MaritIme juSt in time optimiSatION (MISSION)

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Abstract
The MISSION project aims to improve efficiency and reduce greenhouse gas emissions (GHG) in maritime transport by enabling just-in-time (JIT) port calls through digital coordination. Many ports still operate on a first-come-first-served (FCFS) basis, leading to unnecessary waiting times, fuel waste, and emissions. MISSION addresses these challenges by developing an interoperable, real-time optimization tool that supports better communication and collaboration between ships, ports, and hinterland logistics. This article presents the current state of the project.

Keywords
Port Call Optimization, Green House Gas Reduction, Integration Architecture

1. Introduction

Maritime transport plays a vital role in the global economy, facilitating over 80% of international trade [1]. As global shipping volumes rise, mainly due to the expansion of containerized cargo and dry bulk transport [1], so does its environmental impact. Currently, international maritime shipping contributes approximately 3% of global CO_2 emissions [1], making it a critical focus area for decarbonization efforts aligned with the International Maritime Organization's (IMO) goal to reduce GHG emissions by 50% by 2050 compared to 2008 levels [2].

One of the persistent inefficiencies in maritime logistics is the widespread FCFS approach in port operations. This practice often leads to the "sail-fast-then-wait" (SFTW) phenomenon, where ships rush to ports only to queue at anchorage due to unprepared terminals [3]. This results in up to 10% of a vessel's journey spent idling near ports, burning auxiliary fuel, and emitting significant pollutants and particulate matter [4]. The lack of real-time communication about port and terminal readiness exacerbates this issue, often leading to skipped port calls, congestion, and ripple effects across the supply chain [3].

Improved digital information exchange between maritime stakeholders is key to solving these challenges. Early sharing of port readiness information enables vessels to adjust speed and achieve fuel savings of up to 21% [5] while increasing safety and reducing emissions near ports. The "virtual arrival" concept, where a ship's original ETA is honored despite delayed terminal readiness, allows fuel-efficient slow steaming without disrupting port schedules [6, 7].

To address these systemic inefficiencies, the European Commission has launched targeted innovation efforts, including selecting the MaritIme juSt in time optimiSatION (MISSION) project in 2023. MISSION will develop an interoperable, real-time digital optimization and decision-support tool to enhance collaboration among ports, terminals, shipping companies, and service providers. By enabling synchronized ship and berth scheduling, port service readiness notifications, and speed optimization, MISSION aims to streamline operations, reduce fuel and energy consumption, and lower GHG emissions across the maritime logistics chain.

The rest of this work is structured as follows: We present basic project information and the involved partners, then list the project's objectives and expected outcomes. In section 4, we explain the project's

RPEatCAiSE25: Research Projects Exhibition at the International Conference on Advanced Information Systems Engineering, June 16-20, 2025, Vienna, Austria
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relation to the information systems engineering domain. An overview of the IT systems involved in port call optimization follows. The work is closed with an overview of the project's actual status.

2. Project information

Project Name	MaritIme juSt in time optimiSatION	**Acronym**	MISSION
From	January 1, 2024	**To**	June 30, 2027
Funding Agency	European Commission (HORIZON)	**Website**	https://missionproject.eu/

Project Partner

Syddansk Universitet (DK) (Coordinator)	Fundacion Valenciaport (ES)
Universitat Politècnica de València (ES)	Åbo Akademi University (FI)
Awake.AI Oy (FI)	CETENA S.p.A. (IT)
National Technical University of Athens (GR)	Revolve Planet (BE)
TIC 4.0 (BE)	DFDS A/S (DK)
VTT Technical Research Centre of Finland Ltd (FI)	DLR – German Aerospace Center (DE)
Fondazione CMCC (IT)	Fintraffic Vessel Traffic Services Ltd (FI)
Royal Dirkzwager B.V. (NL)	Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping (DK)
NAPA Oy (FI)	Blue Visby Services Ltd (UK)
IOTA Stiftung (DE)	Port of Trieste (IT)
Port of Genoa (IT)	Piraeus Port Authority (GR)
Port of Klaipėda (LT)	Stockholm University (SE)
Erhip S.A.U. (ES)	Essberger & Stolt Tankers GmbH & Co. KG (DE)
COSCO Shipping Lines Spain S.A. (ES)	Finnlines Plc (FI)

3. Project objectives and expected outcomes

Table 1
Specific Objectives and Expected Outcomes of the MISSION Project

Specific Objective (SO)	**Expected Outcome**
SO1: Develop collaborative and harmonized standards aligned with IMO/ISO to enable system interoperability and incentivize JIT operations.	Defined standards, interface documentation, guidelines, and green business models for implementing the JIT concept.
SO2: Ensure secure, resilient, scalable data-sharing infrastructure for real-time stakeholder collaboration.	Interoperable infrastructure with cybersecurity features and user-friendly interfaces.
SO3: Create voyage and port call optimization tools, including hinterland traffic prediction models.	Tools for port call analytics, voyage optimization, safety simulation, and end-to-end orchestration.
SO4: Demonstrate the optimization tools in real environments with multiple traffic types and ports.	Demonstrated GHG reduction in six ports across three traffic types and five shipping lines.
SO5: Evaluate models for cost and benefit sharing of centralized JIT scheduling among stakeholders.	Reports on shared cost-benefit evaluation and regulatory recommendations.
SO6: Assess the safety and resilience of the system and propose mitigation measures.	Operational risk and navigational safety assessment models.
SO7: Define and validate KPIs to assess tool performance and emissions reduction.	Benchmarking methodology for evaluating GHG and cost-benefit outcomes.
SO8: Support stakeholders in adopting new IT-supported work processes.	Change management guidance and training materials.
SO9: Develop and evaluate business models to ensure commercial viability.	Validated business models promoting long-term uptake and scalability.

4. Relevance for Information Systems Engineering

The MISSION project fits well with the CAiSE 2025 theme of sustainability and resilience in information systems. Shipping is responsible for most of the world's trade and produces many GHG. MISSION helps reduce these emissions by allowing ships to arrive "just in time," so they do not waste fuel while waiting at ports. This helps the environment and makes shipping more efficient and climate-friendly.

The project also focuses on making different systems work together. MISSION creates digital standards so ports, ships, and transport companies can share real-time information smoothly and securely. This kind of interoperability is important at CAiSE, where researchers often discuss how to connect complex systems and organizations through shared data and tools.

A big part of MISSION is building tools that support decision-making. These tools help predict when ships arrive, suggest the best routes and speeds, and improve port scheduling. They also include safety simulations. This connects to CAiSE topics like process optimization, smart decision support, and using data to run operations more effectively.

Lastly, MISSION is tested in the real world in five large European ports with different types of ships and cargo. This means the results are practical-driven. It shows how digital systems can solve real problems in global logistics. This kind of hands-on validation is something that CAiSE values, as it brings together research and real-world impact.

5. IT systems in port call optimization

The digital landscape in the maritime sector is currently fragmented, with many IT systems either developed in-house or adapted from commercial software. As a result, these systems often operate in isolation and vary widely regarding standards and procedures, creating significant challenges for shipping companies [8, 9, 10]. Companies have to manage these differences and continue pushing forward their digital transformation. There is also concern among maritime stakeholders about becoming locked into specific IT systems, particularly those promoted by larger industrial players. This has led to a tendency to develop proprietary solutions, further complicating efforts to standardize and connect systems across the sector [8].

Several IT systems are central to port call processes on the shipping company side. These include fleet management systems, ship performance monitoring systems (which often track emissions), and voyage optimization tools, including weather routing services that aim to minimize fuel consumption, travel time, or other metrics. Fleet performance systems typically rely on Automatic Identification System (AIS) data. In addition, vessel traffic services (VTS) use sensor data and communicate with ships via VDES/VHF to manage and coordinate incoming traffic [9].

In the port environment, key systems include Port Community Systems (PCSs), which serve as National Single Windows—electronic platforms that integrate the individual systems of various stakeholders. PCSs facilitate real-time data exchange, reduce administrative burdens, and support the IMO's goal of accelerating digitalization through mandatory single-window systems by 2024 [9, 11]. Supporting systems include port-internal ERP systems, often linked with PCSs and VTS, and Terminal Operating Systems (TOSs), which are used to plan and execute terminal operations such as cargo movement, storage, and asset utilization [12].

Additional tools include berth planning applications, which are still frequently managed using spreadsheets, especially outside the container shipping sector, despite the availability of more efficient software. Other important systems are cargo tracking tools and gate entry systems, which manage vehicle access and cargo flows. Gate appointment systems are increasingly used to schedule truck arrivals at terminals while coordinating cargo train schedules with berth plans. This is gaining more attention as part of wider port-hinterland synchronization efforts [13].

A comprehensive and coordinated approach to standardizing digital solutions for ports and shipping, what some refer to as the "Port of the Future," is still lacking [9, 14]. The ongoing efforts to harmonize systems and integrate innovative technologies show great potential but also highlight the need for collaboration, open standards, and scalable solutions to avoid further fragmentation of the digital maritime ecosystem.

6. Current status

The MISSION project has reached Month 15 and has completed several important steps. The team has finished reports defining how different maritime sector systems can work together and what is needed for better coordination between ships and ports. It has also created a project management plan, including a strategy for communicating with others and a first assessment of ethical issues. These documents help set up the technical and organizational structure for the rest of the project.

The project will move further into the development phase in the next six months. Upcoming work includes studying existing standards for harmonizing the digital communication between ports and ships and providing detailed plans for building the necessary IT infrastructure. The first version of the digital tool's architecture for real-time port call coordination will also be released. This tool will help ports and ships better plan arrivals and departures, reducing waiting times and fuel use. At the same time, the project will provide an early analysis of possible cybersecurity risks and how to handle them. The team will also report on its first communication and engagement with industry partners and other stakeholders.

The MISSION project has already produced several scientific reports and conference papers that explore different aspects of the project's goals. These reports cover the environmental and technical challenges of shipping and the cybersecurity risks related to the digital systems MISSION is developing.

One of the initial scientific contributions of the MISSION project [15] addresses a fundamental inefficiency in maritime logistics, namely the phenomenon of ships sailing at high speed towards ports only to experience extended waiting times at anchorage due to terminal unpreparedness. This "sail-fast-then-wait" behavior leads to operational inefficiencies and significant environmental impacts, including increased greenhouse gas emissions and higher marine fuel consumption. The study notes that ships can consume approximately 15% of their total voyage fuel during anchorage periods while maintaining auxiliary engine operations. The persistence of first-come-first-served (FCFS) practices at many ports and a lack of real-time readiness information exacerbate these inefficiencies and hampers the potential for sustainable port call management.

The publication further examines the current landscape of maritime digitalization, identifying a highly fragmented ecosystem of IT systems utilized by various stakeholders. Systems such as fleet management platforms, vessel performance monitoring, weather routing services, VTS, and PCSs offer valuable isolated functionalities but generally lack interoperability. Variations in data standards, communication protocols, and operational procedures hinder seamless information exchange between shipping companies, ports, and hinterland logistics. The analysis argues that advancing digitalization in isolation is insufficient; systemic integration based on harmonized standards and open communication architectures is required. MISSION directly addresses this challenge by proposing a comprehensive, interoperable digital infrastructure to foster real-time collaboration across the maritime supply chain.

In addition to diagnosing the current shortcomings, the article quantifies the benefits of enhanced digital coordination. By enabling early communication of port and terminal readiness, ships could optimize their sailing speed dynamically, thereby practicing controlled slow steaming without losing their scheduled berthing slots. The potential impact is substantial, with fuel savings estimated at up to 21% per voyage and significant reductions in CO_2 emissions and localized air pollutants. Moreover, reducing congestion around ports would increase maritime safety and operational resilience. The MISSION project's planned integration of real-time data analytics, predictive decision-support systems, and synchronized port call management is thus positioned as a critical enabler for achieving greener, safer, and more efficient maritime transport operations.

A second contribution arising from the MISSION project is developing a domain-specific threat modeling tool, harborLang [16]. The harborLang language was designed to address the unique cybersecurity challenges facing modern digital maritime infrastructures, particularly in the context of real-time port call and voyage optimization systems. Recognizing the increasing reliance on interconnected digital platforms by ports, shipping companies, and logistics providers, the report emphasizes that conventional, general-purpose threat modeling approaches are insufficient for capturing the specific vulnerabilities of maritime environments. harborLang is based on the Meta Attack Language (MAL) [17] framework.

The report explains how harborLang models complex maritime systems. Each component is represented through a set of assets, attack steps, and defensive measures, which can be linked to form complete attack paths and simulate realistic threat scenarios. By utilizing probabilistic modeling techniques and simulation capabilities inherent to MAL, harborLang enables the analysis of multi-stage cyber-attacks, identifies potential attack vectors, and assesses system vulnerabilities under various conditions.

A separate contribution to the cybersecurity research within the MISSION project focuses on the specific threats posed by GPS and AIS spoofing attacks [18]. These attacks involve deliberately falsifying satellite-based positioning signals or maritime identification broadcasts, which can mislead vessel navigation systems, port traffic management services, and coastal surveillance infrastructures. The study highlights that spoofing attacks undermine maritime situational awareness, causing vessels to appear in incorrect locations or masking illegal activities such as smuggling or unauthorized port entries. As modern shipping increasingly relies on automated navigation and real-time location tracking, detecting and mitigating such sophisticated cyber threats becomes critical for maintaining operational safety and regulatory compliance.

The publication employs harborLang as a simulation platform to model various GPS and AIS spoofing scenarios affecting vessel navigation and communication systems. The study constructs threat paths through harborLang's modular attack simulation capabilities, illustrating how attackers could manipulate positioning data, disrupt route planning, or cause traffic miscoordination at ports. By representing these attacks in a structured way, the simulation provides insights into the points of vulnerability across maritime IT infrastructures.

Building upon the development of harborLang, another publication [19] explores integrating this domain-specific threat modeling language with the Yet Another Cybersecurity Risk Assessment Framework (YACRAF) [20]. Recognizing that maritime digital systems must identify potential vulnerabilities and quantitatively assess their impact, the authors propose a combined approach where harborLang serves as the modeling and attack simulation tool, and YACRAF provides structured risk quantification. This integration enables a more comprehensive evaluation of cyber threats by linking detailed system-specific attack modeling with formal risk assessment methodologies, thus offering an enhanced foundation for cybersecurity decision-making in maritime operations.

The report details how harborLang and YACRAF work together to simulate complex, multi-stage cyber-attack scenarios affecting critical maritime systems such as vessel navigation, communication infrastructure, and port logistics services. For instance, the study models attacks that could result in delayed port operations, compromised ETA (Estimated Time of Arrival) communications, or misdirected vessel traffic, leading to operational disruptions and financial losses. By assigning probabilities to attack steps and evaluating potential impacts, the combined framework allows for calculating overall system risk scores. This, in turn, supports the prioritization of cybersecurity investments and mitigation efforts by identifying which system components present the highest vulnerabilities and where defensive measures would be most effective.

The contribution of this work extends beyond technical simulation, as it provides practical guidance for port authorities, shipping companies, and IT system designers seeking to secure increasingly digitized maritime environments. The publication advances the cybersecurity dimension of the MISSION project's goals by offering a replicable methodology for threat modeling and risk assessment. It demonstrates that systematic and quantitative approaches are essential for building resilient, trustworthy maritime IT infrastructures. The integration of harborLang and YACRAF thus represents a strategic enhancement to the project's ambition of delivering secure, real-time port call and voyage optimization tools that stakeholders can confidently deploy in critical and sensitive operational settings.

Although not directly focused on maritime transport, another contribution from the MISSION project team addresses the critical issue of phishing attacks targeting cloud-based systems [21]. As MISSION's digital architecture relies heavily on cloud services for real-time data exchange and collaboration among stakeholders, securing these platforms against phishing threats is a fundamental requirement. The study adopts a systematic literature review approach to analyze current research on phishing defense strategies in cloud environments. It emphasizes that the growing adoption of cloud services, spanning Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS), has introduced new attack surfaces, making cloud users increasingly vulnerable to sophisticated phishing campaigns that exploit both technical and human weaknesses.

The publication synthesizes findings from a curated set of studies and identifies two main pillars of defense: technical security measures and human-centered interventions. Technically, advanced authentication mechanisms, intrusion detection systems (IDS), and machine learning-based phishing detection algorithms are cited as effective tools. However, the study observes that the human factor remains the most exploitable vulnerability despite these technological advancements. Social engineering tactics continue to bypass technical defenses, highlighting the need for integrated solutions that combine technology with proactive user education. The authors advocate for a deeper integration of social dimensions into cybersecurity frameworks and call for research efforts tailored specifically to cloud environments, where traditional security models may be insufficient.

7. Conclusion

The MISSION project addresses critical challenges in today's maritime industry by offering an integrated digital solution to optimize port calls and voyages. By tackling inefficiencies such as the "sail-fast-then-wait" phenomenon, MISSION contributes to significant reductions in greenhouse gas emissions, improved port efficiency, and enhanced maritime safety. Its approach of developing interoperable standards, real-time collaboration tools, and advanced cybersecurity models directly supports making maritime transport more sustainable and resilient.

Throughout its first 15 months, MISSION has successfully laid the technical and organizational groundwork necessary for developing its optimization tools. It has also produced important scientific contributions covering port call optimization challenges, digital system fragmentation, and cybersecurity risks.

As the project moves into its next phase, it will shift toward delivering working prototypes, pilot testing across European ports, and further refining the business models and governance frameworks needed for large-scale adoption. MISSION will continue to provide new insights into how digitalization and collaboration can drive global logistics' green transition, supporting academic research and practical innovation in the maritime domain.

Acknowledgments

This work has received funding from European Union's HORIZON research and innovation programme under the Grant Agreement no. 101138583.

Declaration on generative AI

While preparing this work, the authors used chatGPT-4o and Grammarly to check grammar and spelling, paraphrase and reword, and improve their writing style. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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