and expanded upon through targeted training and certification programs to support cross-national integration.

For the aviation sector, aviation professionals, particularly pilots, air traffic controllers, and maintenance personnel, already undergo standardized training and certification processes at an international level, primarily governed by ICAO. ICAO's Standards and Recommended Practices (SARPs) ensure that personnel are trained to a consistent global standard, allowing for seamless international operations and interoperability. For instance, airline pilots are trained to meet ICAO guidelines, which allows them to operate under compatible procedures and systems across different countries. However, as the aviation sector increasingly integrates ITS technologies, additional training and certification programs could be beneficial for personnel involved in newer aspects of ITS, such as advanced automation, real-time data sharing, and enhanced air traffic management systems. These areas may require specialized skills beyond traditional training, aimed specifically at supporting the

[4] https://sesar.eu/sesar
[5] https://www.faa.gov/nextgen

interoperability and cross-border functionality of ITS systems. Such focused programs could further reinforce regulatory compliance and operational efficiency, expanding upon ICAO's existing global standards to address the specific challenges and opportunities that ITS technologies bring to aviation.

2.4 Policy Support

Effective regulatory frameworks and stakeholder collaboration efforts can be further strengthened by strong policy support, as seen in both the road and aviation sectors.

The European Commission's Action Plan for ITS[6] has helped secure both funding and legislative backing, emphasizing the benefits of ITS in terms of safety, efficiency, and environmental sustainability. This policy-driven approach ensures that ITS technologies are not only adopted but also integrated effectively across the European road network, facilitating interoperable systems that benefit all member states.

Similarly, in the aviation sector, the SESAR project is part of the EU's broader Single European Sky initiative[7], which aims to modernize and harmonize European air traffic management (ATM). This project receives ongoing support through EU regulations and structured funding, allowing it to develop and deploy ATM solutions across European airspace.

2.5 Lessons Learned for Maritime ITS

The insights gained from the road and aviation sectors point out several lessons that the maritime industry can apply to its ITS development efforts shown in Table 1.

Establishing a unified regulatory framework for maritime ITS, similar to those in road and aviation, can facilitate global interoperability and safety. Engaging with international bodies such as IMO and IALA can help the maritime industry develop and implement consistent standards that promote safe and efficient ITS adoption across regions.

Building collaborative platforms among key stakeholders, as seen in the road and aviation sectors, can streamline ITS integration and drive innovation. By facilitating cooperation among shipowners, port authorities, regulators, and technology providers, the maritime sector can ensure that ITS solutions meet the diverse needs of its stakeholders while promoting industry-wide standards.

Just as standardized training and certification have proven critical in the road and aviation sectors, the maritime industry should expand its training frameworks to cover ITS-specific competencies. This investment in workforce development will be key to safe ITS operation and broad industry adoption.

Advocating for ITS benefits to policymakers and the public can provide the maritime industry with the necessary support to accelerate ITS adoption. Emphasizing safety, efficiency and environmental benefits will align ITS initiatives with broader policy goals, attract investments, and drive legislative support.

[6] https://transport.ec.europa.eu/transport-themes/smart-mobility/road/its-directive-and-action-plan_en
[7] https://transport.ec.europa.eu/transport-modes/air/single-european-sky_en

By incorporating these lessons, the maritime industry can develop a more robust, user-centric ITS framework that aligns with global safety and sustainability objectives. As the sector continues to evolve, adopting a holistic approach that integrates regulatory frameworks, stakeholder collaboration, training, and policy advocacy, will ensure that maritime ITS remains responsive to the needs of the industry and its stakeholders.

Table 1 Lessons learned from road and aviation sectors and their application to maritime ITS.

Lesson	Road Sector	Aviation Sector	Application to Maritime ITS
Regulatory Frameworks	UNECE WP.29 established globally harmonized vehicle regulations, reducing fatalities and emissions.	ICAO SARPs set global standards for safety, security, and efficiency, enforced by FAA and EASA.	Develop clear and harmonized regulations through IMO and the International Hydrographic Organization (IHO) to ensure safety and interoperability in MITS.
Stakeholder Collaboration	European C-ITS Platform coordinates vehicle manufacturers, infrastructure providers, and agencies.	SESAR and NextGen programs involve airlines, airports, and regulatory bodies in collaborative efforts.	Foster collaboration among shipowners, port authorities, regulatory bodies, and technology providers to integrate MITS innovations.
Training and Certification	ISO 39001 provides training and certification guidelines for road traffic safety management.	ICAO sets rigorous training protocols for aviation professionals, enforced by national bodies.	Improvement standardized training and certification for maritime professionals, beyond STCW [1], to ensure high competency and adherence to ITS standards.
Policy support	European Commission's Action Plan advocates for ITS benefits, securing funding and legislative backing.	Key organizations have been essential in advocating for ITS innovations, effectively securing crucial public and policy backing.	Gain public and policy support for MITS through advocacy strategies emphasizing safety, efficiency, and sustainability benefits with the support of international organizations.

3 Standardization in Maritime ITS

3.1 Why digitalization and why standards?

3.1.1 The imperative for digitalization in maritime operations

There is a general agreement that the shipping sector must be decarbonized in line with all other consumers of fossil fuels. The International Maritime Organization (IMO) has a goal of 40% reductions of greenhouse gas (GHG) emissions per transport work within 2030 compared to 2008 levels, up to near-zero emissions around 2050 [2].

Various solutions to decarbonize shipping exist, where alternative fuels represent one option. However, availability, price, and design as well as health, safety, and environmental issues make alternative fuels unlikely to solve the problem by themselves. This means that also energy reduction measures must be deployed [3]. This may include new designs, e.g. smaller ships to better utilize wind propulsion, or operational measures such as slow steaming. However, considering that 45% of the existing fleet in international operation is less than 15 years old [4], this means that scrapping or costly retrofits may be out of the questions for this part of the fleet. This further emphasizes the need for better operational methods to save energy.

Operational measures can be either applied to the ship, e.g. improved trim adjustment and weather routing, or based on changes in logistics operations, e.g. just in time arrival, slow steaming and improving the ship's load factor. The former will require onboard improvements in sensors and ship models while the latter requires improved communication and coordination between several parties to the logistics operation, e.g. the ship and its operator, the ports, the cargo owners and others. In both cases improved digitalization is needed. This includes better access to data, more automated data processing, and better communication between parties in the maritime business. This is very similar to the digital transformation that is at the core of "Industry 4.0" [5].

3.1.2 The role of interoperability standards in facilitating digitalization

Digitalization and digitization are sometimes used interchangeably, but it is more commonly illustrated as parts of a hierarchical system as in Fig. 1. Digitization does not give many benefits, other than saving space and money for maintaining the physical libraries. Benefits will first occur when one starts to automate the data processing tasks and gets improvements in efficiency, speed, and accuracy of the procedures. The final layer is the digital transformation that can occur when large amounts or new types of digital information becomes readily available. This involves new ways of doing business, possibly including new business models.

Going back to the two types of digitalization that was mentioned in section 3.1.1, local to the ship or across the logistics chain, the latter type requires a form of digital transformation in how parties interact and organize own internal procedures. However, to achieve a digital transformation one will normally depend on a larger "digital ecosystem" that allows different parties to cooperate in new ways, but which also creates a larger market for new products supporting the transformation. The digital ecosystem ensures that parties can exchange information with an agreed-on format and semantic meaning, i.e. provides interoperability. This is illustrated with the arrow in Fig. 1, which shows the most relevant international standards organizations for digitalization and digital interoperability in the maritime sector.

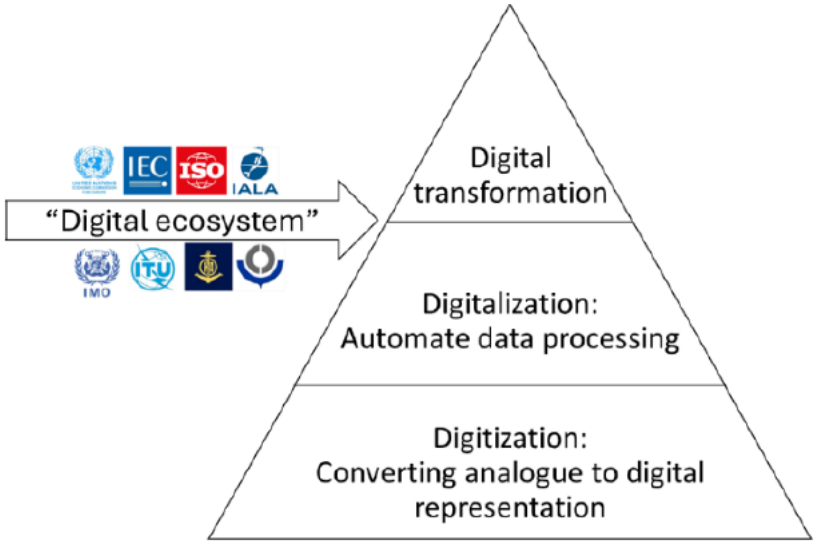

Fig. 1 Digitization, digitalization, and digital transformation

3.1.3 An overview of the main standards organizations in the maritime domain

Table 2 gives a brief overview of the organizations shown in Fig. 1. UNECE, IMO, ITU, IHO and WCO are intergovernmental organizations (IGO) while IEC, ISO and IALA are currently non-governmental organizations (NGO). IALA is in the process of changing from NGO to an IGO.

Table 2 Overview of the main international maritime standardization organizations.

Logo	Name	Role in maritime digitalization
	UNECE: United Nations Economic Commission for Europe	Trade and transport related standards, including EDIFACT.
	IEC: International Electrotechnical Commission	Onboard data networks and protocols, mainly for bridge and navigational purposes.
	ISO: International Organization for Standardization	Onboard systems other than those handled by IEC, operational data exchanges between ship and shore.
	IALA: International Association for Aids to Navigation and Lighthouse Authorities	Nautical information related to coastal state operations, e.g., vessel traffic services.
	IMO: International Maritime Organization	General performance standards, the IMO Compendium and reference model.
	ITU: International Telecommunication Union	Radio frequencies and some digital radio data protocols.
	IHO: International Hydrographic Office	Electronic charts and related nautical information.
	WCO: World Customs Organization	Standards related to data exchanges between administrative authorities, e.g. customs organizations.

In addition, there are several other organizations that do standardization work that is relevant for the maritime sector. Some examples are ASTM International (formerly known as American Society for Testing and Materials, now only ASTM International), and IEEE (Institute of Electrical and Electronics Engineers) that publish standards on a similar level as the organizations listed in the table. Smaller organizations such as RTCM (Radio Technical Commission for Maritime Services), DCSA (Digital Container Shipping Association), SMDG (User Group for Electronic Data Interchange in the Maritime Container Business) and TIC4.0 (Terminal Industry Committee) represent industry interest groups and are more specialised in the types of specifications they publish.

3.2 Overview of main standardization domains

3.2.1 Five main areas

Fig. 2 shows a general overview of the five main domains of maritime digital standardization. The main colours blue, red and green, correspond to a set of "silos" between which coordination is limited. This will be discussed in section 3.2.2.

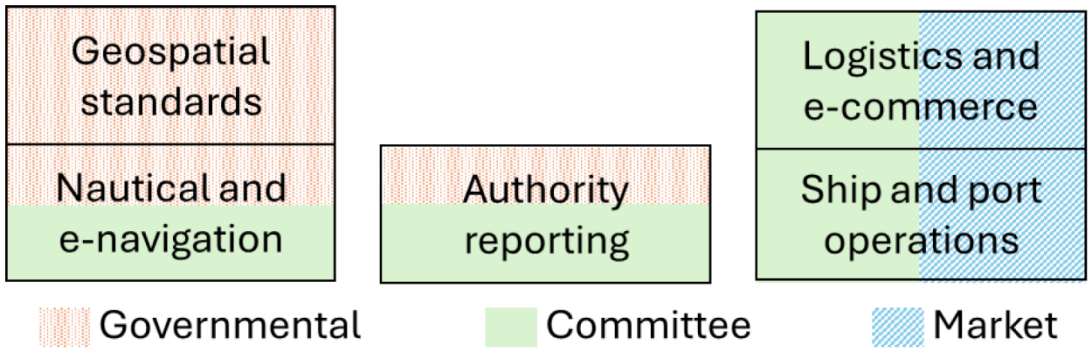

Fig. 2 Five standardization areas.

- **Geospatial standards:** These are various electronic chart related specifications which are mainly developed by or in close cooperation with the International Hydrographic Organization (IHO) . The newest developments in this area are based on the S-100 Universal Hydrographic Data Model from IHO and are given numbers in the range S-101 to S-199 **Feil! Fant ikke referansekilden.**.
- **Nautical and e-navigation**: These standards are developed by or in close cooperation with the International Association of Aids to Navigation and Lighthouse Authorities (IALA). They are closely related to the geospatial standards and the new set of specifications that are also based on the IHO S-100 system, numbered S-201 to S-299 **Feil! Fant ikke referansekilden.**. There are also some standards in the S-401 to S-499 range that are developed by other organizations.
- **Authority reporting**: These are standards that cover mandatory reporting from ships to port or coastal state authorities. It may also include other mandatory reports to class societies or

similar. Most of the reporting requirements are defined in the Convention on Facilitation of International Maritime Traffic (FAL Convention), but most countries and regions have additional requirements that are defined in local or regional legislation. Some standards are developed by UN/ECE and ISO.

- **Ship and port operations**: These are standards related to the commercial or operational interactions between ports, terminals and ships that are necessary to agree on arrival and departure times, where to berth and how to moor the ship, and how to coordinate loading and unloading activities. This may also include pilot or tug assistance. Some of these standards may be specified in the S-200 IALA range, but these specifications are often related to commercial contracts and relationships and may also be developed by various other organizations, including more specific interest groups like DCSA and SMDG. Here can also standards related to voyage orders and reporting be included.
- **Logistics and e-commerce**: These are standards and specifications mainly related to commercial and logistics cargo operations. These specifications are often developed by UNECE or other organizations that deal specifically with the commercial aspects of cargo movements.

3.2.2 Silo-divisions in maritime standardization

As illustrated by the three main colours in **Feil! Fant ikke referansekilden.**, there are three groups of standards that in a sense exist in a kind of silo separate from the other two groups. This is illustrated in Fig. 3.

Fig. 3 Standardization silos

These silos are:

- **Nautical/IMO MSC:** These activities originate from definitions made of e-navigation in IMO MSC and takes place mainly in IHO and IALA, with some work also being undertaken by IEC. Data models are based on the IHO S-100 framework.
- **Administrative/IMO FAL:** These activities generally originate from the FAL Convention [7]and the FAL Compendium that are maintained by the IMO FAL Committee. The data model is the IMO Compendium and work is mainly undertaken in UNECE and ISO TC8.
- **Operative/Commercial:** These are various initiatives that are taken on by different large and small organizations, often without status and international standardization organizations. The activities are not well coordinated between the organizations.

3.3 Current Standardization in maritime ITS

3.3.1 Key initiatives and frameworks for standardization in the maritime sector

The maritime sector is actively engaging initiatives and frameworks to enhance standardization, aiming to improve operational efficiency, safety, and environmental sustainability. Focusing on the data and information exchange in maritime ITS, the three initiatives (Maritime single window, Port community systems, and Just in time) are all linked to the IMO Reference Data Model.

IMO compendium and IMO reference data model

In April 2019, the IMO FAL Committee approved the revised and updated IMO Compendium on Facilitation and Electronic Business [6] to support harmonization and standardization of electronic messages for exchange of ship arrival and departure information from ports. The role of the compendium is to act as a reference data model for technical standards from international standards organizations, currently WCO (World Customs Organization), UNECE (United Nations Economic Commission for Europe) and ISO. This means that different standards from different domains, as illustrated in Fig. 2, can refer to the same data object with the same minimum semantics. The compendium also contains mappings from each of the relevant standards to the reference model objects. The compendium started out with the data objects identified in the FAL Convention but has later extended into other areas such as JIT Arrival, waste delivery, stowaways etc. This has also necessitated the coordination to other standards organizations, most importantly IHO and IALA. This work is still ongoing, but both IHO and IALA have publicly expressed their interest in harmonizing their own data models with the IMO reference model where this is necessary. The existence and use of the IMO reference data model has thus acted as a focus point for harmonization between several of the domains shown in **Feil! Fant ikke referansekilden.** and in particular between the governmental and committee-based standardization efforts. Also, parties from the private sector have joined this work and there is hope that the coordinating effects also will extend further into market-based standardization.

Maritime single window (MSM)

The MSW initiative aims to streamline administrative processes for ships' arrivals, stays, and departures at ports by providing a unified electronic submission system for all necessary documentation [8]. Standardizing data formats and submission processes ensures consistency and interoperability across different ports and jurisdictions, facilitating smoother communication and information exchange between ship operators, port authorities, customs, immigration, and other relevant agencies. The MSW system enhances efficiency and transparency by enabling faster clearance

times, which reduces port congestion and allows ships to better plan their schedules, thus minimizing idle time. Additionally, the reduced time ships spend in port leads to significant reductions in fuel consumption and emissions, contributing to the broader goal of environmental sustainability in the maritime sector. However, the MSW faces challenges related to interoperability, as it is complex to ensure that systems used by different ports and countries work together seamlessly. International cooperation and adherence to global standards, such as those set by the IMO, are crucial to address this issue. Implementation costs can also be significant, but the long-term benefits in terms of efficiency gains and cost savings make it a worthwhile investment. Furthermore, protecting the sensitive information exchanged through MSW systems necessitates robust cybersecurity measures to safeguard data integrity and confidentiality.

Port community systems (PCS)

A PCS is an electronic platform which connects the different systems operated by the different organisations that operate in a port [9]. The primary motivations for establishing PCS were, firstly, the need for a standardised communication platform to improve processes in terms of punctuality, reliability, and costs. Secondly, the need to increase competitive position among ports.

While an MSW is a business-to-administration (B2A) system, the PCS is a business-to-business system (B2B). Thus, it provides much of the same benefits as MSW in the business domain. As each PCS is normally only used in one or a few ports, it is not necessary to have internationally agreed on interface standards. However, standardization will clearly benefit PCS, e.g. in terms of developing standardized application software.

Just in time (JIT)

The JIT arrival initiative [10] aims to optimize the timing of ship arrivals at ports to align with berth availability, reducing waiting times, fuel consumption, and emissions. This system involves precise scheduling of ship arrivals to ensure that vessels arrive when berths are available, requiring real-time communication and coordination between ship operators, port authorities, and logistics providers. By minimizing the time ships spend idling at anchorages, JIT Arrival contributes to global environmental goals by promoting sustainable shipping practices. Challenges for JIT arrival include the need for seamless communication and coordination among multiple stakeholders, which necessitates advanced digital platforms and information sharing protocols. Accurate prediction of berth availability and voyage planning are critical, and the implementation of predictive analytics and real-time data monitoring can help improve the reliability of JIT arrival schedules. Achieving widespread adoption requires buy-in from all stakeholders, including shipping companies, port authorities, and logistics providers. Demonstrating the economic and environmental benefits can help gain support and drive implementation.

4 Drivers and Barriers in Maritime ITS Standardization

Analysing the drivers and barriers is essential for shaping the development and adoption of ITS standards. A master's thesis[8] related to the ISTS project was written, and the results of the interviews conducted in that thesis will be referenced for this deliverable.

4.1 Drivers for Standardization in Maritime ITS

The process of standardization in Maritime ITS is driven by several key factors that play a pivotal role in ensuring its success. These drivers are essential for fostering collaboration, innovation, and the alignment of diverse stakeholders towards common goals.

One of the most important drivers is knowledge sharing. In a sector as complex and global as maritime transportation, the exchange of information and best practices is essential. Knowledge sharing facilitates the spread of new ideas, solutions, and technologies, which are critical for developing standards that can be widely adopted. Collaborative efforts across industry, regulatory bodies, and academia allow for the pooling of expertise and resources. This, in turn, enables more efficient problem-solving and a shared understanding of the challenges and opportunities within ITS. As the maritime sector is characterized by a mix of legacy systems and cutting-edge technologies, open communication and dissemination of knowledge help ensure that all stakeholders are on the same page, moving towards harmonized solutions that work across different platforms and regions.

Closely related to knowledge sharing is trust and commitment. Building trust between stakeholders—especially between industry players and regulatory authorities—is essential for achieving long-term cooperation. Maritime ITS standardization involves a wide range of actors, including technology providers, shipowners, port authorities, and international regulatory bodies like the IMO. For effective collaboration, stakeholders must trust that their interests will be considered and that the process will be fair and transparent. Trust fosters a commitment to the shared goal of developing standards that benefit the entire sector, rather than focusing on individual gains. Commitment is also necessary to ensure sustained engagement in the long, often complex process of standardization. When stakeholders are committed to the process, they are more likely to contribute meaningfully, share their insights, and adhere to the agreed-upon standards.

Another important driver is technological innovation. The maritime industry is undergoing rapid technological change, with the introduction of autonomous ships, digital navigation systems, real-time monitoring tools, and advanced communication technologies. These innovations create a pressing need for standardized protocols and frameworks that can support interoperability between old and new systems. Emerging technologies offer new capabilities, but without harmonized standards, their full potential may not be realized and, in the worst cases, may even prove counterproductive. For instance, miscommunication between systems due to lack of standardization might result in delays, safety risks, or even accidents. Standardization ensures that new technologies can be integrated into existing systems in a seamless manner, allowing for more efficient operations, enhanced safety, and reduced environmental impact. Moreover, as technology evolves, standards help to maintain consistency and reliability across the industry, enabling stakeholders to adopt new tools and systems with confidence.

[8] Drivers and barriers for cooperation and coordination of standards for ISTS, USN, 2022

The alignment of common goals among stakeholders is also a important driver. Standardization efforts are most successful when all participants share a clear and unified vision of what they hope to achieve. In the case of Maritime ITS, the goal is often to create interoperable systems that enhance safety, efficiency, and sustainability in global shipping operations. When stakeholders agree on these objectives, it becomes easier to streamline the development of standards and ensure that they meet the needs of the entire sector. Common goals help to avoid the pitfalls of competing interests, where different actors might push for standards that benefit them individually rather than advancing the broader goals of the industry. The clarity of purpose that comes from shared objectives encourages collaboration and reduces friction, making the standardization process more efficient and effective.

In conclusion, the key drivers for Maritime ITS standardization—knowledge sharing, trust and commitment, technological innovation, and common goals—are interconnected and mutually reinforcing. In combination, these drivers create a foundation for the successful development and implementation of standards that will shape the future of maritime transport.

4.2 Barriers to Standardization in Maritime ITS

While there are several drivers pushing for the successful standardization of Maritime ITS, barriers also exist, slowing down or obstructing progress. Understanding and addressing these barriers is essential to overcoming the challenges that arise in harmonizing the global maritime industry's ITS frameworks.

One of the most notable barriers is regulatory fragmentation. The maritime sector operates across international waters, involving multiple jurisdictions with differing legal frameworks, rules, and standards. Unlike sectors such as aviation, where regulatory bodies like the International Civil Aviation Organization (ICAO) ensure high levels of uniformity across borders, the maritime industry lacks a singular, all-encompassing regulatory authority for ITS. While IMO works toward harmonization, it does not have the same centralized authority as ICAO to enforce global uniformity, especially for complex systems like ITS. In addition, regional regulations often vary, leading to conflicting requirements that make the adoption of standardized protocols difficult. For example, a system compliant with European regulations may face hurdles in being accepted in Asian or American ports due to differing national standards. This fragmentation complicates the task of establishing interoperable ITS systems that can function smoothly across the global maritime landscape. Without a unified regulatory framework, achieving the necessary level of standardization remains a challenging task.

The other problem is the relatively small size of the sector. In 2022 there was around 105 000 ships above 100 gross tons in international trade [4]. Each of these ships have different ICT infrastructures. Even sister ships are different, due to updates to equipment during the time it takes to build a ship. This can be compared to about 8.4 billion smartphone subscriptions currently in use in the world [11], where two operating systems are almost completely dominating the market. These two de facto standards have arguably survived a market-based "evolution". Standardization in the maritime sector is "multi-modal" as defined in [12]. It is to some degree driven by international government-based initiatives through WCO, ITU, IMO and IHO. However, most standardization is either market-based or committee-based, where committee-based standardization also is heavily influenced by market preferences. As the shipping sector is small and in part very specialized, e.g. as in container liner operations versus spot charter bulk transport, the problems of silo-thinking are further increased by the different market segments. In a sufficiently large and homogeneous market one may argue that a

market-based standardization will be easier to achieve due to the stronger collective interests of the market. This is currently not the case for shipping and the sector will have to rely on cooperation through committee-based and government-based standardization.

Another barrier is stakeholder misalignment, which stems from the diverse interests and priorities of different parties involved in the maritime sector. Shipowners, technology providers, regulatory authorities, and port operators may each have varying objectives when it comes to the implementation of ITS standards. For example, technology companies may push for cutting-edge, proprietary solutions that provide them with competitive advantages, while shipowners may prefer simpler, more cost-effective options. Regulatory bodies might prioritize safety and environmental concerns over operational efficiency. These conflicting interests can lead to a lack of consensus on the direction and scope of standardization, slowing down the development process. Additionally, competition among stakeholders, particularly in protecting intellectual property or business secrets, can limit the transparency needed for successful collaboration. Stakeholders may withhold valuable insights or technologies due to concerns that full cooperation could potentially compromise their competitive advantage in the market.

Resource constraints further complicate the standardization process, particularly for smaller players within the industry. Standardization initiatives often require significant financial and technical investments, including the cost of upgrading legacy systems to meet new standards, training personnel, and ensuring compliance with evolving regulatory requirements. For larger, well-funded companies, this may be manageable, but smaller shipping companies or port operators may lack the resources to actively participate in the standardization process or adopt new ITS technologies. The result is a two-tier system where some entities can fully engage with standardization efforts, while others struggle to keep up. This uneven participation further slows down the process, as standardization requires broad-based adoption to be truly effective. Without financial support or incentives, many smaller players may be left behind, resulting in a fragmented market where the benefits of ITS are unevenly distributed.

Additionally, resistance to change is a significant barrier, particularly among more traditional sectors of the maritime industry. Maritime transport has a long history of relying on established practices, and introducing new technologies or standards can be met with hesitancy, particularly from groups like seafarers, who may view automation and digitization as a threat to job security. Smaller companies, too, may resist the adoption of new standards, either due to fear of high implementation costs or a lack of trust in the long-term benefits of ITS. This resistance is compounded by the perception that some standards are too complex or burdensome, especially if stakeholders do not fully understand the value that standardization can bring in terms of safety, efficiency, and cost savings over the long term.

These challenges are interrelated and often reinforce one another. For instance, regulatory fragmentation can exacerbate stakeholder misalignment, while resource constraints may deepen resistance to change. Overcoming these barriers will require coordinated efforts to create a more unified regulatory environment, foster collaboration across diverse stakeholders, provide support for resource-constrained players, and encourage a cultural shift towards embracing innovation and standardization. Without addressing these barriers, the full potential of Maritime ITS may remain unrealized.

4.3 Recommendations for Enhancing Maritime ITS Standardization

Considering the drivers and barriers identified earlier, several recommendations can be made to strengthen the standardization process and facilitate broader adoption of ITS technologies. By focusing on enhancing collaboration, establishing unified regulatory frameworks, investing in training, and securing policy and financial support, the maritime industry can accelerate progress towards effective standardization.

A key recommendation is to enhance collaboration among stakeholders within the maritime sector. As seen in the road and aviation sectors, structured and transparent collaboration platforms are essential for aligning the diverse interests of stakeholders. The maritime industry involves a wide range of actors, including shipowners, technology developers, port authorities, and regulatory bodies. Without a framework that encourages open dialogue and cooperation, the standardization process can be fragmented. Establishing dedicated platforms for maritime ITS stakeholders to collaborate on standardization efforts would not only streamline the exchange of knowledge but also foster mutual understanding of goals and constraints. Collaborative environments, where all parties can openly discuss their needs and concerns, would mitigate some of the stakeholder misalignment issues previously identified as barriers. By drawing lessons from other transport sectors, the maritime industry can implement models that facilitate public-private partnerships and multi-stakeholder engagement, which are crucial for creating a unified approach to ITS standardization.

Another important step is the development of a unified regulatory framework that can reduce the current regulatory fragmentation. The maritime industry, by its very nature, operates globally, crossing international borders and jurisdictions. While the IMO plays a central role in maritime regulation, the lack of harmonization across national and regional regulations presents a major obstacle to ITS standardization. Advocating for more aligned regulations across key international bodies, such as the IMO, IALA, and ISO, would establish a more consistent regulatory environment. A unified regulatory framework would enable greater interoperability between different ITS systems, facilitating their adoption across various regions without the need for constant adjustments to meet differing local standards. This would also reduce the regulatory uncertainty that often hinders investment in new technologies, as stakeholders would have clearer guidelines and expectations regarding compliance with ITS standards.

In addition to regulatory harmonization, investment in training and capacity-building initiatives is essential to ensuring the effective adoption of Maritime ITS standards. The maritime industry is currently experiencing a significant shift due to technological advancements such as autonomous vessels, digital navigation systems, and real-time communication tools. For these technologies to be integrated smoothly into daily operations, the industry must ensure that its workforce is adequately trained to handle the complexities of new ITS solutions. Training programs should be developed specifically for ITS-related competencies, addressing both technical skills and operational requirements. This would not only increase stakeholder engagement in the standardization process but also build confidence in the new technologies, reducing resistance to change. Furthermore, offering standardized certification programs, similar to those in the aviation sector, would ensure that personnel across the globe are equipped with a consistent level of knowledge and skills, further supporting the interoperability of ITS technologies.

Lastly, policy and financial support from both governments and international organizations is important for the successful implementation of ITS standards. Standardization initiatives often require significant upfront investment, particularly in upgrading legacy systems and developing new technologies. Securing funding and policy backing from governments would support to reduce the financial burden on smaller stakeholders, enabling them to participate more fully in the standardization process. Moreover, clear policy directives that emphasize the benefits of ITS for safety, efficiency, and environmental sustainability can help to drive adoption across the industry. Policymakers should also consider offering incentives or subsidies for companies that actively participate in standardization efforts or adopt ITS technologies early on. This would not only accelerate the deployment of standardized systems but also encourage innovation within the sector, as companies would be more willing to invest in developing cutting-edge solutions if they have the financial backing and regulatory support needed to succeed.

Table 3 show the drivers and barriers with relevant recommendations for enhancing Maritime ITS standardization. The strategy to effective Maritime ITS standardization lies in fostering greater collaboration, harmonizing regulatory frameworks, investing in workforce training, and securing robust policy and financial support. By addressing these areas, the maritime industry can overcome existing challenges and better harness the potential of ITS technologies, contributing to a safer, more efficient, and sustainable future for global shipping.

Table 3 Drivers, Barriers, and Recommendations for Enhancing Maritime ITS Standardization.

Drivers/Barriers		Description	Recommendations
Driver	Knowledge Sharing	Collaboration and exchange of information among stakeholders enhance standardization	Enhancing Collaboration: Establish structured platforms for stakeholders to collaborate and align goals
	Trust and Commitment	Strong relationships and trust between stakeholders promote cooperation	Fostering Trust: Facilitate regular interactions (physical meetings, workshops to build trust)
	Technological Innovation	Emerging technologies push the need for standardized systems for better integration	Support Technological Integration: Ensure new technologies align with interoperable standards
	Common Goals	Shared objectives streamline standardization processes across different stakeholders	Align Stakeholder Objectives: Develop clear goals and ensure stakeholder commitment from the start
Barrier	Regulatory Fragmentation	Differing regulations across countries lead to inconsistencies in standards adoption	Unified Regulatory Frameworks: Advocate for harmonized regulations through bodies like the IMO
	Stakeholder Misalignment	Conflicting interests hinder progress in standardization efforts	Stakeholder Alignment: Use platforms to coordinate and align the diverse priorities of stakeholders
	Resource Constraints	Limited financial and technical resources slow down adoption, particularly for smaller stakeholders	Investment in Training & Support: Organize training programs to build ITS competencies and encourage adoption with sufficient support

	Resistance to Change	Traditional stakeholders may resist adopting new technologies and standards	Encourage Adoption: Offer incentives and clear policy support to mitigate resistance and promote innovation

Understanding the key drivers and barriers provides essential context for establishing user requirements, ensuring that ITS solutions are designed to address both the motivations and challenges faced by stakeholders. With these insights in place, specific user needs can be outlined to guide the development of effective and practical standards.

5 Establishment of User Requirements

Establishing user requirements is an essential step in the development and standardization of ITS for the maritime industry. Understanding and integrating user needs is fundamental because it ensures that the technologies and solutions developed are aligned with the real-world challenges and operational demands faced by stakeholders. In addition, establishing user requirements is about more than just understanding technical needs; it is about ensuring that ITS systems support the broader regulatory, collaborative, and operational frameworks in which they will function. This user-centric approach increases the likelihood that the systems will be effective, compliant, and widely adopted across the maritime industry.

5.1 User-Centric Approach in Maritime ITS

A user-centric approach in the development of ITS for the maritime sector is essential to ensure that the technologies and systems being developed are not only advanced but also practical and relevant to the actual needs of the users. Unlike traditional technology-driven development, a user-centric approach prioritizes the needs, preferences, and challenges of end-users—those who will interact with and rely on these systems in their daily operations.

In the maritime context, end-users include a wide range of stakeholders. To effectively implement a user-centric approach, it is essential to first understand the key stakeholders in the maritime ITS ecosystem. These stakeholders can be broadly categorized as follows:

- Ship Operators and Crew: The primary users of onboard ITS technologies, ship operators, and crew members require systems that enhance navigational safety, operational efficiency, and compliance with international regulations. Their input is crucial for ensuring that ITS solutions are practical and do not add unnecessary complexity to shipboard operations.
- Port Authorities: Port authorities play a critical role in maritime operations, particularly in managing traffic, ensuring security, and coordinating logistics. ITS solutions must address their needs for efficient vessel traffic management, real-time communication with ships, and streamlined administrative processes.
- Logistics Coordinators: These stakeholders manage the flow of goods through the supply chain, coordinating between shipping companies, ports, and customers. Their requirements often center on timely and accurate data exchange, predictive analytics for cargo handling, and efficient coordination with port and ship operators.
- Regulatory Bodies: National and international regulatory bodies, such as IMO, set the standards for safety, security, and environmental protection in maritime operations. Engaging with these bodies ensures that ITS solutions are compliant with existing regulations and are designed with potential future regulations in mind.
- Technology Providers: Companies developing ITS technologies must understand the needs of all other stakeholders to create solutions that are interoperable, scalable, and adaptable. Their role is to translate user requirements into technical specifications and to ensure that their systems integrate seamlessly with existing maritime infrastructure.
- Environmental Advocates: With growing emphasis on sustainability, environmental groups have become important stakeholders in the maritime sector. ITS solutions that reduce

emissions, optimize fuel consumption, and promote sustainable practices align with their goals and can gain broader acceptance.

Each of these stakeholders has distinct needs and operates under different conditions, which makes the user-centric approach particularly valuable. By focusing on the user, the development process becomes more aligned with real-world applications, leading to systems that are more intuitive, effective, and widely adopted.

5.2 Expert Interview Insights for Deriving User Requirements

5.2.1 General interview

The survey was conducted to collect expert feedback in order to better understand how to improve the harmonization and effectiveness of maritime ITS standardization processes. The questions were as follows:

1. What do you think characterizes a good and effective standardization process? (In these committees/projects)
2. What has it been wise to do (by you or others) to promote good cooperation/reach an agreement? That is, concrete actions.
3. What should have been avoided by you or others? That is, actions.
4. Of the points we have covered (do/don't do), which do you think is the most important to focus on?
5. Is there something you personally would like to learn more about/get other people's experiences on?

The interviewees are eight Norwegian experts with around 15 years of experience in ITS standardization. Key insights and findings were gathered from their interview responses as follows.

Effective Standardization Process

The interviewees emphasize several characteristics of a good standardization process, including:

- Close collaboration with stakeholders to ensure standards are relevant
- Validation and testing of standards to ensure compatibility
- Transparent processes from conception to finalization
- Strong participation by motivated individuals
- Small committees to maintain effectiveness
- Prioritizing thorough involvement of all stakeholders early on to avoid problems
- The importance of adopting and agile approach and knowing when to end a standard

Group Dynamics and Cultural Differences

Committees often face challenges such as cultural differences, especially between Eastern and Western delegates, and differing approaches to standardization. There are concerns about delegates trying to sabotage progress or large companies attempting to control the process through sudden

interventions. There is also little formal training for standardization work, and evaluation of group dynamics and collaboration is minimal, even though it is important.

Commercial Models and Cross-Collaboration

The way standards are commercialized impacts their accessibility. Different models exist, such as ISO's pay-per-standard or ETSI's free standards with paid membership. Despite agreements for cross-collaboration between standards and standards-developing organizations (SDOs), competition and parallel work still occur, driven by industry's push for proprietary standards.

Challenges with Maritime Standardization

There is a focus on the harmonization of various maritime standards (e.g., S100, IMO compendium, IHO standards). The lack of harmonization is attributed to limited oversight and cooperation, as well as the influence of commercial interests on the process. Challenges include discrepancies between the standards and their implementation, and certain stakeholders (e.g., IMO and IALA) not working together effectively.

Implementation Challenges

Two major challenges were highlighted in the interview results. First, some solutions are proposed but either not implemented or, when implemented, they often fail to comply with international standards. Second, the reporting systems used by ships are inconsistent, highlighting the need for a standardized and digitalized reporting system.

Based on these insights, a summary table has been established to organize the findings and key points from the interviews.

Table 4 Key requirements for harmonized Maritime ITS Standardization: Insights from expert interviews.

Challenge	Requirement
Lack of stakeholder collaboration	Ensure early involvement of industry and authorities to maintain practical relevance of standards
Process transparency issues	Enhance transparency in processes to prevent misalignment and build trust among stakeholders
Lack of compatibility across systems	Implement rigorous testing and validation to ensure interoperability among different systems
Cultural differences in standardization	Incorporate cultural sensitivity, considering diverse approaches to standardization from East and West
Dominance by commercial interests	Establish technology-neutral standards to prevent large companies from controlling the process
Complexity and high cost of access	Simplify access to standards by reducing complexity and cost, making adoption easier
Intentional delays by vested interests	Implement measures to prevent disruption from stakeholders with vested interests
Lack of clear criteria for concluding standards	Define clear criteria for standard conclusion to avoid outdated practices

Insufficient collaboration between SDOs	Foster cross-organization collaboration to reduce redundant efforts and parallel developments
Inconsistent reporting systems	Develop a standardized, digitalized reporting system to streamline operations and increase efficiency
Stagnation from limited expertise renewal	Encourage renewal of expertise to prevent stagnation from the same individuals dominating processes
Ineffective feedback mechanisms	Improve feedback integration to increase engagement and address stakeholder concerns
Risk of proprietary standards being pushed by industry	Strengthen government oversight to ensure standards serve public interest over commercial gain

Based on the interview results, requirements have been derived as essential elements for improving the harmonization and effectiveness of maritime ITS standardization (Table 4). By addressing these key areas, stakeholders can work towards a more efficient and collaborative standardization process that aligns with industry needs and fosters global cooperation.

5.2.2 Interview for MSW

To identify the challenges and requirements for the harmonized standardization of the Maritime Single Window (MSW) framework, a survey was conducted, gathering expert insights on current issues and potential improvements for global implementation. The questions were as follows:

1. Basic premise
   1.1. Do you agree that there a need for more/better global standardization of MSWs?
2. About existing standards for MSW
   2.1. What do you think are the most important/relevant standards/guidelines for MSWs?
   2.2. What do you think are the pros/cons of using the IMO compendium as a global standard for MSWs?
   2.3. Are you aware about any challenges with these standards/guidelines?
3. About collaboration on MSWs
   3.1. What organizations/countries/arenas/collaborations/processes/consortia do you see as the biggest/most important contributors to global MSW standardization today?
   3.2. Is it clear to you who is leading/coordinating the collaboration on the global level?
   3.3. How do you keep informed about the ongoing work?
   3.4. How to you get access to relevant MSW standards/guidelines?
   3.5. In your view, what are the main challenges/barriers for more efficient development/implementation of global MSW standards?
   3.6. What do you think should be done to reduce these challenges/barriers? By whom?
   3.7. Are you aware of any documents/reports (or people) that is related to the implementation challenges of MSWs?

Table 5 summarizes the key challenges and corresponding requirements identified in the survey responses related to the MSW. The challenges highlight issues such as slow adoption, complex integration, and insufficient enforcement of standards. In response to these challenges, the experts suggest requirements like stronger global leadership, harmonized data formats, better enforcement mechanisms, and the development of secure data-sharing protocols. Addressing these challenges and meeting the outlined requirements is crucial to achieving effective and harmonized global implementation of MSW.

Table 5 Challenge and requirements for the Harmonized implementation of the Maritime Single Window.

Challenges	Requirements
Slow state adoption of MSW standards and guidelines	Clearer mandates and political will to enforce standardization at the national level
Complex integration of legacy systems with modern business processes	Simplified and harmonized data formats and standards for easier implementation
Insufficient coordination between various regional standards	Stronger global leadership from the IMO to coordinate and harmonize standards
Lack of enforcement and oversight of IMO decisions	Better enforcement mechanisms to ensure compliance with IMO standards
Fragmented approaches to customs and trade data integration	Improved integration between customs/trade single windows and MSW
Limited political will and resources for implementation in certain countries	Allocation of adequate resources and budgets for implementing MSW
Difficulty accessing and sharing relevant standards and guidelines globally	More accessible and centralized platforms for sharing standards and guidelines
Security and trust issues in sharing sensitive data across different authorities	Development of secure data-sharing protocols that build trust between stakeholders
Overlapping or contradictory standards leading to confusion	Further harmonization of existing standards to reduce overlaps and discrepancies

5.3 User Needs and Expectations

The standardization of Maritime ITS must reflect the diverse needs and expectations of stakeholders across the maritime industry, including ship operators, port authorities, regulatory bodies, and technology providers. This section provides a broader summary of general user demands and expectations for Maritime ITS standardization, derived from the specific requirements identified in Section 5.1. The following key needs and expectations have been identified based on stakeholder inputs (Table 6).

Table 6 Key user needs and expectations for Maritime ITS standardization.

User Needs	Expectations
Interoperability	Seamless communication across platforms, vessels, and countries
Efficiency and Real-time operations	Streamlined operations, real-time data exchange, and predictive maintenance
Safety and Security	Enhanced situational awareness, secure data, and emergency response
Global Regulatory Compliance	Adherence to international and national regulations, standardized reporting
Sustainability	Optimized fuel consumption, reduced emissions, and JIT operations
User-Friendliness	Intuitive systems with minimal training requirements
Flexibility and Adaptability	Ability to adapt to emerging technologies and evolving standards
Collaborative Development	Active participation and collaboration between stakeholders

The core requirement emerging from stakeholders is the demand for interoperability. Maritime operations span international boundaries, and therefore, users need ITS solutions that facilitate seamless communication across different platforms, vessels, and countries. Interoperability is essential to ensure the smooth exchange of data between ships, ports, and regulatory agencies, particularly when integrating legacy systems with new, advanced technologies.

Efficiency is another key expectation, particularly regarding real-time operations and data exchange. Stakeholders in maritime transport rely on ITS to streamline operations, reduce administrative burdens, and improve resource management. Solutions are expected to support real-time reporting, automated data management, and predictive maintenance, ultimately reducing delays and increasing operational efficiency.

Safety and security remain primary concerns in the maritime industry. Users expect ITS standardization to support enhanced safety protocols by improving situational awareness and emergency response systems. Additionally, given the sensitivity of maritime data, robust cybersecurity measures are crucial to protect against data breaches and ensure secure communication across ITS platforms.

Another critical expectation is compliance with global regulatory standards. Maritime ITS systems must align with international and national regulatory frameworks to ensure standardized reporting and monitoring, especially in areas such as emissions control and environmental sustainability. Adherence to evolving global guidelines is essential for maintaining regulatory consistency and avoiding operational disruptions.

Sustainability is also a growing priority for stakeholders. Maritime ITS solutions are expected to promote sustainable practices by optimizing fuel consumption, reducing emissions, and facilitating Just-In-Time (JIT) operations, which help minimize idle times at ports. Such capabilities not only improve operational efficiency but also align with global environmental goals, which are increasingly influencing the direction of the maritime industry.

Users also emphasize the importance of user-friendly ITS systems. Given the complexity of maritime operations, the ITS interfaces must be intuitive, requiring minimal training to operate effectively.

Systems should be practical, taking into account the specific needs of end-users to ensure that adoption is widespread and that the systems deliver on their intended benefits.

Additionally, stakeholders expect flexibility in ITS solutions, with the ability to adapt to ongoing technological advancements. The maritime industry is rapidly evolving, with new technologies such as autonomous ships and advanced communication tools emerging. ITS standards must allow for continuous updates and adaptation to ensure they remain relevant and beneficial in the long term.

Stakeholders also emphasize the importance of collaborative development in the standardization process. Active participation from ship operators, port authorities, regulatory bodies, and technology providers is crucial to creating systems that reflect the needs of all parties involved. Collaborative platforms are necessary to harmonize these diverse perspectives, ensuring that the ITS standards are both practical and widely accepted.

Meeting these expectations is key to ensuring that Maritime ITS systems support a safer, more efficient, and sustainable future for global maritime operations.

6 Bridging Gaps in Maritime ITS Standards from User Requirements Perspective

In the development and standardization of Maritime ITS, addressing user requirements is essential for ensuring practical, efficient, and widely adopted solutions. However, several gaps exist between current ITS standards and the actual needs of stakeholders. These gaps, which have been identified through the analysis of drivers, barriers, and user requirements discussed in Chapters 3, 4 and 5, arise from the complexities inherent in the maritime industry, including the diversity of its stakeholders, the legacy systems in use, and the highly international nature of maritime operations. Addressing these gaps presents both challenges and opportunities that need to be carefully considered in order to develop more user-aligned ITS standards.

6.1 Identification of Gaps and Opportunities

In alignment with the core objective of user-centric standardization, this report identifies key gaps in Maritime ITS standards, as highlighted in Chapters 4 and 5. These gaps, including regulatory fragmentation, technological challenges, and diverse stakeholder needs, underscore the importance of integrating user feedback throughout the standardization process. Addressing these gaps with a user-centered approach will ensure that ITS standards better align with practical requirements, enhancing the effectiveness and adoption of these standards across the maritime industry.

Interoperability is a significant gap identified in Chapter 4, where the fragmentation of regulatory and technological frameworks limits seamless communication among stakeholders. This challenge is compounded by reliance on legacy systems and the lack of uniform protocols, creating substantial barriers to integrated maritime operations. Without interoperability, effective data exchange and coordination across regions become difficult, reducing operational efficiency and coherence in Maritime ITS applications.

Another major challenge, standardization fragmentation, reflects the regulatory inconsistencies explored in Chapter 5. Although organizations like the IMO have made strides toward cohesive frameworks, varying adoption rates and regional adaptations hinder global interoperability. These regulatory discrepancies complicate efforts to develop ITS standards that can operate consistently across international maritime contexts.

In addition, incomplete collaboration among organizations has led to fragmented efforts and incomplete standards, resulting in inconsistencies and vulnerabilities. Furthermore, the lack of a user-centered design approach, as highlighted in Chapter 4, limits the practical applicability of many ITS standards. Although technically advanced, systems often fail to accommodate the specific needs of end users, such as ship operators and port authorities, resulting in low adoption rates. For instance, systems like real-time vessel tracking and port management must prioritize usability and reliability to meet stakeholders' operational requirements effectively.

Lastly, inconsistent implementation of standards, discussed in Chapter 5, undermines the effectiveness of Maritime ITS across regions. Variations in local interpretations, resource constraints, and oversight gaps lead to fragmented adoption, diminishing the potential benefits of a standardized ITS framework. However, these gaps present multiple opportunities. Chapter 4's emphasis on global harmonization points to the potential for greater coordination between the IMO, regional bodies, and industry stakeholders. Establishing unified frameworks could facilitate interoperability and broaden the adoption of ITS technologies, resulting in smoother and more cohesive maritime operations globally.

An important objective of this project is to support these harmonization efforts by contributing findings to the IMO for potential inclusion in the IMO compendium. By integrating these results, the project aims to facilitate the establishment of unified standards that can enhance the interoperability of ITS technologies throughout the maritime industry.

Continuing to conduct similar studies and initiatives will further contribute to the long-term goal of global interoperability, gradually aligning diverse systems under cohesive international standards. Technological innovation, another opportunity outlined in Chapter 5, holds significant promise for addressing current gaps. Technologies like blockchain and AI-driven analytics can support secure data exchange and predictive decision-making, allowing ITS systems to respond dynamically to operational demands while remaining consistent with standardized protocols. Further, a strengthened user-centric development approach, central to this report, is essential. By incorporating feedback from users and stakeholders at every stage, ITS standards can be tailored to practical needs, aligning with Chapter 4's insights into the value of stakeholder engagement. This approach not only fosters systems that reflect operational realities but also promotes more effective and widespread adoption.

Finally, policy support and financial incentives, as discussed in Chapter 5, could accelerate standardization by supporting stakeholders in the adoption of interoperable systems. Providing resources for updating legacy systems and enhancing regional alignment would ensure broader participation in the digital transformation of maritime operations. In conclusion, addressing these gaps through a user-centered approach and leveraging the opportunities identified in Chapters 4 and 5 will enable the maritime industry to create ITS standards that are both practical and globally applicable, supporting a more connected, efficient, and responsive maritime transport system.

6.2 Recommendations for Standards Evolution

To bridge the identified gaps and leverage identified opportunities, recommendations is proposed to evolve Maritime ITS standards effectively from a user requirements perspective. These recommendations focus on actionable steps that address interoperability, adaptability, and user engagement, with an emphasis on long-term sustainability and stakeholder alignment.

Establish Cross-Sector Collaborative Platforms

While current initiatives by the IMO and EU demonstrate important steps toward collaborative standardization, there remains a need for a more specialized, user-focused platform that integrates ongoing feedback directly from end users into the ITS standardization process. Existing platforms, such as IMO's e-Navigation initiative and the EU’s various ITS-focused projects, focus largely on high-level standardization and regulatory harmonization. However, to address the practical, day-to-day challenges identified in previous chapters, a targeted platform is needed that allows ship operators, port authorities, regulatory bodies, and technology providers to contribute detailed operational insights. This proposed platform would go beyond traditional forums by establishing specific channels—such as interactive workshops, pilot programs, and dedicated technical working groups—to gather user-driven insights on specific ITS functionalities, including interoperability requirements, real-time data exchange needs, and practical challenges in digital navigation. For example, pilot programs could focus on testing and refining data exchange protocols or security standards for real-time operational use, directly addressing the interoperability gaps discussed in Chapter 4. Additionally, technical working groups should include representatives who operate in diverse maritime environments, thus ensuring that the standards developed are adaptable to varied regional conditions. By fostering continuous, structured dialogue and hands-on participation in the standard development

process, this platform would help create a feedback loop that ensures ITS standards are both practically applicable and flexible enough to evolve with technological advances. This approach not only reinforces the immediate operational relevance of standards but also supports long-term adaptability, fostering widespread adoption and ensuring that user needs remain central to Maritime ITS evolution.

Adopt a Modular Standardization Framework

To ensure Maritime ITS standards remain adaptable, the maritime industry should shift toward a modular approach to standardization. Rather than developing rigid standards that may quickly become obsolete, a modular framework allows individual components of the standard to be updated or replaced as new technologies emerge. For example, standards related to cybersecurity, data interoperability, and autonomous systems could evolve independently within the overarching ITS framework. This modular approach not only accommodates future technological advancements but also enables easier integration of new functionalities without overhauling the entire standard.

Implement Global Training Certification Programs

Given the need for specialized skills in operating ITS technologies, developing a global certification program that standardizes ITS training across regions would be beneficial. This program should cover essential competencies in digital navigation, data management, and cybersecurity, equipping personnel with the knowledge necessary for effective ITS operation. An internationally recognized certification would facilitate knowledge transfer across regions and ensure that the maritime workforce is prepared for the transition to standardized ITS operations. Furthermore, certification programs would help maintain consistency in system usage and operational efficiency worldwide.

Develop Robust Oversight Mechanisms and Compliance Incentives

To ensure uniform application of ITS standards, it is recommended to create a tiered oversight system in which international organizations, like the IMO, coordinate with national agencies to monitor compliance. Alongside oversight, implementing compliance incentives—such as offering operational benefits or cost reductions for certified compliance—could encourage more stakeholders to adhere to standards. This approach would ensure that even resource-limited stakeholders can participate in standardized operations, ultimately strengthening the consistency and reliability of Maritime ITS.

Leverage Pilot Programs for Technological Validation

Policymakers and industry stakeholders should collaborate on pilot programs to validate and refine new ITS technologies under real-world conditions. Unlike general incentives, pilot programs allow stakeholders to test ITS innovations in specific contexts, providing data that can directly inform standard development and adaptation. Such programs also serve as demonstrations of the practical benefits of standardized ITS, showcasing efficiency improvements, operational savings, and safety enhancements, which can motivate broader adoption.

Standardize Data Exchange Protocols for Interoperability

To achieve true interoperability, establishing universal data exchange protocols is crucial. Building on initiatives such as the IMO's Maritime Single Window, industry stakeholders should develop a set of standardized data models and protocols that ensure data consistency across systems and jurisdictions. By ensuring all ITS systems operate on a unified data framework, the industry can reduce

communication errors, enhance data security, and improve collaborative operations across different regions and platforms.

To summarize the key gaps identified and the strategic recommendations proposed to address them, them, Table 7 provides an overview of each challenge and its corresponding solution.

Table 7 Summary of key gaps and strategic recommendations for maritime ITS standardization

Gap	Description	Recommendation
Interoperability	Fragmented systems hinder integration	Establish collaborative platforms for standard harmonization
Regulatory fragmentation	Regional variations disrupt cohesive adoption	Adopt a modular framework for adaptable standards
User-Cantered Design lacking	Systems overlook practical user needs	Engage stakeholders in standard development
Inconsistent implementation	Varying resources lead to non-uniform application	Provide global training and compliance incentives
Validation Needs	Insufficient real-world testing	Launch pilot programs to ensure practical applicability
Incomplete coverage	Standards cover only specific areas, leading to gaps	Expend standards to comprehensively cover critical aspects
Fragmentation of Efforts	Parallel standardization efforts create inefficiencies	Centralize and coordinate efforts to pool resources and unify standards
Silo-Structure	Isolated development of standards limits integration	Encourage cross-sector communication to align similar standards
Sector size limitations	Maritime sector’s small size limits global influence	Increase collaboration to enhance policy influence

Addressing gaps in Maritime ITS standards require a multi-layered approach that goes beyond identifying opportunities and focuses on actionable, specific steps. By bridging these gaps with targeted actions, the Maritime ITS standards can better align with user requirements, supporting a more integrated, efficient, and user-centric maritime industry.

7 Conclusion

The development and standardization of Maritime Intelligent Transport Systems (ITS) present a key opportunity to transform maritime operations, making them more efficient, safe, and sustainable. This report has identified essential user-centred requirements and analysed gaps within the current ITS standards. Addressing these gaps through a structured, collaborative, and adaptive approach is essential to unlock the full potential of ITS for the maritime sector.

Effective Maritime ITS standards must be grounded in interoperability, regulatory harmonization, user-centred design, and strong implementation. Recommendations include establishing collaborative platforms, adopting a modular framework, implementing global training and certification programs, and standardizing data exchange protocols. These strategies will help the maritime industry to overcome existing challenges and create a more cohesive, flexible, adaptive and user-friendly ITS ecosystem. This transformation requires continuous stakeholder feedback, technological innovation, and policy support to ensure ITS solutions remain responsive to the evolving needs of global maritime transport.

WP1 of the ISTS project specifically advanced the maritime sector's readiness for user-centred ITS standards by identifying core requirements and existing gaps, particularly in accessibility, interoperability, and adaptability. WP1's findings emphasize the need for international collaboration and a modular approach to standardization, which allows stakeholders—including regulators, ship operators, and technology providers—to play an active role in refining ITS standards.

Looking forward, the ISTS project has laid a foundation for the ongoing evolution of maritime ITS, aiming to validate and promote these standards on a global scale. The sustained development and implementation of these standards promise to make a lasting impact on maritime transport by enhancing safety, efficiency, and environmental sustainability.

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