Exploring ConOps Prototypes for Initial Risk Assessment of Autonomous Ship Operations

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Abstract: The Concept of Operations (ConOps) is a document that describes the characteristics of a proposed system from the perspective of its users. It aims to provide a broad overview of the proposed system, including its critical components, functionalities, and intended use. This facilitates communication of the system's concept among stakeholders, including users, system developers, and business decision-makers. Using ConOps to share a conceptual understanding of the subject enables various assessments in the early stages of development, thereby reducing rework at later stages.

In the maritime sector, there is a significant surge in the development of autonomous ships. Various systems and equipment have been developed, ranging from navigation aids to remote control, as elemental technologies. Autonomous ships are created by selecting and integrating these technologies according to their respective objectives. Due to the inherent complexity of autonomous ships, along with new technologies and innovative ideas for their use, it is challenging to communicate a comprehensive concept of their complete form. Developing ConOps documents is considered beneficial for forming and explaining concepts related to autonomous ships. However, this is not an easy task, due to the lack of widely available standard document formats and a mature discussion on the essential components.

This paper discusses ConOps for autonomous ships, specifically intended for use in risk assessment during the early stages of development. First, existing ConOps literature related to the aviation, road transportation, and maritime sectors, which share similarities with autonomous ship technology, is comprehensively reviewed, and key elements are extracted. Following this, a draft table of contents is presented, along with illustrative examples for several primary components.

Keywords: Concept of Operations (ConOps), Autonomous ships, Risk assessment.

1. INTRODUCTION

In the maritime transportation sector, there is an active trend toward ship autonomy. In Japan, there is a particular emphasis on navigation autonomy [1], rooted in extensive experience in the country with ship-handling aids such as track control systems to maintain pre-planned routes and berthing control systems. Among the core technologies are autonomous navigation functions, which enable ships to automatically avoid collisions by generating and following avoidance routes when encountering other ships or obstacles. This technology has emerged founding on the development of more advanced control algorithms and higher-performance sensors and actuators. Ongoing development aims to enhance these functions, enabling ships to make complex decisions by processing a variety of input data. Consequently, it is appropriate to classify autonomous navigation systems as software-intensive systems.

While some believe that autonomous navigation capabilities will enhance safety, others argue that they may increase risk depending on the design and operation. The safety of autonomous ships depends on factors such as the scope, conditions, and scenarios of usage; therefore, it is essential not only to verify individual functionality and performance but also to consider the holistic operation of the vessel. Effective sharing of information about the entire concept of operation, including sailing locations and meteorological conditions, is necessary for comprehensive risk assessment. However, sharing the concept of such a complex system among involved parties is challenging. Conveying and understanding innovative ideas, such as concepts and operational methods for new technologies that do not yet exist, is even more difficult.

One recognized method for communicating a comprehensive view of a system is through a document known as the Concept of Operations (ConOps). In 1998, the IEEE published a guide to the ConOps document for software-intensive systems [2], formalizing this document type. NASA's 2016 System Engineering Handbook

[3] positions ConOps as a crucial element of systems engineering, highlighting its utility across various design phases and providing structural examples in the appendix. While ConOps documents for aviation, road transport, and maritime projects are available online, those for autonomous ships are still rare. Creating ConOps for autonomous ships is challenging due to the lack of a widely accepted standard format and limited discussion on essential elements, which makes addressing safety considerations difficult.

In this paper, we discuss essential elements of ConOps for autonomous ships with a focus on their usage in early-stage risk assessment. First, we present a comprehensive review of ConOps case studies and guidelines related to autonomous ship technology, identifying key elements and proposing a draft table of contents. Next, we outline the information required for the risk assessment, including system understanding, hazard identification, and accident progression scenarios leading to potential consequences. Finally, we provide example descriptions of use case scenarios.

2. ANALYSIS OF CONOPS ACROSS AVIATION, ROAD TRAFFIC, AND MARITIME SECTORS

2.1. Aviation

In this section, we analyse ConOps in fields similar to autonomous ships and identify the necessary elements for a common understanding of this target. In the air transportation sector, numerous ConOps documents are publicly available online. We conducted a comprehensive review of these documents and selected several that provide valuable insights. Table 1 presents an overview of the ConOps reviewed in this study.

The European Aviation Safety Agency (EASA) has issued ConOps [4] for the integration of drones into the existing aviation system. It defines three categories of drone operations based on their impact on people on the ground and aviation, taking into account risks from geographic areas and other factors. The ConOps outlines risk control procedures and guidelines for determining the need for authority permits or certificates for each operational category.

The FAA's ConOps for Unmanned Aircraft Systems (UAS) Traffic Management (UTM) [5] describes UTM operations. It introduces the conceptual architecture, defines the roles and responsibilities of various actors, and provides a self-declaration mechanism for compliance with standards. The mechanism is based on the complexity of airspace and uses risk-oriented metrics such as ground population density, proximity of aircraft near UAS operations, and UAS density. This ConOps also includes operational scenarios to demonstrate the interaction between actors, covering basic operations in various airspaces as well as contingencies and urgent situations, such as equipment degradation and conflicting flight operations.

Another FAA Concept of Operations for Urban Air Mobility (UAM) [6] outlines the envisioned evolution for UAM operations. It defines key indicators for this evolution and presents essential elements of the operational concept: a set of practices referred to as Cooperative Operating Practices, the roles and responsibilities of each entity, UAM corridors forming the airways, and the notional architecture. Operational scenarios demonstrating this evolution are also included.

In aviation, several other ConOps documents are publicly available. For instance, the ConOps for a synthetic vision system for commercial and business aircraft [7] provides examples of its application, organized according to each flight phase. The ConOps for European Aeronautical Information Services Database [8] illustrates its system, services, data and information flows, and roles and responsibilities.

2.2. Road Traffic

While there is not as much publicly available information on ConOps for road transportation as for aviation, we found some notable examples. The ConOps [9] of a project by the California Association for Coordinated Transportation outlines technology services available to both transit operators and rideshare providers, aiming to enable a new level of equitable services accessible to a diverse range of riders. It describes the proposed system, stakeholders and actors, modes of operation, and operational scenarios.

ConOps [10], developed by the Texas A&M Transportation Institute, describes a traffic incident management system that uses unmanned aircraft systems to gather information from the scene of incidents and make decisions about response. It outlines components, capabilities and functions, operational scenarios, and architecture required to address the identified needs.

2.3. Maritime

In the maritime sector, we have encountered several ConOps documents available online, covering surface and underwater operations. After a comprehensive review, we identified a few documents as particularly beneficial for autonomous ship operations and associated risk assessment.

A design team at the Naval Postgraduate School developed a ConOps [11] for the design and operation of a new arsenal ship that addresses personnel manning limitations through technologies such as automation and redundancy. This document outlines design philosophy, including the prioritization of design considerations, and the reduced manning design, covering training and maintenance concepts.

The ConOps of Maritime Domain Awareness (MDA) [12] provides a foundation for achieving an effective understanding of anything associated with the global maritime domain. It includes a list of targets for continuous monitoring, essential tasks for effective decision-making related to these targets, a prioritization structure for information collection, and an architecture for information sharing.

Queensland Fire and Emergency Services (QFES) in Australia has presented ConOps [13] for a new approach to marine rescue operations. It clarifies the mission and roles of Queensland Marine Rescue and outlines the organizing framework, structure, and attributes, as well as capabilities and capacity requirements.

In relation to autonomous ships, Wennersberg et al. [14] offer a comprehensive set of information required by maritime guidelines and propose formalizing the ConOps. Their proposed formalization includes a system description, context description, operational environment description, and scenario description for autonomous ships.

Table 1. Targets and Core Elements Across Sectors in the Selected ConOps

Sector	Literature	Year	Target	Core elements
Aviation	EASA [4]	2015	Integration of drones into the existing aviation system.	Three categories of drone operations based on their impact on people on ground and aviation.
	FAA[5]	2020	Unmanned Aircraft Systems Traffic Management (UAS-UTM).	Conceptual architecture, roles and responsibilities of actors, self-declaration mechanism, and operational scenarios.
	FAA[6]	2023	Urban Air Mobility (UAM).	Cooperative Operating Practices, roles and responsibilities, UAM corridors, notional architecture, and operational scenarios.
	Williams et al. [7]	2001	Business aircraft synthetic vision systems (SVS).	Operational concept and SVS applications, organized by five flight phases.
	EUROCONTROL[8]	2018	Enhanced European Aeronautical Information Services Database (eEAD).	System, services, data and information flows, and the roles and responsibilities, between the eEAD and stakeholders.
Road	Craig et al. [9]	2021	Coordinated transportation ITS4US deployment project.	Proposed system, stakeholders and actors, modes of operation, and operational scenarios.
	Stevens [10]	2017	Unmanned aircraft systems use for traffic incident management.	Components, capabilities and functions, operational scenarios and system architecture.
Maritime	Baumann et al. [11]	2007	Arsenal Ship.	Design philosophy and design for reduced manning.
	NMIO[12]	2007	Maritime Domain Awareness.	A list of targets for persistently monitoring, essential tasks, and information sharing architecture.
	QFES [13]	2022	Marine Rescue Queensland.	Organising framework, structure, and attributes, and capability and capacity requirements.
	Wennersberg et al. [14]	2020	Autonomous ship systems and operations.	Description of autonomous ship system, system context, operational environment, and scenario.

2.4. Key Elements for Autonomous Ship's ConOps

Based on the reviewed cases, the following statements have emerged as crucial elements in systems similar to autonomous ships:

1-a) **Overview**: Basic principles and prerequisites, encompassing goals, objectives, missions, and roles.
1-b) **Conceptual Architecture**: Overall system architecture.
1-c) **Relevant Actors and External Entities**: Entities and their respective roles.
1-d) **Level of Automation**: Automation level, operational conditions, including crew positioning.
1-e) **Operational Categories**: Descriptions of surrounding conditions, such as sea area and traffic density.
1-f) **Key functions**: Internal system functions governing overall information flow.
1-g) **Operational Scenarios**: Usage scenarios and corresponding interactions.
1-h) **Degradation Modes and Procedures**: Management strategies for planned and unplanned events.

These elements form a comprehensive framework for understanding and analyzing autonomous ship systems.

3. CONOPS FOR RISK ASSESSMENT OF AUTONOMOUS SHIP OPERATION

3.1. Key Contents for Risk Assessment of Autonomous Ships

In this section, we discuss key contents necessary for ConOps to serve as an input for early-stage risk assessment, with a focus on risk analysis activities. During the development of concepts for the target system and its operation, certain assumptions essential for risk assessment may be overlooked, and additional information may be required at later stages. By referring to established system-related guides, we have compiled a list of essential elements that we believe are generally required for the risk assessment process of autonomous ships.

From a risk analysis perspective, it is essential to clarify prerequisites such as the role and scope of the target system [15, 16]. An accident is an undesired event that results in what stakeholders consider a loss [17], and risk analysis activities identify possible pathways to these undesired outcomes in the context of hazards, loss scenarios, and consequences. Therefore, the definition of what constitutes these undesired outcomes is an important prerequisite.

Risk assessment of autonomous ships requires methods suitable for complex, software-intensive systems. Some studies [18, 19] have employed the system-theoretic approach [17], while others have proposed the structure model-based hazard identification method [20]. Information for these analyses can be broadly divided into two categories: descriptions of the system that is often the source of hazards, and descriptions of the behaviours within and outside the system that are often associated with undesired outcomes.

In summary, the following elements are necessary for the risk assessment of autonomous ships:
2-a) **Assumptions**: The role and scope of the target system.
2-b) **Constraints**: Undesired outcomes.
2-c) **System configuration and function**: Possible sources of hazards within the system.
2-d) **System behaviour**: Internal and external behaviour related to the evolution of hazards.

3.2. Structure of ConOps for Typical Systems

The IEEE's classic ConOps guide [2] provides essential content tailored for information technology contexts. Building upon this framework, various industry-specific guides have been developed. These guides typically include a referential table of contents outlining the proposed system's concept, including background, objectives, scope, and operational scenarios. This comprehensive structure addresses many key issues discussed in this paper.

The NASA Systems Engineering Handbook [3], widely referenced in the field, emphasizes the importance of ConOps in identifying initial requirements shortfalls and conflicts and provides an annotated outline. According to this handbook, ConOps is updated through a development process known as the V-model, which considers both development and validation phases and serves as a reference for them.

Table 2 illustrates the typical structure of ConOps for various systems, as sourced from the literature [3]. It highlights the information identified thus far as crucial for the risk assessment of autonomous ships, marked with an asterisk (*) and noted in the right column.

Table 2. ConOps Structure in [3] and Key Items for Risk Analysis of Autonomous Ships

NASA System Engineering Handbook[3]	**Key items**	**NASA System Engineering Handbook[3]**	**Key items**
Cover Page		3.3 Interfaces*	1-c)
Table of Contents		3.4 Modes of Operations*	1-h)
1.0 Introduction		3.5 Proposed Capabilities*	1-d), 1-f),
1.1 Project Description			2-c)
1.1.1 Background*	1-a), 2-a)	4.0 Physical Environment*	2-d)
1.1.2 Assumptions and Constraints*	1-e), 2-a),	5.0 Support Environment	
	2-b)	6.0 Operational Scenarios, Use Cases	
1.2 Overview of the Envisioned System*	1-b), 1-c),	and/or Design Reference Missions	
1.2.1 Overview	2-c)	6.1 Nominal Conditions*	1-g), 2-c),
1.2.2 System Scope			2-d)
2.0 Documents		6.2 Off-Nominal Conditions*	1-g), 1-h),
2.1 Applicable Documents		7.0 Impact Considerations	2-c), 2-d)
2.2 Reference Documents		7.1 Environmental Impacts	
3.0 Description of Envisioned System		7.2 Organizational Impacts	
3.1 Needs, Goals and Objectives of		7.3 Scientific/Technical Impacts	
Envisioned System*	1-a)	8.0 Risks and Potential Issues	
3.2 Overview of System and Key		Appendix A: Acronyms	
Elements*	1-b), 2-c)	Appendix B: Glossary of Terms	

3.3. Draft Table of Contents for Risk Analysis of Autonomous Ships

Summarizing the contents up to Section 3.2, Table 3 presents a draft table of contents for the risk assessment of autonomous ships, incorporating the particularly important elements.

Table 3. Draft Table of Contents of ConOps for Risk Analysis of Autonomous Ships

Table of Contents for risk analysis of autonomous ships	**Key items**
Cover Page	
Table of Contents	
1. Introduction	1-a), 2-a)
2. Documents	
3. Envisioned System	
- Objectives and Roles of the System	1-a), 1-d)
- Constraints in Achieving Objectives	1-e), 2-b)
- Overview of System and Related Entities	1-b), 1-c), 2-d)
- Key Elements/Functions and Modes of the System	1-f), 2-c)
4. Use Cases	
- Overall Operation Phases	1-e), 1-g), 1-h), 2-c), 2-d)
- Use Cases Corresponding to Each Phase	1-e), 1-g), 1-h), 2-c), 2-d)
Appendix A: Acronyms	
Appendix B: Glossary of Terms	

Section 1 of the draft table of contents provides a high-level overview of the subject project for which the autonomous ship is developed and operated, namely, its goals, objectives, mission, and scope. It may also include an overview of the vessel, such as its ship type and operational area, but detailed descriptions should not be included. Section 2 contains reference materials that are relevant to the subject project and vessel.

Section 3 includes the envisioned system description, which comprises the following four subsections:

- **Objectives and Roles of the System**

This section describes the objectives and roles of the target system in achieving the overall goal. Identifying them is crucial for understanding the differences from the current situation. If the overall goal is to reduce human error and workload, objectives can be envisioned as work support functions and partial automation. Table 4 summarizes the objectives and tasks being developed in Japan [21–26]. From the table, the missions and scopes of automation currently under development focus on transitioning from present human-operated procedures to introducing work support and implementing partial automation in specific areas, particularly in navigation tasks.

Table 4. Technology Development Efforts for Autonomous Ships in Japan

Literature	Objectives	Tasks
Kuwahara, et al. [21]	Secure safety and reduce work burden.	Collision risk judgment and autonomous operation of vessel.
Hashimoto, et al. [22]	To address collisions caused by human factors and shortages of seafarers.	Collision avoidance.
Suzuki [23]	Reducing workload and preventing human error.	Operation from unberthing to berthing (perception, cognition, judgment, and control).
Inoue and Mori [24]	Reduce the workload of crew and strengthen cost competitiveness.	Port entering and leaving, navigation, and engine room monitoring.
Miyoshi and Ioki [25]	Prevention of human error due to the shortage and ageing of seafarers.	Navigation state control, situational awareness, collision avoidance, and manoeuvring control.
Kureta et al. [26]	Safety of marine transportation.	Manoeuvring, propulsion, communication, and central information management.

- **Constraints in Achieving Objectives**

Constraints in achieving objectives include protecting human life, property, and the environment from potential losses in the event of an accident, and specifying these constraints is necessary. Generally, various existing mandatory regulations and rules protect these aspects, but they do not necessarily provide fully applicable requirements for autonomous ships. Additionally, it may be necessary to identify system-specific constraints.

- **Overview of System and Related Entities**

When identifying hazards and considering their progression, it is necessary to anticipate how the system and its surrounding elements will interact in achieving its objectives. To understand these interactions, it is important to define the target system, including software, and clarify the boundaries among entities. Furthermore, explaining the relationship between humans and systems is essential. One approach to this is the concept of automation levels, which helps in understanding where a system is positioned, ranging from direct human operation to without human involvement. As a reference, ConOps for aircraft [6] explains the relationship between humans and aircraft automation at three levels.

- **Key Elements/Functions and Modes of the System**

How the key elements and functions within the system share roles in achieving the objectives is also important in detecting hazardous scenarios. To do this, it is useful to decompose tasks into functions and show how these functions are shared among humans, hardware, and software. Some functions may operate in different modes or control parameters depending on specific circumstances, known as modes of the system. Since these modes can be confusing to users and potentially hazardous, it is also important to clearly define these modes early in the development process and explicitly describe them in ConOps to promote a unified understanding. Examples of modes of the system could be those set by different manoeuvring methods in the navigation function, such as unberthing/berthing, congested waters, coastal waters, and evasive manoeuvring.

Section 4 of the draft table of contents includes information on the use cases, which comprises the following two subsections:

- **Overall Operational Phases**

When assumptions about how an autonomous ship will be operated vary depending on the situation, it can be helpful to explain these assumptions by introducing broadly defined operational phases. Typical information that facilitates understanding of each phase might include high-level events likely to occur, described as operational scenarios. An operational phase differs from a mode of the system and represents an aspect of the ship's overall operation. Although the two do not necessarily correspond one-to-one, there may be a relationship that defines the mode of the system to be used for each operational phase.

- **Use Cases Corresponding to Each Phase**

The use cases depict concrete event sequences, along with condition statements and overviews, to help readers visualize the system in operation. Creating one or more use cases for each operational phase is recommended. When many use cases are developed, categorizing them by entity role, in addition to operational phase, can improve comprehension. Furthermore, the use cases may be incomplete at the time of ConOps delivery and should be expanded as development progresses. Multiple use cases are provided in references [5–7].

Based on the above discussion, the following sections will further explore the operational phases and scenarios for autonomous ships. Since the focus here is on early-stage risk assessment, particularly the identification of hazards and their progression, we will address the presentation of surrounding conditions. While this information will also be useful for subsequent assessment stages, it is not the primary focus of this paper.

3.4. Illustrative Examples of Key Items

This section presents specific examples related to the introduction section, including a high-level overview, as well as use case examples that correspond to the overall operational phases. It should be noted that not all operational methods described here conform to current legislation and conventions; rather, they include hypothetical operational methods envisioning future scenarios. Figures 1(a) and 1(b) illustrate the relationships among the entities within the (a) planning phase and (b) navigation phase, respectively.

3.4.1 Introduction

Project Description of Autonomous Ships The vessel for this project is a coastal 499 GT general cargo ship transporting steel products from Ise Bay in central Japan to various ports such as Sendai and Shiogama in the northeast, and the Seto Inland Sea in the west. These ships are typical types and routes in Japan's coastal waters. This project explores introducing an automated system for lookout and steering tasks to reduce seafarer workload. Planning will be overseen by the navigating officer, with the automated system operating from pre-departure to post-arrival, eliminating the need for a manual lookout at times.

3.4.2 Use Cases

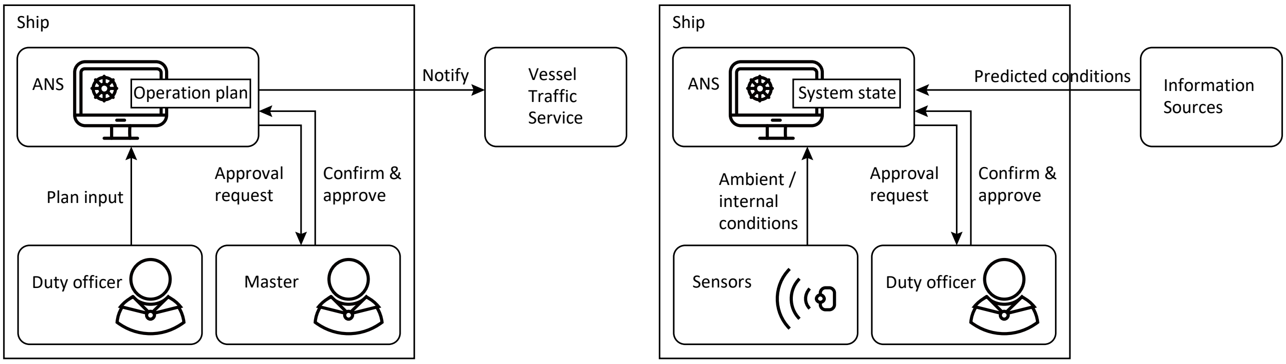
Use Case Overview The vessel in this scenario is a 499 GT general cargo ship for steel products in coastal service. It transports cargo from Ise Bay to various ports, including Sendai and Shiogama, and the Seto Inland Sea. This size and type of vessel is one of the most typical in Japanese coastal waters.

(1) Planning Phase

Actors include the autonomous navigation system, the duty officer responsible for creating the voyage plan, the vessel's master, and outside stakeholders, such as the Vessel Traffic Service. A use case outlining the key events likely to unfold in this phase is also provided below.

1. Planning Phase The vessel is scheduled to sail from a central port in Japan, Ise Bay, to a major city in northeast Japan, Sendai. Autonomous operation planning is conducted concurrently with the vessel's voyage planning the day before departure. Based on the route plan and related information, autonomous functions are scheduled to commence at 15:00 at Pier A, followed by sequential usage of corresponding functions under operational modes such as unberthing, congested waters, coastal waters, and berthing, terminating at Pier B in Sendai. Functions are activated and switched at defined zones. The second officer responsible for the voyage plan creates and enters the autonomous operation plan into the system, which is then approved by the master using an approval password. Duty officer manning and standby limits, including movement in and out of the bridge and the wearing of portable communication devices, depending on the type of autonomous function and the sailing area as defined in prior plans.

After the checking function confirms no conflicts between routes and planned functions, relevant authorities are notified. A trigger, such as time, initiates the first autonomous operation function, with the scheduled time registered in the system. Information on the duty officer's standby limits is displayed on a dedicated bridge display and transmitted to the receiver worn by the duty officer.



(a) Planning Phase (b) Departure Phase

Figure 1 The Relationships among the Actors in Each Phase

(2) In-Navigation Phases

The in-navigation phase consists of three subphases: departure, navigation, and arrival, all crucial for the progression of the voyage. Below is a use case outlining the key events likely to unfold in each of them.

2. In-Navigation Phases

Each of the in-navigation phases has its own preparation time. The initiation of each phase is triggered by the vessel's position or time of day. Prior to entering each phase, the respective function undergoes preparation operations, such as collecting necessary information and verifying proper situations, which are then verified by the duty officer.

Throughout all phases during the voyage, the responsible functions are clearly displayed on the bridge. Specific operations can be viewed on a dedicated display within the bridge and on portable devices. All external calls received via Very High Frequency (VHF) are relayed to the duty officer through displays on the bridge and portable devices. The duty officer responds by accessing the vessel's bridge.

2.1 Departure Phase

Two hours before departure, the system is activated to begin its preparation as scheduled. It collects information on the current ambient and internal conditions, as well as predicted conditions such as weather forecasts. Using this data, the system verifies if each state is sufficiently within the operational design domain (ODD). Once the required ODD is confirmed, approval to start is requested from the duty officer, who accepts it.

The unberthing mode function is initiated, allowing the vessel to leave the pier under proper control. Subsequently, the forward speed gradually increases, and the vessel switches to the navigation mode for congested waters as it crosses the pre-defined gateline.

2.2 Navigation Phase

The function proceeds with sailing according to the autonomous operation plan. When it needs to avoid other vessels or obstructions, the system switches to evasive manoeuvring mode. Detected objects and manoeuvring intentions are displayed on a dedicated screen in the bridge and on portable devices. As the vessel passes the gateline marking the boundary between the harbour or bay and the coast, the system switches to coastal waters mode and switches back to congested water mode when the vessel crosses the next gateline.

2.3 Arrival Phase

While manoeuvring in port, the Vessel Traffic Service (VTS) alerts the vessel about a vessel ahead requiring attention. The duty officer inputs this information into the manoeuvring function, which calculates an appropriate separation distance, adjusts the course, and continues navigation. The officer monitors the planned route and actual manoeuvring conditions to ensure everything is proceeding correctly.

As the vessel approaches the gateline for the berthing phase, the system activates the autonomous functions for berthing, gathers information for the transition, and confirms that the course to the pier is clear using AIS, radar, or other sources. It then requests approval from the duty officer.

The officer checks the displayed position information of the own vessel and other vessel for anomalies. After visually confirming the vessel's condition, the officer approves and monitors the autonomous system as it manoeuvres the vessel. The vessel crosses the gateline and enters the berthing phase, where speed and heading are controlled to complete berthing.

(3) Post-Operations Phase

The post-operations phase encompasses everything that takes place after the end of the voyage until all tasks are finalized. Below is a use case outlining the key events likely to unfold in this phase.

3. Post-Operations Phase
Each display indicates that the autonomous operation plan has been completed and all related functions have been terminated. Each relevant party is notified of the completion of registered plans. The required autonomous operation data is archived.

The above examples of a specific figure and descriptions for each phase are intended to provide the information needed to begin the risk assessment. However, more detailed descriptions may become necessary as the analysis progresses.

4. CONCLUSION

In this paper, we discussed essential elements of ConOps for autonomous ships, with a primary focus on early-stage risk assessment. First, we conducted a comprehensive review of several ConOps available online in the aviation, road traffic, and maritime sectors that share similarities with autonomous ship technology, as well as related guidelines. This review helped identify key elements and provided a draft table of contents. We then discussed the information required for understanding the target project, hazard identification, and hazardous scenario detection. Finally, we provided illustrative examples, including a high-level overview and use case scenarios.

ConOps is not considered complete once developed; rather, it becomes more detailed as the design process progresses. At the same time, more detailed assumptions will be required as risk assessments are conducted, and it will be refined as the analysis advances.

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