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Impact of portable piloting units on the situation awareness of maritime pilots perspectives of Danish and West African pilots

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IMPACT OF PORTABLE PILOTING UNITS ON THE SITUATION AWARENESS OF MARITIME PILOTS

PERSPECTIVES OF DANISH AND WEST AFRICAN PILOTS

BERNARD KUWORNU

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

2023

Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): **...**

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Abstract

Title of Dissertation: **The impact of portable piloting units on the situation awareness of maritime pilots:** perspectives of Danish and West African pilots

Degree: **Master of Science**

Many maritime pilot organizations have adopted Portable Piloting Units (PPUs) to improve safety during pilotage. However, the impact of PPUs on pilots' cognitive processes, particularly their situation awareness and decision-making, has not been investigated. The aim of this study,therefore, is to identify the effects of PPUs on situational awareness and decision-making of Marine Pilots. The objectives of the study are to describe how marine pilots make navigational decisions during pilotage, to catalogue the decision-support systems and tools used during pilotage, and to evaluate the impact of PPU on pilots' situational awareness and decision-making. Qualitative research methodology associated with the interpretive paradigm approach that aimed to generate a better outcome through description was used. In all, respondents were sampled for the study using expert sampling and judgmental sampling approaches. The respondents were drawn from West Africa and Denmark. An interview guide was the main research instrument designed and administered. The general opinion of the respondents was that most ports around the world have adopted technologies such as ECDIS and PPUs to ensure navigational safety during pilotage, especially in complex and congested waterways. PPUs are incorporated into daily operations across all work schedules aboard vessels except those which do not have facilities for its use and those involving minimal manoeuvring complexity. The study shows that using the PPU along with other tools available to maritime pilots improves their situation awareness, leading to better decision-making. The results are conclusive in demonstrating the positive impact of PPU on the safety outcomes of pilotage manoeuvres. This provides valuable evidence for decision-makers who are considering implementing PPUs for their pilotage organizations. For further research, an investigation can be conducted to determine whether the use of PPU has reduced accidents that occur during pilotage.

KEYWORDS: Portable Piloting Units, marine pilots, situational awareness, decision-making, Training

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List of Abbreviation

AIS	Automatic Identification System
D/GPS	Differential Global Positioning System
GALILEO	European Navigation Satellite System
GLONASS	Global Navigation Satellite System
ECDIS	Electronic Chart Display and Information System
FAA	Federal Aviation Authority,
IMO	International Maritime Organisation
IMPA	International Maritime Pilots' Association
ISPO	International Standards for Pilotage Organisations
OODA	Observe-Orient-Decide-and- Act
PPU	Portable Piloting Unit
REC	Research Ethics Committee
ROT	Rate Of Turn
SA	Situation Awareness
TCAS	Traffic Collision Avoidance System (used in aviation)
UID	User Interface Display
UNCTAD	United Nations Conference on Trade and Development

1 Introduction

Estimates provided by UNCTAD in 2022 shows that, more than 80 per cent of the volume of global trade occurs on the world's oceans (UNCTAD, 2022). The contribution that the shipping industry makes to global economy is essential. The ability to transfer huge quantities of commodities at a reasonable cost is made possible by shipping, which is why shipping is considered to be the "enabler" of international trade. At the moment, there are more than 130,000 ships with a gross tonnage of more than 100 GT (Allianz Global Corporate & Specialty, 2022).These ships carry a variety of goods, including crude oil and oil products, grains, iron ore, coal, semi-finished products, and finished products, amongst other things, to help drive the global economy. Protection of life and property at sea is vital, and various issues/concepts contribute to a better level of safety at sea. Some of these are the IMO conventions like SOLAS (Guevara & Dalaklis, 2021).

Ships carry out trade by transporting cargo from one port to another, either in the same country or in different countries. Therefore, to obtain entry to the ports and conduct their business, ships require the assistance of maritime pilots who are trained to safely navigate hazardous marine environments(Butler et al., 2022). According to Lappalainen et al. (2014), maritime piloting comprises an essential part of vessel operations that are typically characterised by congestion, increased hazards of grounding, and chances of collisions. Coupled with the fact that the waterways are not also increasing in depth and width in tandem with the ships, this makes maritime pilotage an essential service. Safe pilotage contributes to maritime safety, environmental protection, and continuity of global trade.

This is evidenced by the Ever Given blockade of the Suez Canal in 2021, which caused a daily trade hold-up of US$ 6.9 billion for each day she remained stuck in the canal (BBC, 2021). Maritime pilotage is defined as the practice of controlling ships at ports, terminals and berths and ensuring their safe transit through crowded waterways that represent a variety of risks, such as shallow water and closeness to other navigational hazards (Andresen et al., 2007). Due to a lack of local knowledge of the terrain on the part of Shipmasters and the need for coordination with mooring services like tugs and linesmen, maritime pilot assistance is required for entry and exit of the port in the majority of jurisdictions (Martin, 1977; Sharma et al., 2019). This is the case for both domestic and international seaports. According to Lahtinen et al.(2020), maritime piloting can also be defined as the technique of properly navigating ships through crowded waterways.

Maritime pilots are typically ship captains or deck officers who have undergone specialised training and certification to operate vessels in key port and coastal waters. This training and certification allow marine pilots to navigate vessels in waterways that are vital to the port and the shore. According to Hadley (1999), marine pilots are mariners who possess excellent ship-handling skills in addition to specialized knowledge of the topography of the surrounding area. They board the inbound vessels at predetermined sites that are referred to as pilot boarding stations, and then the crew on the bridge assists them in bringing the vessel to its berth. Although the ship's captains retain complete control of the vessel at all times, "conduct" of the navigation is often given to the pilots; however, in reality, most ship crews completely rely on the input of pilots (Wild, 2011). They navigate the ship through busy or hazardous waterways until it is in a safer position or has arrived at the moorings that have been set for it (Orlandi & Brooks, 2018).

As a consequence of this, pilotage requires sophisticated interactions with the bridge team, tug masters, linesmen, vessel traffic services, and electronic equipment (Betz, 2015). The International Maritime Organization's main focus has always been on improving maritime safety. As a direct consequence of this, the Organisation has taken the necessary steps to improve maritime safety by adopting various instruments and procedures. Despite this, incidents continue to take place. Between January and December 2021, there were a total of 3,000 maritime casualties and events, 54 of which were total losses. Even though the number of ships lost has gone down by about

57% in the last 10 years, the number of marine casualties and incidents has gone up (Allianz Global Corporate & Specialty, 2022).

It is abundantly clear that the shipping industry still faces a problem with accidents and mishaps. According to the findings of investigations and surveys conducted into these accidents, human error is responsible for around 75-96% of the causes of these mishaps. Notably, almost 70 percent of large accidents and allisions happened in pilotage waters, and a pilot was in command of either one or both of the vessels involved (Hanzu-Pazara et al., 2008; Sánchez-Beaskoetxea et al., 2021). In the case of groundings, the predominant causes were resource management, adverse mental state, skill-based errors, and technological environment (Yıldırım et al., 2019).

The analysis of these marine accidents shows that decision errors, resource management, violations, inadequate work planning, and incompetence were to blame. On the other hand, the most common causes of marine accidents were found to be decision errors, resource management, violations, inadequate work planning, and incompetence. According to (Newnam et al., 2020), the most common contributory reasons for accidents were errors in judgment and choices made by the individuals involved. The information presented above makes it abundantly evident that the decision-making process of pilots is an essential component in the overall safety of marine pilotage.

The process of decision-making for pilots is influenced by a wide variety of information sources, including people, ships, the environment, and real-time requirements (Xue et al., 2019). To accomplish this goal, information regarding the decision-making process of piloting needs to be automatically obtained, articulated, and have a higher level of efficacy. The concept that has been discussed and referred to as "Situation Awareness" is an important part of this decision-making process. The state of information that an individual possesses about an evolving environment is referred to as situation awareness, abbreviated as SA (Melnyk et al., 2022). A perception of relevant aspects, a grasp of their relevance in conjunction with and with reference to the operator's goals, and a projection of future environmental conditions based on this knowledge are all included. People with a high SA are more likely to use the information at hand to arrive at the appropriate conclusions and do well in environments that are dynamic.

The level of SA possessed by an operator represents the final human safety barrier that prevents an incident from developing into an actual incident (Endsley & Jones, 2004). According to Endsley(1995a), an operator's incapacity to interpret critical information, develop an accurate mental model of the situation, or anticipate how the scenario will play out may be a contributing factor in the occurrence of an accident Chauvin et al. (2013), also found that a lack of appropriate situational awareness frequently comes before making poor decisions. As a result, this demonstrates that having a solid SA is essential to the process of making effective decisions.

This decision-making process can be compared to Col. John Boyd's OODA loop theory, which originally explained the decision-making process of fighter pilots in aerial combat (Ryder & Downs, 2022). This theory involves a series of steps that begin with observing both the internal and external environment, followed by orienting oneself to the situation. These initial steps are consistent with Endsley's situation awareness theory, which emphasises the need to perceive and comprehend the situation at hand accurately. The next stage of Boyd's OODA loop involves deciding based on the information gathered in the observation and orientation stages, followed by taking action on that decision. It is essential to note that the decision made in this stage is based not only on the information gathered but also on the experience and intuition of the fighter pilot. Finally, the cycle repeats, with each repetition providing new information and allowing the pilot to adjust their approach accordingly. The OODA loop theory is a valuable tool for decision-making in high-pressure situations, such as aerial combat, as it emphasizes the need for speed, accuracy, and flexibility (Junega, n.d.).

By combining these two models, individuals and organizations can develop a comprehensive approach to decision-making.

There is less time for monitoring, interpreting, digesting, and updating information to stay current when more focus is needed to support performance, as is often the case in marine pilotage, especially while approaching or leaving berths(Vidulich & Tsang, 2015). This can make it difficult to maintain awareness of the present state of affairs. According to Grech et al.(2002), when operators are faced with conditions like these, it may be beneficial for them to make use of more modern technology (such as that which is included in portable piloting units), as this type of equipment is capable of processing information more quickly.

A PPU is a portable, computer-based device that a pilot puts onboard a ship and utilises as a decision-support aid when navigating in restricted waters. It does this by combining an electronic chart display with a positioning sensor interface, like a D/GPS so that it can display the current position of the vessel and its progress in real-time. PPUs that are also connected to an AIS interface to additionally provide the location as well as the movement of other ships. PPUs are being utilised more frequently to display additional navigational data such as soundings and depth contours derived from recent hydrographic surveys, dynamic water levels, current flow, ice coverage, and security zones (Alexander & Casey, 2008). When berthing or unberthing, the PPU is able to provide accurate information on vectors and distances. The path predictor track is yet another tool that is quite helpful.

The portability of the PPU makes it easier for the pilot to carry it to the bridge wings, which is the most preferred position when approaching or leaving the berth or terminal. Technology has made it possible for a vessel that is operating near the limits of its operational area to do so in a considerably safer manner (Wild, 2011). The purpose of this dissertation is to fill in this gap in the existing research and make a contribution to both theory and practice by investigating the effect that technology (in the form of the PPU) has on the situational awareness of pilots and, as a result, the safety of pilot operations in general.

1.1 Background

Many academic works have been published on the topic of pilot safety technology (Alexander & Casey, 2008; Ostendorp et al., 2015; Stanley, 2020; Trzuskowsky et al., 2016). These studies have focused mostly on practical applications of the technology; hence, there is a knowledge vacuum regarding the effect of these technologies on the pilots' mental tasks. This study fills that need by examining the impact of new technologies on pilots' minds and determining how to harness their full potential for maritime safety is an important goal.

1.2 Aim

This dissertation aims to examine the impact of Portable Pilot Units (PPU) on the situational awareness and decision-making of Marine Pilots. The study was guided by four objectives. Firstly, to describe how marine pilots make navigational decisions during pilotage. Secondly, to identify the decision-support tools used during pilotage. Thirdly, to evaluate the impact of PPU on pilots’ situational awareness and decision-making. Finally, to explore ways of enhancing the use of PPU to improve navigational safety.

To achieve these objectives, the dissertation seeks to answer three key questions. Firstly, during pilotage, what decision-making process do marine pilots use and what decision-support tools do they rely on? Secondly, what are the effects of using PPU on marine pilots’ situational awareness and decision-making? And lastly, how can the use of PPU be improved to enhance navigational safety?

1.2 Scope and Limitations

The purpose of the dissertation was to investigate the impact of portable pilot units on the situation awareness of maritime pilots. Maritime pilots are affected by many factors, some of these factors include fatigue, communication, and bridge team management amongst many others, however, the perspective of this dissertation is technological, thus portable pilot unit impacts the pilot cognitively.

The study population was drawn from Denmark, and West Africa (Ghana and the Republic of Benin). Due to the geographic spread of the location of the participants and also the limited time available for this research, the study adopted interviews using digital media such as Zoom. The researcher interviewed 12 participants who are marine pilots and use portable pilot units in their pilotage manoeuvres.

1.4 Proposed Methodology

As mentioned earlier, there have been some attempts to research marine pilotage issues, but there is inadequate research on the use of the PPU. Furthermore, there is no evidence of research on the cognitive aspect of using PPU. Therefore, to investigate this aspect, the appropriate research methodology used is a qualitative approach. Investigating attitudes can be done through qualitative research using methods like focus groups or interviews. It obtains an in-depth perspective from the participants (Dawson, 2002). According to Kunnaala et al. (2018), to acquire a comprehensive view of the subject at hand, interviews provide more depth, and those being interviewed have the opportunity to air their opinions thoroughly and further specify and explain the issues in more detail. This allows for a more complete picture to be obtained. Since the purpose of the dissertation is to investigate the effect that PPU has on the situational awareness of marine pilots, the qualitative technique gives the level of in-depth analysis that is necessary to address the questions raised by the research.

An interview guide (attached as an appendix) was prepared after a review of the appropriate literature. The interview guide was then sent to an experienced pilot for moderation, and the necessary corrections were applied.

Consent forms were mailed to participants for completion and return. To ensure smooth and efficient interviews with respondents across different regions, the Zoom conferencing software was utilized. During the interviews, the software's built-in recording feature was used to capture the conversations. To transcribe the data obtained from the interviews, Otter.ai software, which is known for its accuracy and speed in transcribing audio data, was used. After obtaining the transcriptions, they were carefully reviewed and verified for authenticity and accuracy. Due to the limited sample size, a manual data analysis was employed to gain a comprehensive understanding of the findings.

1.5 Ethical concerns

Before conducting any study that involves human respondents, approval must be obtained from the World Maritime University Research Ethics Committee. The committee follows specific policies and criteria to ensure ethical research practices. In this case, the researcher conducted a critical review of the literature and created a questionnaire to gather the necessary data. A maritime pilotage expert moderated the questionnaire to ensure that it effectively addressed the research questions. The questionnaire, along with the research proposal, protocol form, and consent form, were submitted to the REC for approval. Once the approval was granted, the research was able to proceed.

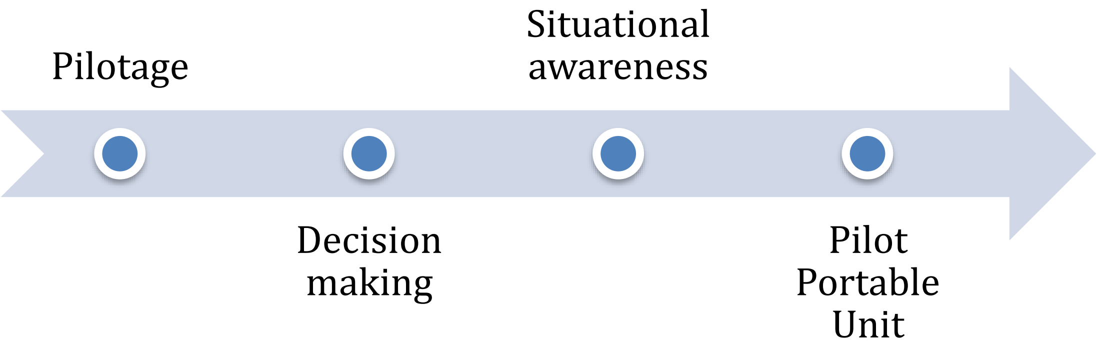
1.6 Structure of the Dissertation

Chapter Two of the literature study focuses on maritime pilotage, decision-making, situational awareness, and portable pilot units (PPU). In Chapter 3, we discuss in detail the methodology employed, sample size determination, and research instruments and describe our analysis and interpretations of the data. The results obtained from the analysis are presented in Chapter Four, while Chapter Five concludes the study, provides suggestions, and suggests areas for further research consideration.

2 Literature Review

The purpose of this research was to examine the impact of Portable Pilot Units (PPU) on the situational awareness and decision-making of Marine Pilots. The study was guided by four objectives. Firstly, to describe how marine pilots make navigational decisions during pilotage. Secondly, to identify the decision-support tools used during pilotage. Thirdly, to evaluate the impact of PPU on pilots' situational awareness and decision-making. Finally, to explore ways in which the use of PPU can be enhanced to improve navigational safety. This chapter reviews the literature on maritime pilotage, decision-making, situational and portable pilot units and their impact on pilots' situational awareness. The review of the literature will help ascertain the extent to which other academics have studied the concept of decision-making on marine pilots' situational awareness, especially in the current advent of Portable Pilot Units (PPUs).

Figure 1: Visual Chapter Outline



2.1 Maritime Pilotage

To gain a better understanding of the complexities involved in maritime pilotage operations and the decision-making environment, it is important to discuss maritime pilotage. Maritime pilotage is the conduct of the vessel through sensitive and hazardous maritime zones during the arrival and departure from port phases of a vessel's voyage (Butler et al., 2022) . As per the research conducted by Westinet al.

(2019), pilots are well-equipped with in-depth knowledge of their particular geographical area and are acknowledged as specialists in local navigation. Furthermore, they possess a thorough understanding of multiple vessels and technical tools utilized in their field. In compulsory pilotage, pilots provide local knowledge of the navigation conditions prevailing in the area. It is the entire responsibility of the pilot, who reports to the Master, to ensure that the vessel is navigated safely. The Master continues to be ultimately responsible for the safety of the vessel, but he or she depends on the local knowledge and capabilities of the pilots to operate the ship in a manner that is both secure and efficient (TSB, n.d.).

In many places, the piloting of ships into and out of ports is mandatory due to the constraints and the sensitive nature of the port approaches(Wild, 2011). With years of seafaring experience, daily contact with the marine environment, constant observation, practical skills, and specialized training, pilots possess thorough familiarity with their localities. They are well-informed when channels change, storms carry away buoys or extinguish lights, or wrecks obstruct the channel(Martin, 1977). Consequently, they are the most qualified individuals to bring ships safely into and out of port. Shipmasters who are absent from the harbour for prolonged periods or use different ports frequently may not be aware of these crucial details (Martin, 1977). It is a fact that a pilot is rightly defined as the “temporary engagement of an expert” (Martin, 1977).

A crucial factor in favour of maritime pilotage is that ships are getting larger to benefit from economies of scale. However, the waterways are not expanding to accommodate these larger vessels, which restricts the amount of navigable water. Expert assistance is necessary to navigate through these restricted areas (Konstantinus, 2021).

2.1.1 History and Development of Maritime Pilotage

For centuries, the practice of pilotage has been essential for ships entering or leaving harbours with restricted waters. Skilled individuals familiar with the local navigation challenges were required to guide the vessels. Over time, pilotage has grown from humble beginnings to become a vital component of navigation around the world.

Although each country has its own specific laws and regulations, the international concept and implementation of pilotage remain largely consistent (Martin, 1977).

The practice of pilotage dates back to Hammurabi's Babylonian Code (1700 BC), which established regulations for pilot compensation and penalties for accidents and lost ships. The Christian bible also mentions pilots in Ezekiel Chapter 27 verses 8, 28-29. Additionally, Rhodian law, which originated in the third century on the Greek Island of Rhodes, included provisions for pilot wages. The regulations that were established on the little island of Oleron, which is located in the Bay of Biscay, continue to serve as the foundation for contemporary maritime law. A pilot who lost his ship by default was to be taken to the windlass and there beheaded by the crew, and the crew were not answerable to any judge because the Lodesman had committed high treason against his undertaking of pilotage. These laws, which were introduced in England in the 12th century, laid out severe punishments for the act of losing a ship (Martin, 1977).

Throughout history, travellers and explorers have often relied on the expertise of pilots. For instance, Marco Polo hired Arab pilots during his journeys. Arab pilots were also actively involved in the Near East and the Indian Ocean in 1498. Vasco da Gama similarly employed pilots on his first journey around the Cape of Good Hope on his way to India.

Prior to the 15th century, pilots were not required to possess detailed knowledge of the routes they were navigating. Their knowledge was limited to the location and basic shape of the coastline, which they could have gained from their experience as former Shipmasters. As ships increased in size, they began hiring local pilots who had extensive knowledge of the areaIt was unfortunate that there was no way for ships and pilots to communicate with each other, which caused pilots on the Thames River to wait in their boats and keep watch for incoming vessels. This situation was probably the same in other regions as well. Consequently, there was often a competition among pilots to offer their services to the incoming ships (Martin, 1977).

The need for formalized pilotage emerged due to the fear that inexperienced and young men were replacing older and more experienced individuals, resulting in ships being put in danger and leading to property damage and loss of lives. The Trinity House, an Association of Shipmen and Mariners with a semi-religious background, requested a charter from Henry VIII. On May 20th, 1514, the charter was granted, paving the way for organized pilotage in the UK (Martin, 1977).

The first recorded history of American pilots dates back to 1694 when the Governor of the Colony of New York issued the first Sandy Hook pilot license. Information about pilots before this time is limited. However, it is known that at the beginning of pilot services, there was intense competition among pilot crafts to be the first to reach incoming vessels and guide them into port. The first Boston lighthouse keeper was a pilot appointed in 1716, and due to the fierce competition, he successfully petitioned to become the established pilot of Boston Harbour (Martin, 1977).

In the late 1700s, the initial Congress of the United States acknowledged the occupation of pilotage and passed laws to delegate control to the individual states.

Regulations governing pilotage have been in place in Canada since colonial times, with New Brunswick introducing pilotage laws as early as 1789. The Canadian pilotage system as we know it today dates back to 1873. In Australia, the first official mention of pilotage was on May 29, 1803, while in New Zealand, the earliest recorded instance of pilotage dates back to 1839. The first international pilot service was established on the Hooghly River in 1669, where English pilots surveyed the local terrain and began offering services to ships that were previously unable to navigate the river due to natural hazards and pirate attacks (Martin, 1977).

In 2003, the IMO Assembly passed a resolution called A.960 (23) “Recommendations on training and certification and operational procedures for maritime pilots other than deep-sea” that addressed training, certification, and operational procedures for maritime pilots who are not deep-sea pilots. This resolution included recommendations for the training and certification of these pilots, as well as guidelines for their operational procedures (IMO, n.d.). The above is a recommendation and not a requirement, meaning that States are not obligated to follow them. This results in varying standards of pilotage across the world.

2.1.2. Importance of Maritime Pilotage

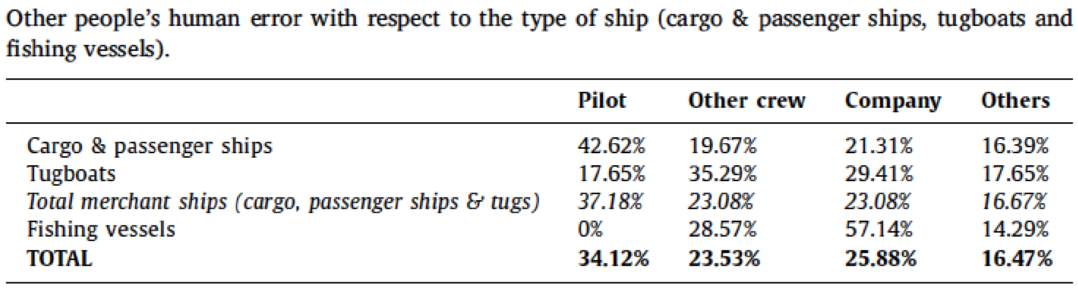
Professionals who work at ports are responsible for ensuring that incoming ships have a safe place to dock and for protecting the infrastructure of the port. Successfully and safely navigating vessels within the confines of the port requires a complex and interdependent relationship based on shared responsibilities and cooperation. Shipmasters and port authorities depend on the knowledge, skill, and expertise of individual maritime pilots to ensure safe vessel navigation during port passages. This is a crucial part of their shared objective (Betz, 2015).

According to Chiing et al. (2021), the likelihood of a ship colliding while not being piloted is approximately nine times greater than when a pilot is present. Picture the danger presented by a massive vessel transporting hazardous materials, manoeuvring through narrow waterways where the chances of mistakes are high, and the resulting effects could be disastrous (Konstantinus, 2021).It's crucial to highlight the importance of maritime pilotage in ensuring environmental safety and protecting commercial interests. In the event of marine accidents, the costs incurred can be substantial, affecting property, infrastructure, and the environment, particularly around ports where the population is concentrated. The pilot's responsibility is to prevent such incidents from happening.

2.1.3 Challenges

Maritime pilotage presents several challenges, especially in how it is organized. The pilot may only have knowledge of the ship's basic dimensions and rely on experience and general rules to estimate other characteristics, but they can still successfully bring the ship to the dock with a high rate of success (Westrenen, 1995). Although some endeavours have been successful, there are also instances where they have not. For example, a study conducted by Sánchez-Beaskoetxea et al. (2021) in the U.S. maritime transport sector revealed that pilot error is responsible for 43% of incidents involving cargo or passenger ships.

Table 1: Other people's human error with to the type of ship



Other people's human error with respect to the type of ship (cargo & passenger ships, tugboats and fishing vessels).

	Pilot	Other crew	Company	Others
Cargo & passenger ships	42.62%	19.67%	21.31%	16.39%
Tugboats	17.65%	35.29%	29.41%	17.65%
Total merchant ships (cargo, passenger ships & tugs)	*37.18%*	*23.08%*	*23.08%*	*16.67%*
Fishing vessels	0%	28.57%	57.14%	14.29%
TOTAL	**34.12%**	**23.53%**	**25.88%**	**16.47%**

Source: Sanchez-Beaskoetxea et al, 2021

From the table above, it is evident that pilot error is responsible for 43% of incidents involving cargo or passenger ships, while 21.31% are caused by the company. Other crew members cause 19.67% of incidents, while the remaining 16.39% are caused by other factors such as weather, and engine failure, among others. This shows that the human element is prone to cause the majority of incidents that happen onboard.

Pilotage operations consist of eight primary tasks: requesting and receiving the pilot, establishing a positive group dynamic, installing the pilot, evaluating the surroundings and weather, determining the best route, monitoring navigation, and coordinating with tugboats and berthing (Ernstsen & Nazir, 2018). When performing these tasks, mistakes may result in unwanted situations, such as accidents and incidents.

Based on the research by Oraith et al. (2021), several factors have been identified as leading causes of incidents and accidents during maritime pilotage. These include distractions during manoeuvring, a lack of situational awareness, unfamiliarity with electronic navigational equipment, failure of tug masters to follow pilots' instructions precisely, and pilot error.

Ernstsen and Nazir (2018) found that the most common errors made by pilots during operations are related to not taking action (deciding not to act), and the second most common error is communication mistakes. The most important factors in the piloting process were identified as situational awareness and decision-making (Chiing et al., 2021). It is the aim of this paper to ascertain the impact on technology especially the PPU on the above factors.

2.1.4 Role of Technology

Pilots primarily rely on visual cues from the window to monitor vessel movements and the positions of other vessels. They use onboard radar, gyrocompass, and chart displays, as well as their own PPUs, mainly for confirmation purposes (De Vries, 2017). Over the years, pilots have relied on outside view when navigating vessels, but they also use the equipment on board. As technology advances, maritime pilotage has seen the adoption and use of various equipment, including the PPU.

Betz (2015) stated that maritime pilots are adopting modern technologies in the form of PPUs. These devices can be carried onboard and provide accurate navigation data directly to navigation stations onshore.

In 2008, Alexander and Casey discovered that PPUs were customized to address challenges specific to the local pilotage district. These challenges include tracking changing depths and meeting points and assisting with docking. Different pilot stations utilized various software and hardware solutions to address these challenges.

Advances in technology for maritime pilotage have led to the availability of augmented reality-based equipment. Notably, Ostendorp et al (2015) tested smart glasses designed to mimic the PPU, which enhance pilots' situational awareness by providing information about their working environment.

2.2 Navigational decisions during pilotage

According to Hutchins (1995), the difficulty that a navigator has is usually not one of determining how to process the information in order to obtain a predetermined result. In most cases, the difficulty is simply using the current tools and techniques to process the information acquired by the system and create a suitable evaluation of the ship's position or an appropriate recommendation about how the ship should proceed to arrive where it is supposed to go. From the foregoing, it can be seen that decision-making poses a challenge in the maritime domain, due to the multiplicity of information and information sources.

Klein et al (2010) defined decision-making, as the selection of one option from a set of choices. In familiar work settings, job performance is often based on the experience and knowledge gained from older colleagues during training and improved through practical application. Professionals in these settings do not typically rely on a thorough analysis of the situation before making decisions. They have a good understanding of their work environment and are familiar with the options for action that are relevant in a given situation. These options are known by heart, and they only need a cue to make a choice. The choice is based on a specific piece of information that distinguishes between those few options. If the work system conditions change, the familiar cues that professionals rely on will no longer be valid. Even if their performance is locally acceptable, undesirable side effects may propagate through the collaborative network (Svedung & Rasmussen, 2002).

Making decisions can be quite complicated, especially in situations where there are multiple factors such as time constraints and a need for cooperation. Elgin and Thomas (2004) pointed out that decision-making tasks that occur in naturalistic settings are often multifaceted and can involve problems that don't have clear-cut solutions, as well as uncertainty in the information available and environmental cues that keep changing. Pilotage is an active and multifaceted operation (Sharma & Nazir, 2017), where the risk of incidents is increased (Lahtinen et al., 2020). Which function in a complex (Chambers & Main, 2015), high-risk (Main et al., 2017), and time-sensitive work environment; (Andresen et al., 2007; Barbarewicz et al., 2019). Pilots' onboard leadership, local knowledge, passage planning guidance, and risk management skills are critical for safe port operations. Achieving optimal pilotage necessitates collaboration among different stakeholders in the maritime industry (Sharma et al., 2019). Pilots are onboard experts who assist the Master and crew in safely manoeuvring vessels in confined waters (Butler et al., 2022).

The process of making decisions regarding maritime pilotage closely resembles the NDM (Naturalistic Decision Making) paradigm that has been previously discussed.

Elgin & Thomas (2004) integrated 3 models of the NDM paradigm which are: (i) Rasmussen’s model of cognitive control distinguishes three types of behaviour: skill-based, rule-based, and knowledge-based. This operates within a decision ladder framework that allows for heuristic cut-off paths (Klein, 2008).

Skill-based behaviour

The term skill-based behaviour refers to automatic, integrated patterns of sensory-motor performance that occur without conscious control once an intention has been stated. In most skilled sensory-motor tasks, the body synchronizes movements with the environment using a multivariable continuous control system. Performance depends on an efficient dynamic internal model and feedforward control. In general, human activities can be considered a sequence of skilled acts composed for specific purposes. Skilled performance is flexible due to the ability to choose from a repertoire of automated subroutines (Rasmussen, 1983).

Rule-based behaviour

Subroutines in a work setting are controlled by stored rules derived through instruction, problem-solving, or empirical data. Control is teleological, with successful past experiences informing the selection of rules. However, reaching the goal may require a long sequence of acts and direct feedback correction may not be possible (Rasmussen, 1983).

Knowledge-based behaviour

Rasmussen's (1983) research suggests that when faced with unfamiliar situations, individuals must shift their performance control to a higher conceptual level that is both goal-driven and knowledge-based. This involves explicitly formulating a goal based on an analysis of the environment and overall aims. A practical plan is then developed by selecting and testing various options against the goal, either through physical trial and error or conceptual understanding of the environment's functional properties. Butler et al. (2022) have confirmed this by demonstrating that in novel pilotage situations, pilots rely on simulation to make informed decisions.

(ii) Hammond's cognitive continuum theory suggests that decision-making varies in the degree to which it relies on intuitive and analytical processes. Factors such as the amount of information available and the time constraints determine where decisions fall on the continuum and whether people rely more on patterns or functional relationships (Klein, 2008).

During intuitive processing, environmental cues are sensed and responded to automatically. There is no further demand on cognitive resources. Analytical processes involve higher levels of cognitive control and slower deliberate processing. Quasi-rational processes represent the cognitive compromise between intuitive and analytical processing. A person enters quasi-rational processing when full analysis of the situation is impossible and full intuition is not acceptable (Elgin & Thomas, 2004).

(iii) **Rapid Decision-Making model**:

The Recognition-Primed Decision (RPD) model combines two processes: recognizing the situation and evaluating the course of action through visualization (Klein, 2017). There are 3 variations of the RPD model as shown in the figure below.

Variation 1 Simple Match: When faced with a fire, factory fire, or search-and-rescue job, decision-makers take action based on their understanding of the situation. They prioritize goals, identify important cues, anticipate what's next, and recognize typical responses that are likely to succeed (Klein, 2017).

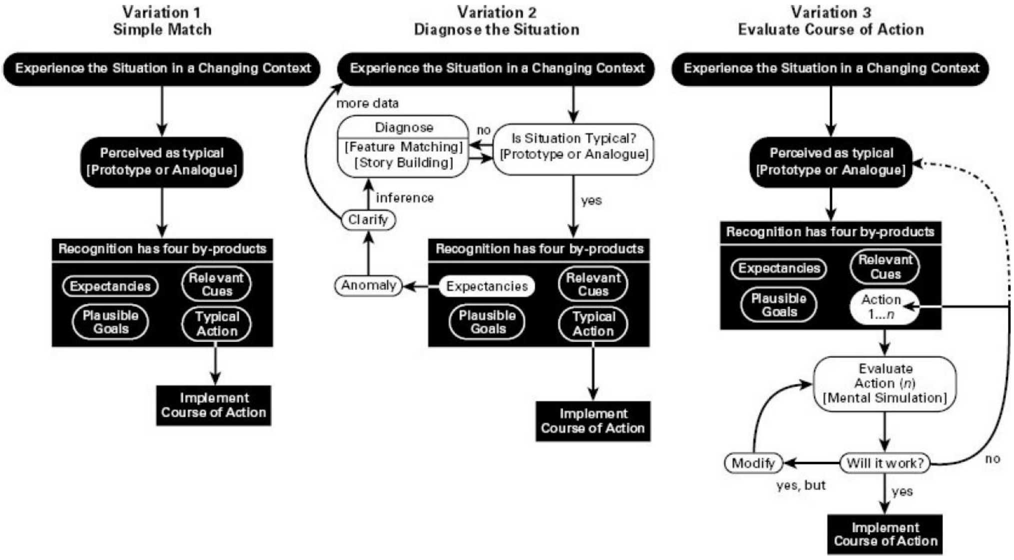


Figure 2: Recognition primed decision model

Source: Klein, 1999

Variation 2 Diagnose the situation:

In some cases, decision-makers may encounter situations that don't seem to match any typical case or that are similar to more than one typical case. In such situations, they may need to gather more information to better understand the situation. It's also possible that decision-makers may misinterpret the situation and only realize their mistake after some time has passed. When these anomalies or ambiguities occur, decision-makers will take steps to address them (Klein, 2017).

Variation 3: Evaluate course of action

In Variation 3, decision makers are described as evaluating single options by utilizing their imagination to envision how a particular course of action will play out. This mental exercise enables them to anticipate any potential difficulties that may arise as a result of their chosen path. If a decision maker perceives that their chosen course of action may be problematic, they may need to adjust their approach accordingly, or potentially even reject it altogether and seek out alternative options. This careful evaluation and consideration process is crucial for effective decision-making, as it allows decision-makers to make informed choices aligned with their goals and objectives (Klein, 2017)**.**

Fig. below shows the three variations integrated.

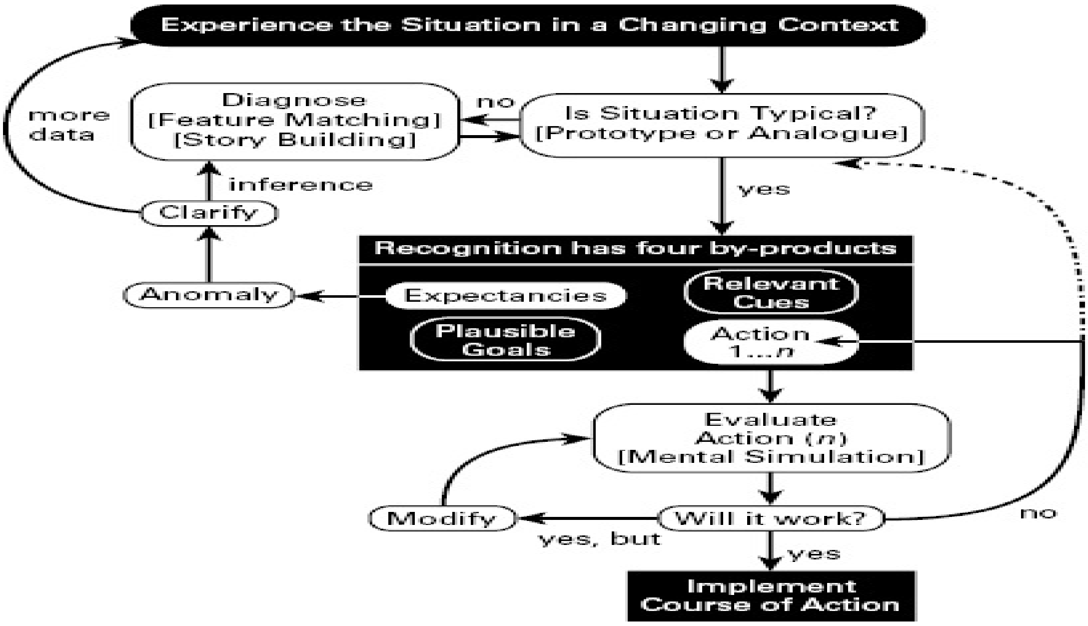


Figure 3: An integrated version of the recognition-primed decision model

Source: Klein, 1999

An integrated model of Naturalistic Decision Making

There are many approaches to decision-making that aim to replicate natural processes. However, we can combine these different models into a comprehensive framework by using Rasmussen's cognitive control theory. This theory provides a useful way to understand the cognitive mechanisms that are involved in decision-making and can help us to better understand how maritime pilots make their decisions. By synthesizing various naturalistic decision-making models into a single framework, we can gain a deeper understanding of the factors that influence decision-making, and develop more effective strategies for enhancing our decision-making abilities (Elgin & Thomas, 2004).

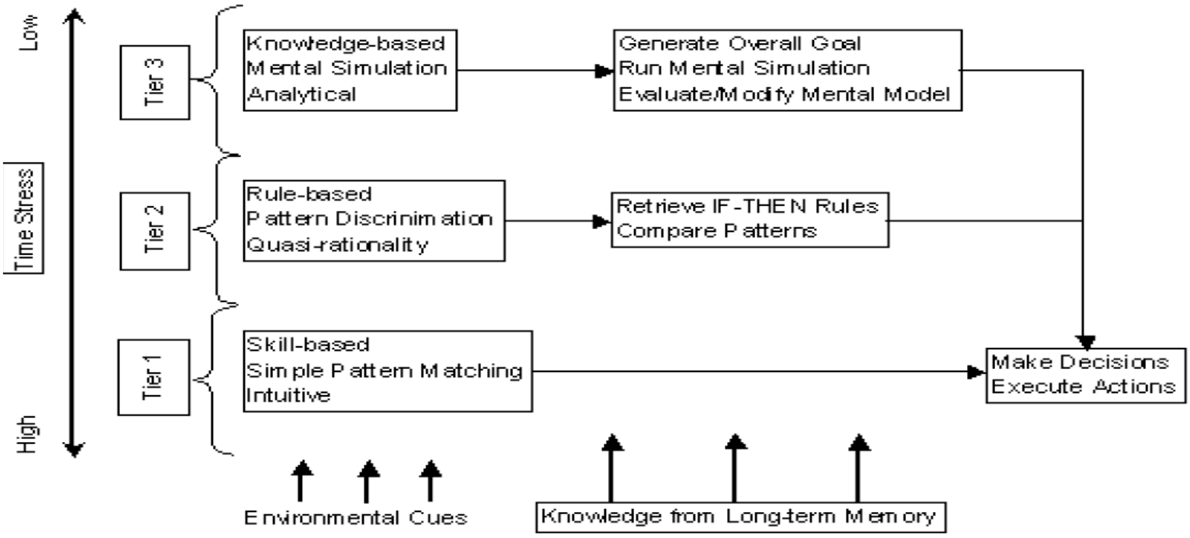


Figure 4: An integrated model for Naturalistic Decision-Making

Source: Elgin, 2004

The integrated model of naturalistic decision-making is a comprehensive framework that sheds light on the cognitive processes involved in making decisions. It explains how information from various sources, such as environmental cues and long-term memory, is processed in working memory to arrive at a decision. The model identifies three tiers of decision-making, which are based on the characteristics of the situation at hand. This approach offers a more nuanced understanding of decision-making and can be applied to various domains, including business, healthcare, education, and transportation (Elgin & Thomas, 2004).

Tier 1

Tier 1 decision-making is a robust process that occurs when decision-makers have enough time to perceive environmental cues as signals and react to them. Experts process information under high time stress or high task load through Tier 1 processes such as skill-based decisions, decisions based on simple pattern matching, and decisions based on intuitive processes. However, Tier 1 processes can only interact with information that can be processed as signals and are not amendable to complex information (Elgin & Thomas, 2004).

Tier 2

Tier 2 decision processes require more cognitive resources and time than Tier 1. Decision-makers can integrate and assign meaning to signs, but other forms of information are left unattended, even when there is moderate time stress. When Tier 2 decision processes can be engaged, experts can rely on rule-based IF-THEN strategies to discriminate between cue patterns. In addition, Tier 2 decision processes are quasi-rational, meaning some cues can be processed analytically and others intuitively (Elgin & Thomas, 2004).

Tier 3 decision-making requires more time and mental resources than Tier 2 or Tier 1. When ample time and resources are available, individuals can integrate, assign meaning, and project future behaviour of information. However, even under low-time stress, other information such as signals and signs can still be integrated into decision-making processes. Tier 3 processes are engaged when Tier 1 and Tier 2 processes do not provide satisfactory solutions or decisions and time is available (Elgin & Thomas, 2004).

In a study conducted by Butler et al. (2022), it was revealed that maritime pilots employ a combination of intuitive and analytical approaches to arrive at quick and precise decisions, especially in Tier 1 and Tier 2 situations. The researchers also found that simple matching and diagnostic methods are more frequently utilized by pilots as opposed to simulation techniques, which are usually reserved for unfamiliar pilotage situations. Overall, this study provides important insights into the decision-making processes of maritime pilots and sheds light on the methods they employ to navigate complex and challenging scenarios. This view is corroborated by (Svedung & Rasmussen, 2002). Professionals in various fields often rely on familiar cues and patterns to make quick and informed decisions in their work environments. These cues can be based on prior experience, established protocols, or even personal intuition. However, any changes to the system or environment can have unintended consequences that may not be immediately apparent or easily predictable. It is important for experts to stay vigilant and adaptable in order to navigate any unexpected challenges that may arise effectively.

To make optimal decisions in dynamic environments, decision-makers must deduce and assimilate perceived cues in working memory. This helps create accurate awareness of the current and evolving situation. People interpret and integrate environmental cues through executive processes to comprehend the current state of their surroundings. This cognitive process is regularly termed situation awareness (Jones & Endsley, 1996). From the foregoing, it is clear that Situational Awareness is critical to decision-making. The figure below elaborates clearly on this relationship.

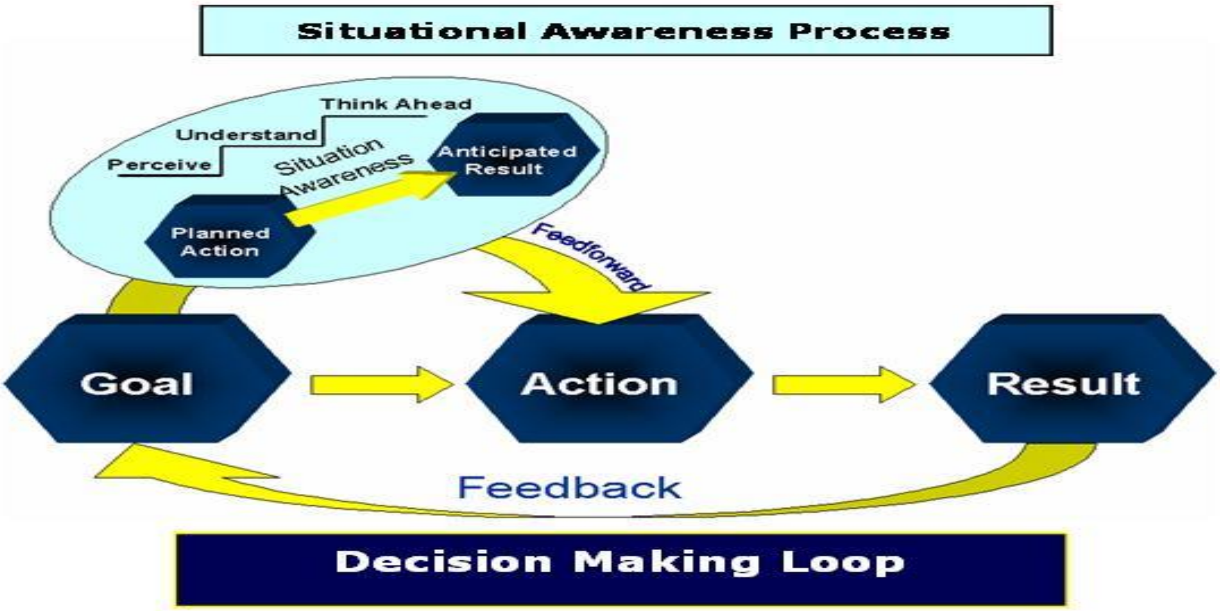


Figure 5: Decision-Making Loop

Source: (Flight Safety Foundation, n.d.)

2.3 Concept of situational awareness and its role in decision-making

Situational awareness is the ability to comprehend and interpret the information present in your surroundings and to determine its relevance to your goals and objectives(Endsley, 1995a). This skill is especially critical in high-stress operational contexts, such as driving, patient care, and air traffic control, where the ability to quickly and accurately assess one’s, environment can mean the difference between success and failure, safety and danger, or even life and death. By maintaining situational awareness, you can make informed decisions, anticipate potential challenges, and respond effectively to unexpected events, all while staying focused on achieving your intended outcomes (Ensley & Jones, 2004).

The significance of SA as a basis for making informed decisions and enhancing performance holds true across a wide range of disciplines, despite the presence of distinctive constituent components (Endsley & Jones, 2004).

(Endsley, 1995a)defined Situation awareness as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Another definition worthy of note is that of the FAA, which defines SA as a continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent picture, and the use of that picture in directing further perception and anticipating future events (FAA, 2014).

The concept of situation awareness is composed of three levels, as stated in both definitions. Nevertheless, the definition provided by the FAA suggests that one must actively gather information from the surrounding environment to achieve a higher level of situation awareness. The maritime industry is a complex and dynamic environment that is constantly evolving, and as a result, it is constantly under threat from various risks. Therefore, it is essential to have a high level of situational awareness in order to make informed decisions that can help mitigate these risks. A comprehensive situation analysis based on relevant theories and principles is crucial in ensuring that the decisions made are appropriate and effective. By carefully considering all available information and analyzing it in a systematic and structured manner, we can minimize the risks associated with operating in the maritime industry and ensure the safety of all those involved (Melnyk et al., 2022).

The definition of SA defines three levels of SA, and these are:

Level 1: Perception

Level 2: Comprehension

Level 3: Projection

Level 1: Perception of elements in the environment

The first step to achieving situational awareness is perceiving the status, attributes, and dynamics of relevant elements in the environment. Situational awareness requirements vary depending on the domain and job type (Endsley & Jones, 2004). For example, a maritime pilot must be aware of important elements such as other vessels, the proximity of navigational hazards, the status of the vessel's equipment and warning alarms, as well as their relevant characteristics. Perception of information may come through visual, auditory, tactile, taste, or olfactory senses, or a combination.

In complex systems, electronic displays are often emphasized, but Level 1 situation awareness (SA) also comes from directly perceiving the environment, verbal and nonverbal communications, and different sources of information with varying levels of reliability. Detecting all needed Level 1 data can be challenging (Endsley & Jones, 2004).

Level 2 SA: Comprehension of the current situation

The process of comprehending a situation involves the synthesis of various level 1 elements, which may appear disjointed at first glance. However, in order to reach a higher level of situational awareness, one must go beyond simply being aware of the elements present and strive to understand their significance in the context of the operator's goals(Melnyk et al., 2022). This is what is known as level 2 situational awareness.

Level 2 situational awareness requires a deeper understanding of the level 1 elements, particularly when they are combined to form patterns with other elements. By piecing together these patterns, the decision-maker is able to form a more holistic and comprehensive picture of the environment. This allows them to not only identify objects and events but also understand their significance and how they relate to the operator's objectives. Overall, the ability to achieve level 2 situational awareness is a crucial component of effective decision-making in complex and dynamic environments (Endsley, 1995b).Therefore, in order to achieve level 3 SA, a maritime pilot must interpret environmental cues accurately to project the situation.

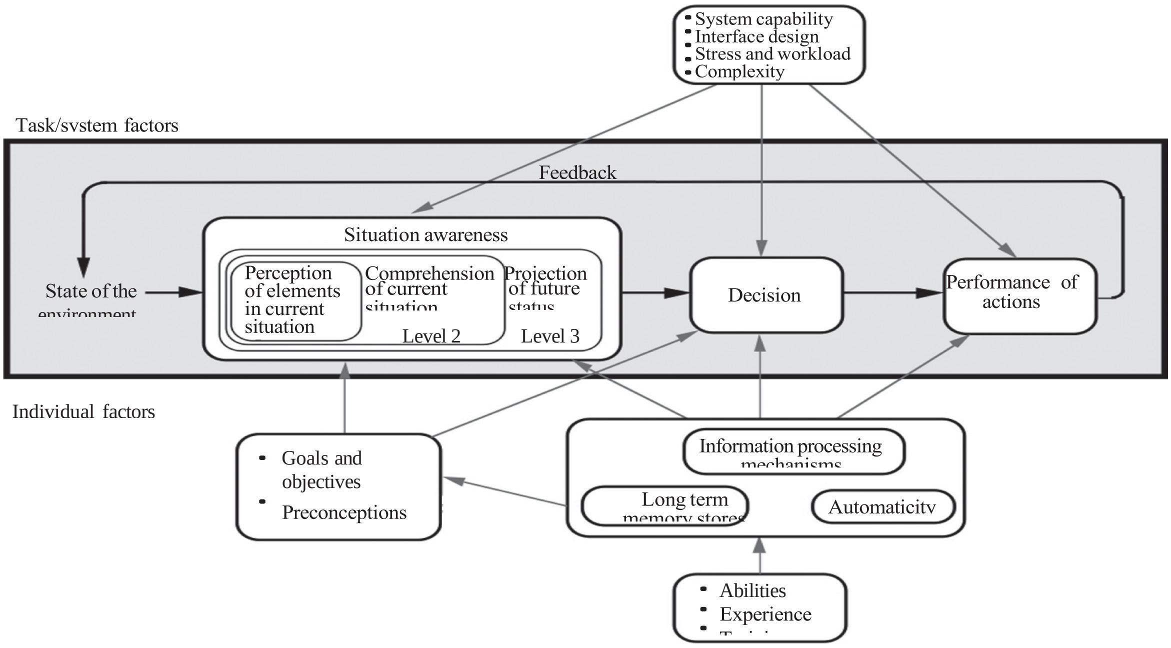


Figure 6: Model of SA in dynamic decision-making

Source: Jones & Endsley, 2004

Level 3 SA: Projection of Future Status (Thinking Ahead)

In order to effectively develop situational awareness, the operator relies on models that allow for the prediction of future system states. This process involves extensive analysis and evaluation of accurate data in order to achieve a desired outcome. It requires a great deal of critical thinking and assessment to ensure that the resulting situational awareness is as comprehensive and accurate as possible (Melnyk et al., 2022).

In the context of maritime pilotage, projecting the estimated time of arrival (ETA) can prove to be an essential tool in managing traffic at busy ferry crossing areas. By having access to this crucial information, the pilot can make informed decisions that align with their objectives. It provides them with the necessary insight and time to determine the most optimal course of action, ensuring the safety and efficiency of all involved parties.

Situational awareness encompasses more than just observing and gathering information about one's surroundings. It involves interpreting and understanding the significance of that information, comparing it to the desired objectives, and projecting potential outcomes that aid in making informed decisions. It is a comprehensive concept that applies to various fields of study and involves numerous cognitive processes that are common across them (Endsley, 1995b).

The following text examines the factors that affect SA. It's important to consider these factors when designing any system that will impact SA.

1. Time

SA is a person's knowledge of the environment. However, it is temporal in nature, meaning that it is not acquired instantaneously but built up over time. This knowledge includes temporal aspects of the environment, relating to both the past and the future (Endsley, 1995b).

2. Space

Situation awareness (SA) for an operator should incorporate information about the relevant subset of the environment for tasks and goals. Elements can be further subdivided into levels of importance for SA or can be viewed on a relevance continuum. The spatial, temporal, or functional relationships of elements to goals can determine the relevance of elements. Elements may vary in their relevance over time, but they do not generally become completely irrelevant. At least some SA is needed on all elements, even if this only indicates that the element is not very important at the moment(Endsley, 2004).

3. Attention

The deployment of attention in perception can limit accurate perception in complex environments. Operators of complex systems often use information sampling to overcome this. Working memory plays an important role in modifying attention deployment based on goals and objectives. Attentional resources can increase through physiological arousal mechanisms, and attention sharing is a skill that can be learned. Finally, automaticity can circumvent attention limitations (Endsley, 1995a).

4. Perception

The perception of information is influenced by both working memory and long-term memory. Advanced knowledge of the characteristics and location of information can aid in perception, while preconceptions and expectations about information can affect the speed and accuracy of perception. Experience in a particular environment can create expectations about future events, predisposing individuals to perceive information accordingly(Endsley, 2004). Long-term memory plays a significant role in categorizing perceived information into known mental representations, which forms the foundation for higher levels of situational awareness. With well-developed memory stores, individuals can make fine categorizations, allowing for access to detailed knowledge about the capabilities of the objects being perceived. The cues used to achieve these classifications are important for situational awareness and are developed through expertise(Endsley & Rodgers, 1994).

5. Working Memory

When faced with Levels 2 and 3 of situational awareness, individuals are tasked with formulating and selecting responses, and then carrying out subsequent actions. According to Wickens (1984) achieving good situational awareness involves accurately predicting future states, which is a challenging feat that places a significant burden on working memory. This is because individuals must be aware of present conditions, anticipate future conditions, and follow the rules for generating future responses. To achieve good situational awareness, it is crucial to possess the ability to predict future states with accuracy. However, this requires a well-developed cognitive capacity to effectively manage these multiple and complex tasks. Hence, situational awareness demands a high level of cognitive ability to effectively handle these responsibilities, which include maintaining awareness of present conditions, anticipating future conditions, and adhering to the rules for generating future responses.

6. Long-Term Memory

Long-term memory structures can be used to overcome the limitations of working memory. Schemata and mental models are important for effective decision-making in various environments. Schemata provide coherent frameworks for understanding information and organizing it for storage, retrieval, and processing. Scripts, a special type of schema, provide sequences of appropriate actions for different types of task performance(Endsley, 1996). Mental models are mechanisms that allow humans to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future states. Experts develop mental models in a shift from representational to abstract codes. Mental models can be described as complex schemata used to model the behaviour of systems(Endsley, 2015).

A situation model, also known as situation awareness, is a schema that depicts the current state of a system model. It allows for recognition-primed decision-making by matching to prototypical classifications linked to associated decision-making or scripts. A well-developed mental model provides knowledge, integration, and projection of future states of the system based on its current state and dynamics(Jones & Endsley, 1996).

Humans have a mechanism for generating alternative behaviours and selecting among them based on categorization mapping. This process can be almost instantaneous due to pattern-matching mechanisms(Hammond et al., 1987). Mental models for behaviour are developed through training and experience and allow for attention to critical cues, expectations for future states, and a direct link between situation classifications and typical actions. Novices may have only vague ideas of important system components and rules, but with experience, schema and model development occurs based on recurrent situational components and associations(Ernstsen & Nazir, 2018).

Developing specific and numerous categorization functions can enable people to refine their classification of perceived objects and provide better predictions. Default information and confidence levels are important features for recognized attributes of situation awareness. Default values may be used to predict system performance unless a specific exception is triggered, while confidence levels can influence decisions made using information(Endsley, 2004). Uncertainty associated with the mapping of world information to the internal model can be taken into account in the decision-making process. These features allow experts to have access to reasonable defaults and make effective decisions despite numerous uncertainties(Endsley, 1995a).

7. Automaticity

When people process information automatically, they are conscious of the situation but not necessarily aware of the mechanisms used to arrive at a decision. They know what happened but not how they arrived at their decision. If asked to explain their decision, they may have to construct a rationale using logical processes. However, they can still verbalize the state of the situation itself (Endsley, 1995a).

Automatic cognitive processing allows for good performance with minimal attention allocation but can result in difficulty accurately reporting on internal models used for processing and decreased responsiveness to new stimuli. This can lead to decreased decision timeliness and effectiveness in atypical situations. However, automaticity provides an important mechanism for overcoming human information-processing limitations in achieving situational awareness and making decisions in complex, dynamic environments (Endsley, 1995a).

8. Goals

Maritime pilots have various goals such as berthing the vessel safely, avoiding collision with other vessels and avoidance of grounding of the vessel. These goals may have sub goals, such as adhering to the collision regulations and avoiding shallow patches. The pilot chooses goals based on importance and situation. The current goal indicates the model and frame to be active. A model for collision avoidance directs attention to key environmental features and allows the pilot to determine the best way to manoeuvre the vessel. The pilot remains alert to critical features that might indicate a new model should be activated, such as a new threat. The threat assessment model would be activated consistent with that goal. The model selected directs situation comprehension, future projection, and decision-making. Threat assessment models might include information about offensive versus defensive activities and known tactics for countering given threat actions (Endsley, 1995a).To make sound decisions and ensure safety, having situational awareness and its attributes is crucial. It serves as the driving force behind effective decision-making and action. As a result, any tool or equipment that improves situational awareness ultimately aids in better decision-making and safety.

2.4 The decision-support systems and tools used during pilotage

Several tools and systems have been adopted to support navigation during pilotage. In contemporary times, a portable computer-based system known as a PPU is used by maritime pilots on board vessels to assist with decision-making in confined waters.

Real-time position and movement tracking is enabled by interfacing with positioning sensors like D/GPS, GLONASS, and GALILEO, and using electronic chart displays with PPUs. Along with this, the AIS interface also provides information about the location and movement of other vessels. PPUs are now being utilized to showcase additional navigation-related details like depth contours, soundings from recent hydro surveys, dynamic water levels, ice coverage, and security zones (Alexander & Casey, 2008b; IMPA, 2016).

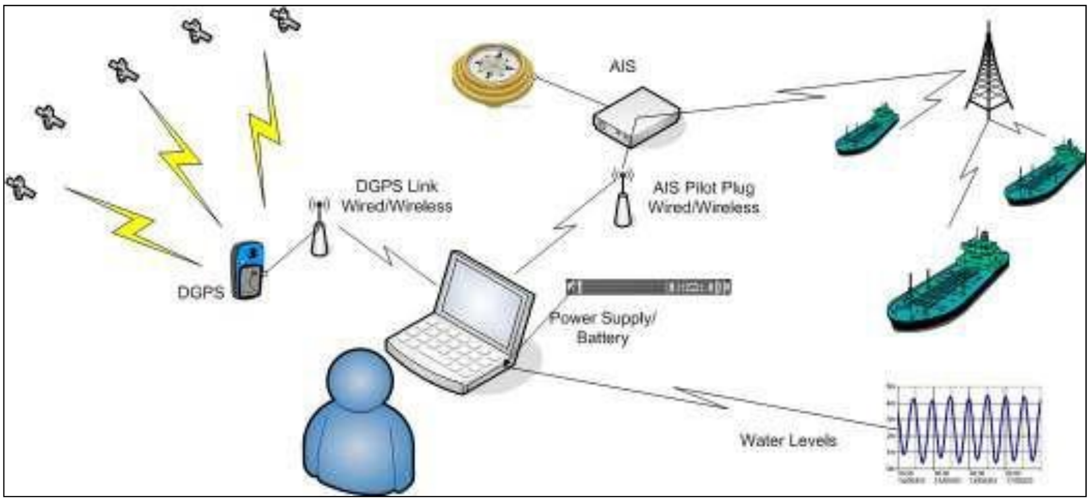


Figure 7: Schematic Diagram of the PPU System

Source: Alexander & Casey, 2008

The PPU provides independent positional information superior to that onboard the ship through its own position sensors. The vessel traffic situation is displayed on the PPU through the AIS plug, this feature is very useful as it gives the pilot an overview of the vessel traffic situation, enabling him to achieve level 1 SA(Stanley, 2020). The PPU is also useful for timing own-ship arrival at a pinch point and anti-collision functions corresponding to level 3 SA, the projection of the status into the future. The PPU provides accurate vector and distance information during the berthing/unberthing stage, thus providing the pilot with information on how the vessel will proceed, enabling him to make appropriate decisions to facilitate the safety of the manoeuvre(Ransara, 2018) this also conforms to level 3 SA. According to Wild (2011), the path predictor track which aids pilots in achieving level 3 SA is also useful but may not be as accurate as the information on the ship's ECDIS; however, Ransara (2018) disagrees with this stance. The disagreement seems mainly to arise from the technological development of the PPU as the PPU of 2011 will definitely not have the same functions as the PPU of 2018.

Wild (2011) also claimed that a negative aspect is that the display size restricts viewing to one or two individuals simultaneously; however, as per the 2016 guidelines released by IMPA, it is essential to note that the PPU is exclusively intended for use as a navigation aid and decision-support for the pilot. It is not meant to be utilized as a part of the bridge team's equipment. Although the bridge team can view the PPU display, it is not designed for their use and, therefore, should not be relied upon. It is crucial to adhere to this guideline to ensure the safety and efficiency of navigation operations (IMPA, 2016). Notwithstanding this the PPU can be viewed by the Shipmaster or the OOW so as to have a similar appreciation of the manoeuvre as the Pilot has.

2.5 Improving navigational safety through PPUs

According to ISPO (2015), a PPU is a portable, computer-based system that marine pilots use as a decision-support tool for navigating through confined waters. It operates independently of the ship's navigation and computer systems, providing information, navigation, and docking functionalities. PPUs are used to improve the safety and efficiency of the pilotage passage and the ship handling process in confined waters by supporting the decision-making process of the maritime pilot. Ransara (2018) also in agreement with the above definition noted that the PPU generates highly accurate data that surpasses the ship's equipment. Additionally, he stated that the PPU's accuracy is deterministic and can be maintained or improved to meet pilotage demands, unlike the vessel's fixed ECDIS system, which means that the pilot can determine the type of information to be displayed which is suited to his/her needs. This is consistent with Jones's (2015) three-pronged approach to SA-related design. This strategy results in a UID whose functionality is organized in a manner that makes sense to the user and ensures that functionality is provided where and how the user requires it. In determining the display functionality, the requirements phase also systematically delineates the dynamic information utilized by the user in a hierarchical manner and structures this information to provide insight into how users integrate this information to support higher levels of SA(Jones, 2015).

UIDs are grouped according to their goals, with the necessary functionality to support all aspects of achieving those goals provided within each grouping. This approach goes beyond merely creating effective UIDs and provides information to assist system architects in ensuring that the type of information the user requires is displayed on the UID. By directly supporting people in developing higher levels of SA, such as by enhancing their ability to predict how various potential changes to the environment would affect the system, the system design satisfies the cognitive requirements of the users and promotes better decision-making(Jones, 2015). The PPU fits this description aptly and therefore contributes to the attainment of higher SA levels which consequently promotes better decision-making. It is for this reason that most maritime pilot organizations are adopting advanced technologies in PPUs to enhance navigation accuracy and offer direct data feeds to shore-based navigation stations, as noted by Betz in 2015.

The PPU has a significant impact on some of the factors that affect SA (Situational Awareness). For instance, it helps to improve attention by providing real-time feed to the Pilot, allowing them to regain their focus if they become distracted(Stanley, 2020). Additionally, the PPU helps to prevent decision-making errors that may occur due to misreading cues or missing them altogether, especially among experts. The PPU achieves this by projecting the consequences of a decision, thereby providing an opportunity for correction if the results are not as expected(Betz, 2015).

The PPU offers two navigation options: it can receive independent information via its portable antenna array or connect to onboard sensors through the AIS pilot plug. Some stand-alone systems have corrected GPS receivers that provide high accuracy. Additionally, some units come with a ship-to-shore radio that allows for data transfer to monitoring stations. This feature enables a shore-based pilot to view the same information as the onboard PPU and offer advice if needed (PARCEL, 2009).

Electronic pilotage techniques are a major aid to pilotage. In order to ensure effectiveness, the plan displayed on the ship's ECDIS and ARPA must match the plan the pilot is working towards. However, even with a shared plan and understanding, it is common for pilots to receive limited support from the rest of the bridge team, making them a potential single point of failure. Therefore, pilots should enhance their ability to monitor the passage by using alternative means such as a PPU (Stanley, 2020).

Figure 8: A PPU Screen showing the prediction feature

Source: Stanley (2020)

Accurate ROT is a crucial input for electronic charting systems in pilotage. The software should use it with position and course/speed over the ground to predict future positions during turns. While high-level PPUs possess this ability, not all ECDIS systems do, and some older ships' gyros do not generate ROT at all. In all the past grounding incidents, a PPU could have provided an early indication of trouble (Stanley, 2020).

The PPU screen displayed above provides a comprehensive overview of the vessel's situation, enabling the pilot to understand their surroundings better. The predictor function is particularly useful, as it uses current parameters to project the vessel's future positions. This allows the pilot to take corrective action if any anomalies are detected, ensuring a safe and efficient manoeuvre.

In many ports, it is becoming customary for ships to use PPU on every trip. Pilots need to operate the equipment effortlessly as it is hazardous to fiddle around with it during critical moments. Consistent use of the PPU on every trip after initial training is crucial to build the necessary familiarity and competence(Stanley, 2020). Additionally, it helps build the pilot's confidence in the equipment's performance, knowing its reliability and accuracy. Having the PPU at the conning position provides instant access to accurate heading and speed, and shows present and future positions on the chart without leaving the preferred position, this also allows for cross-checking the ship’s equipment and the personnel as a wrong report of speed or heading will be easily apparent to the pilot, whereas in the absence of the PPU, this will not be the case which could lead to wrong decision making on the part of the pilot on the basis of wrong information received(Trzuskowsky et al., 2016).

Furthermore, PPUs allow pilots to review individual jobs while they are fresh in memory, which is invaluable in improving performance. The Cambridge Handbook of Expertise and Expert Performance states that superior performance comes from deliberate practice and regularly receiving accurate feedback, which the PPU provides (Stanley, 2020).

Aside from allowing pilots to review individual jobs, it also serves as a knowledge-sharing and training platform for pilot trainees. It helps trainee pilots develop necessary schemata for decision-making (Endsley, 1995a; Rasmussen, 1983).

Regardless of weather conditions or level of support from the bridge team, a good PPU can effectively compensate for deficiencies and provide a reliable "second opinion" when needed. This is especially important for ports handling large, unwieldy bulk carriers with critical under-keel clearance requirements, where the PPU has become the main reference for pilotage. However, it is important to use the PPU in conjunction with other available information, such as visual, ECDIS or radar, and not rely solely on it for navigation (Stanley, 2020). IMPA (2016) recommends using PPUs that generate their own position and ROT data, as they offer higher accuracy than a ship's ECDIS. Since ECDIS equipment can vary between ships, the PPU is the most consistent tool that pilots can rely on to achieve higher levels of SA and make better decisions for the safety of navigation.

3 Description of methodology and analysis of results

Effective research methodology involves not only selecting appropriate research methods but also understanding the reasoning behind those methods within the context of the study. By explaining why specific techniques are chosen over others, researchers can ensure that their results are not only valid but also easily evaluated by themselves and others (Kothari, 2004).

To provide a comprehensive understanding of the research methodology, this chapter delves into the research philosophy, approach, and strategy. It also details the sampling strategy, data acquisition and analysis methods, ethical considerations, and limitations of the study.

3.1 Research Philosophy

Interpretive Paradigm

The Constructivist or Interpretive paradigm asserts that communication, interaction, and practice are key factors in the construction and reproduction of both reality and knowledge. As a result, researchers play a crucial role in mediating knowledge about reality (Tracy, 2013).

According to social constructivists, individuals strive to comprehend the world around them through subjective interpretations of their experiences. These interpretations are unique and diverse, prompting researchers to embrace the complexity of perspectives rather than limiting them to a few predefined categories. In pursuit of the participant's

Diagrammatic presentation of Methodology

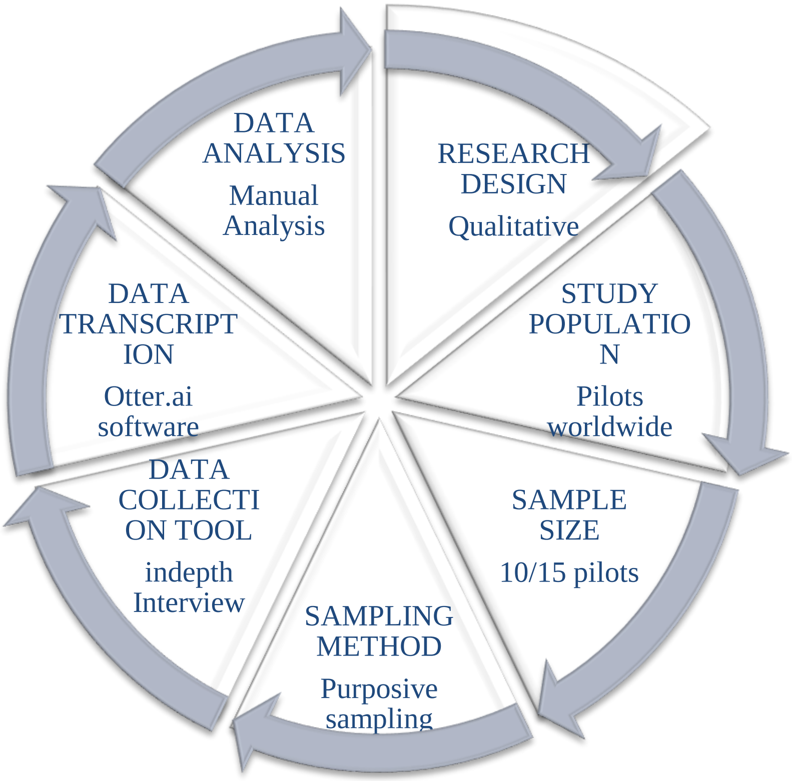


Figure 9: Framework of Methodology Chapter

perspective, researchers ask broad and open-ended questions, encouraging participants to construct meaning in discussions and interactions with others. By listening attentively to the responses, researchers gain insight into how individuals negotiate subjective meanings socially and historically. Qualitative research is commonly associated with the interpretive paradigm approach. The nature of the current research falls in line with this paradigm.

3.2 Research Approach

Qualitative research methodology was employed for this study. Qualitative research methods are highly beneficial in generating detailed descriptions of intricate phenomena, monitoring exceptional or unforeseen occurrences, shedding light on the perspectives and understandings of individuals with diverse interests and positions, and providing a platform for underrepresented voices to be heard (Sofaer, 1999).

3.3 Sampling Strategy

To thoroughly examine the effect of PPU on marine pilots' situational awareness, the study targeted maritime pilots who utilize PPU during their manoeuvres. The researcher leveraged personal connections and industry ties to gather participants for the research. Given the research's focus on a particular profession, the expert sampling technique was employed.

There are different techniques used in sampling, including expert sampling and judgmental sampling. Both of these techniques are non-probabilistic, meaning that they do not rely on random selection. Instead, they involve a deliberate and purposeful selection process.

Judgmental sampling assumes that the chosen sample has the necessary knowledge and experience to meet the research needs. This technique is often used when a researcher is interested in a specific group of individuals who possess specific characteristics or traits.

On the other hand, expert sampling assumes that all participants have a high level of expertise in the field of study. This technique is often used when a researcher is interested in studying a group of individuals who are considered to be experts in a particular area (Creswell, 2014).

For example, when studying marine pilots, their expertise is well-known, and they are considered to be experts in their field. Therefore, expert sampling was an appropriate technique for marine pilots. The researcher learned more about the experiences, perspectives, and insights of expert marine pilots by selecting a sample. The use of the PPU is a necessary criterion to ensure respondents are knowledgeable in its use and can answer questions about it.

Twenty (20) pilots from various geographical locations were expected to participate in the research but due to time constraints, the number of respondents interviewed were 12.

Romney et al (1986) found that small samples can provide complete and accurate information within a cultural context, as long as participants are knowledgeable about the domain being studied. (Guest et al., 2006) concluded that 12 interviews are sufficient for research aiming to understand common perceptions and experiences among a relatively homogenous group.

The sample consisted of twelve maritime pilots, six from Ghana, five from Denmark, and one from Benin. They were contacted through email and WhatsApp messages.

3.4 Data Collection

An interview guide was prepared after reviewing literature. It was discussed with a senior marine pilotage expert who was not a respondent for his opinion. Necessary corrections were made, and approvals were sought from the University's ethics committee to conduct the interviews.

In order to conduct the research, the researcher took the necessary steps to gather data from respondents. This involved mailing out an interview guide and consent form to each participant, who was then responsible for completing and returning the forms at their earliest convenience. Given the spatial separation between the researcher and respondents, all interviews were conducted via Zoom video conferencing to facilitate a safe and convenient means of communication.

To maintain the privacy and confidentiality of the respondents, strict measures were implemented during the interview process. Specifically, the participants were advised to disable their video cameras and utilize only their voices during the recorded session. Additionally, they were offered the chance to seek further clarification for any queries they found ambiguous or unclear. To avoid any potential biases in the study results, participants were encouraged to respond to the questions as if they were addressing a novice. A structured approach was employed at the beginning of the interview to gather demographic information from the participants.

The interviews were conducted in the months of July and August, 2023. The interviews were recorded using facilities provided by Zoom video conferencing.

The interview took an average of 35 minutes each, with the longest about 45 minutes and the shortest about 28 minutes, all depending on how well the participants chose to elaborate on the issues.

The interview guide, attached as an appendix, consists of 5 sections and 32 questions. The sections cover Demography, Maritime Pilots' Navigational Decisions during pilotage, Decision Support Systems, Impact of PPU on Maritime Pilots’ Situational Awareness and Decision-making, and Optimization of PPU use to enhance navigational safety.

3.5 Analysis of data

The interviews were conducted remotely using the video conferencing platform, Zoom, and were subsequently transcribed using the transcription software, Otter.ai.

The software developed by Otter.ai is capable of transcribing both voice and video files into text, however, it is important to note that the accuracy of such transcriptions relies heavily on human intervention. This means that manual corrections are necessary in order to ensure that the final output is as accurate as possible. While the software is certainly a helpful tool, it is important to recognize the role that human oversight plays in achieving the best possible results.

The transcripts, thus, were then thoroughly reviewed by the researcher to ensure their accuracy and fidelity to the original interviews.

Due to the limited number of interviews conducted, the researcher's lack of familiarity with computer analysis software, and time constraints, a manual analysis was deemed necessary. This approach allowed for a more thorough and in-depth examination of the data gathered. Further details on the analysis process was provided below.

3.6 Ethical issues

According to University rules, all research involving human participants must be approved by the Research Ethics Committee. Therefore, an application, along with relevant documents, was submitted via email. Approval was received in June 2023, and the WMU REC protocol form, participant consent form, and approval email are attached in the appendix.

The information that was collected during the research was handled with the utmost confidentiality. The data was securely password-protected and saved on an external hard drive to ensure its safety. Once the necessary analysis had been completed, the data was promptly destroyed to prevent any unauthorized access or use.

3.7 Limitations

The primary objective of the researcher was to gather responses from a wide range of geographical locations. Unfortunately, due to certain logistical issues, this aim could not be accomplished. However, according to the findings of Romney et al (1986) it was observed that as long as the participants possess a good understanding of the domain being studied, and as the domain does not pertain to any specific location, the responses received are considered as an accurate representation of the diverse areas in which the PPU (Portable Pilot Unit) is utilized.

3.8 Research Findings

3.8.1 Introduction

In this section, the responses to the instruments used in the collection of data on the study are presented and analyzed. Research interviews with the study participants are evaluated. The interview guide contained a number of questions aimed at identifying the respondents' opinions and discernments on the effects of Pilot Portable Units (PPU) on the situational awareness and decision-making of Maritime Pilots. The findings of the survey are as follows:

3.8.2 Rate of Response

A sample size of 20 was selected for this study. They were marine pilots from different parts of the world, however, 12 respondents finally responded to the interview.

3.8.3 Biodata of respondents

Demographic information was essential to understand the respondents more effectively.

3.8.3.1 Gender distribution of respondents

The respondents were made up of males, accounting for the total percentage of the entire respondents. The respondents were made up of twelve (12) males, taking 100% of the entire respondents. However, no female was recorded. This is evident to say that although some females are bold enough to venture into the traditionally classified "male dominated industry, the level of women participation in pilotage is on a low.

3.8.3.2 Age distribution of respondents

Meanwhile the age distribution of the respondent shows most of the respondents fall in the youthful age bracket of 18-35. The middle age bracket was 36-49. The elderly bracket was for those who are 50 and above. The table and figure below demonstrates the details and findings.

Table 2: The age categorization of respondents

Age	Frequency	Percentage
Young (18-35)	1	8.33%
Middle age (36-49)	8	66.67%
Elderly (50+)	3	25%
Total	12	100

As can be seen from the table above, majority of respondents were within the mid-age bracket. That is, majority of the respondents were between the ages of 36 to 49 years which constitute middle age of a total of 66.67% of the respondents. Since in most pilotage districts, there is a prerequisite for seagoing service which often runs into a number of years, therefore the average joining age is higher than most professions as evidenced here.

3.8.3.3 Level of education

The level of education of each respondent is below. This is important to know whether the marine pilots have obtained basic education especially on the maritime industry. The result indicates that most of the respondents are highly educated which gives a great impact to the responses.

Table 3: Educational Level

	Frequency	**Percentage**
Diploma	2	16.6%
Masters	5	41.7%
Others	5	41.7%
Total	12	100

Out of 12 respondents, 2 of them which accounts for 16.6% had Diploma certification, while 5 of them which accounts for 41.6% had Masters' Degree. The remaining 5 respondents accounting for 41.6% had other form of qualification. And this is the master mariner certificate. All respondents have Certificate of Competency, this is important because it shows they all have rich sea going experiences.

Table 4: Certificate of Competency

	Frequency	**Percentage**
Class III	1	8.3%
Class II	3	25%
Class I	8	66.7%
Total	12	100

From the table, one respondent, accounting for 8.3%, has Class III, while 3 respondents, accounting for 25%, have Class II. The remaining 8 respondents, accounting for 66.7%, had Class I. The respondents all possessed unlimited certificates for various classes, which allowed them to serve at sea without any restrictions, regardless of the size of the vessel or area of operation. Specifically, the Class I unlimited certificate, also known as the Master Mariner certificate, enables the holder to command a vessel. It is clear that the respondents are qualified mariners capable of working on board all types of ships in a sea-going capacity.

3.8.3.4 Kind of Pilotage Performed

All respondents do harbour pilotage; however, some of them do transit pilotage, deep sea pilotage and channel pilotage.

3.8.3.5 Length of time working as a Pilot

The table above shows how long the respondents have been working as maritime pilots.

Table 5: Period of working as a marine pilot

	Frequency	**Percentage**
1-5 years	6	50%
6-10 years	1	8.3%
Above 10 years	5	41.7%
Total	12	100

From the table, 6 respondents accounting for 50% of the population have been working as marine pilots between one and five (1-5) years while 1 respondent accounting for 8.3% has been working between 6-10 years. The remaining 41.7% of respondents have been working for more than 10 years. This shows that the respondents are well versed in the subject area with great expertise built on the long-term experiences.

3.9 The basic tasks and responsibilities of a marine pilot

According to the respondents, the basic tasks of marine pilots are to ensure the safe manoeuvring of ships into the port and sailing out of the port, or shifting from berth to berth or shifting from berth to Anchorage. This is usually done through the advisory role or assistance to ship masters on safe navigation into the harbour.

First of all, the pilot checks for the availability of berths and mooring operators, as they are important to facilitate the smooth process of pilotage. Other duties include ship and tug handling, consulting with ports and shipping companies, safeguarding the marine environment and also port facilities and managing personnel logistics.

Basically, when a ship calls at a port, the signal station gets information about the ship, and this includes the draft of the vessel and the length overall. Draft is very important to ports that are restricted by draft of which Tema is an example. After, berth is allocated in accordance with the drafts and then the purpose for which vessel is at berth. In some ports, bulk carriers have their designated berth, while container ships also have their berths.

The responsibilities of Deep-Sea pilots are to guide the vessels through the great belt and that of a harbour pilot is to go in and out of the ports of course, to assist them for doing manoeuvring of the vessel but also to speak to tug boats and mooring people. Generally, just advice about the area.

3.10 Navigational Decisions during Marine Pilotage

Marine pilots are faced with some critical decision-making during pilotage. The outcome of their decision can either end in an accident/incident or can ensure safe navigation. In order to ensure the safety of navigation, several tools or systems have been adopted by different ports. One of which is PPU. The PPUs are indispensable tools for modern maritime pilotage, especially in situations involving tight manoeuvres and close-quarter situations. This is because they offer valuable real-time and predictive data, enhancing safety and situational awareness. However, challenges related to GPS signal stability, chart alignment, data delay, and outdated survey data need to be addressed to fully leverage the benefits of PPUs.

3.10.1 Information required to make decisions that will ensure safe pilotage

Ideally, the primary information required by the pilot is to know the ship that is bound to take a berth; this includes basic characteristics of the ship such as the type of ship, draft, length overall, beam and the type of engine (fixed pitch propeller, right hand or left hand, and whether the bow thruster is it working or not). If there are some limitations on the ship, for example, the number of consecutive starts of the engine, the air draft also to understand how the vessel will behave in the channel. Again, check if it is permissible to take the particular berth that has been allocated for her.

The weather conditions and tide at the time are also important as they will show whether it is conducive for the vessel to proceed and will advise on the depth of water available, which will be safe for operation, the readiness of the tugs and mooring team and the equipment to be used, how safe and how prepared they are for the operations. And this information is salient because, without them, the berthing process may not be safe. You may be constrained by the draft then that might be a problem.

Details about the vessel’s rudder and propulsion; whether it is acting left-handed or right-handed, and the thrusters also, whether there are any deficiencies.

Ship characteristic how the deadweight level of capacity of thrusters and propulsion rudders and so on in order to assess if the language for harbour assistance is needed from tug, we have a matrix which graduate you know for the use of zero tugs two tugs three tugs etc. we don't we don't have a requirement for this is called tug but for some small operations we use it but it's not it's not a government requirement it is basically pilot recommendation so.

3.10.2 Sources of the information used in decision-making

Every information required for safe pilotage has a source. Strategic management information is disseminated through the port control to the pilots. And this information is usually obtained from the outcome of meetings.

Information regarding the vessel is obtained from the vessel itself; particularly during discussion with the master. Some information is also obtained from the pilot card, and this includes information about the weather and tides gathered from a department in the port in charge of sharing this information about weather and meteorological information.

The tugboat operators also provide some information; this can be a time of passing close to the breakwater, the tugboat operator will inform you on the distance of any obstructions until the vessel is alongside and they also can advise on the state of the current.

The tide book helps make reference of the tide on any particular day.

Some information is gathered before coming on board, particularly with regard to weather and current and navigational warnings, and so on and so forth. Other pilots traveling in the opposite direction or VTS may have important information regarding the route ahead. Regarding the weather, there are some websites that publish information from regarding wind and current. Also, some information is obtained from the helmsman, while others are obtained from the ECDIS.

3.10.3 The nature in which information obtained is presented

Usually, raw data is given so that you combine and make sense of the information about the ship's particulars; which are provided by the Captain's Declaration on board. And this is directly usable. The pilot card is the standard where all ships are supposed to present some information. As a result, information from the vessel, and other additional information required are obtained easily. Other sources of information are internet, verbally from the crew, radar screen and the PPU. This information may either be visual or audible; and you have to make sense of the whole atmosphere on the bridge. However, information provided by external sources, such as port control or tugboats are not directly usable. This information guides the reliability check of what is seen on the equipment on the bridge. The ECDIS gives us situational awareness about some situations. This information is electronically displayed while some are analogue; for instance, the speed of the vessel definitely has a speed log that is previous information on the bridge that was in the radar and in rudder indicators, rate of turn.

3.10.4 Reliability of the information obtained for decision-making

In order to ascertain whether the information made available to pilots during navigational decision making are reliable. The table below shows the result.

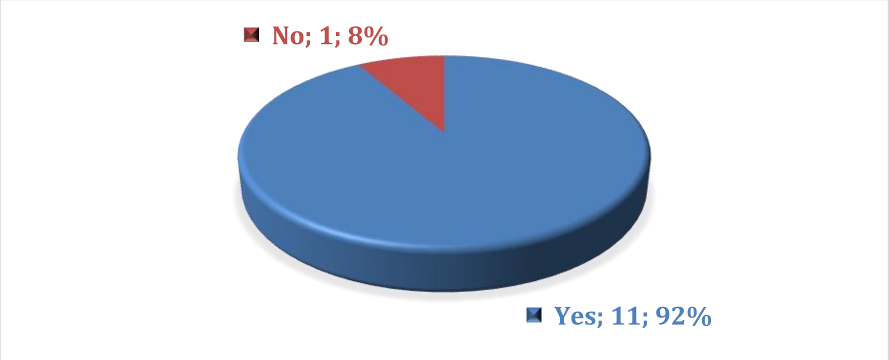


Figure 100: Reliability of the information obtained for decision-making

Out of the 12 respondents, 91.7% stated that the information available to them during pilotage is reliable while 8.3% stated that the information is not reliable. Although majority of the respondents stated that information provided is reliable, it is impossible to say all information obtained for safe decision-making during pilotage are 100% reliable. Some of the information are reliable, however, others are not, especially information about the weather. In this situation, the pilot needs some other information to ascertain the information that has been made available to him. During master-pilot exchange, detailed information is provided and this helps ascertain deficiencies, faulty equipment among others.

3.10.5 Determining the reliability of the information

Some of the information is standardized, while others are dynamic. The dynamic information has to be visually assessed based on the characteristics of the vessel and confirmation from the master using the pilot card and the wheelhouse poster. Assume the captain tells you that at rpm of about 60 or 80, that is dead slow ahead, which gives you seven knots. That information is validated by putting it on dead slow ahead or at that RPM to see whether you can make that speed for other information, like the stoppage power. It may or may not be reliable.

Sometimes, on board the vessel, the Master says that the ship has bow and stern thrusters and that everything is working fine. But when you enter the vessel and start using the bow thruster, you will identify some electrical problems. At other times, you test to ascertain whether everything is okay, but during the manoeuvre, the device stops working.

Aside from the ECDIS, we also go on board with various PPUs that have been adopted recently. In ports where PPUs are used, the internal position of the PPU confirms the position of the vessel, and this is cross-checked from the radar to see if the positions are the same.

The PPUs help us know how the vessel is drifting at every point in time. You can actually check the bow drift rate, the stern drift rate and how the vessel is moving, actual courses on the ground, compared with the GPS speed and then the actual speed also on the ground. And based on that, you're able to make the decision.

3.10.6 Rate of failure of the information during decision making

Working with humans and equipment make room for errors or mistakes, and these errors affect operational performance. There are instances where information on decision making fail pilots.

Table 6: Rate of failure of the information during decision making

	Frequency	Percentage
Yes	12	100%
No	0	0
Total	12	100%

All respondents gave a consensus on the fact that, although the PPUs are very helpful, they can sometimes fail. At times, one source of information becomes scanty and might not be the best to influence your judgments. So even though some information is handed over to the pilot, the onus lies on him to ascertain the reliability or otherwise of the information. When this happens:

1. The pilot needs to fall on his contingency plan (A case in point where a pilot had to drop an anchor to stop the vessel, and this saved that situation).
2. Although electronic gadgets have their own limitations, it is ideal to compare the PPU information with the ship's AIS. Aside from the comparison, we do a visual assessment in order to rely on the information obtained. There are some small disparities in some cases, which can actually make the information inaccurate.
3. The helmsman is also prone to make mistakes, and very often they are found carrying orders wrongly. So, double-checking is the word in this.

3.11 Decision support systems and tools used in decision-making

All the respondents stated that they use various tools to aid navigational decisions. These tools include:

1. Portable Pilot Units (PPUs), which are useful in assessing information and enhancing operations as they give a bird's eye view of the environment within which manoeuvring is being carried out.

2. Electronic navigational aids such as ECDIS, radar, wind indicators, parallel index variable range markers and ARPA's navigation index bearing, which provide information to determine decisions and actions.

3. Gyro compass and binoculars are used to check the position of the vessel.

4. Buoyed channels provide safe water for navigation.

5. Lighthouses provide guidance on the right direction to follow.

Here are some important points about marine navigation in ports:

6. The port authorities can send critical marine information directly to the Pilot's Portable Pilot Unit (PPU) using shore-based servers.

7. Tugboats also assist in navigating safely within the port.
8. Web cameras are strategically placed in certain locations throughout the port to help monitor the traffic situation.

Prior to the era of PPUs distances and dimensions were mainly estimated visually and many other information had to be checked with other persons who also usually estimate this information.

3.12 Impact of PPUs on Pilots' Situational Awareness and Decision Making

All respondents stated that they use PPUs during navigation. According to the respondents, the PPU is the mini form of the (ECDIS) electronic navigational aid which has a chart display with AIS incorporated and provides information about the vessel and other vessels in the vicinity for routing during the piloting. The PPU have two modems; one main CAT RoT which is connected to the ship's AIS plug and the secondary one, CAT ONE ROT, which enables better accuracy via receiving a space correction signals from low orbit satellites.

It also displays the rate of turn, speed, course and lateral movements of the ship. It provides the vessels details, for instance the vessels name the vessel, MMSI number, IMO number, length and beam. In addition, it also gives prediction of the vessels movements, and turning movements. So you are able to know from the prediction what will happen if you proceed with the same speed and course.

Then the berthing parameters, the vessels information it gives you also the predicted track of the vessels and then the distance to go so that the PPU is actually a mini ECDIS with additional information which assist in piloting duties. The PPUs aids decision making while navigating in and out of port. This puts the vessel in safe waters always and helps gives accurate speeds at various stages.

3.13 The use of Pilot Portable Units

The PPU is an interesting equipment which is computer based that shows chart of vessel's situation compared to other vessels position extracted from the AIS of the vessel. It is connected to the vessel's antenna and other information sources. The PPU helps to know exactly how the vessel is drifting or passing from the buoys, breakwaters, berth or the other vessels.

Table 7: Respondents use of Pilot Portable Units

	Frequency	Percentage
Yes	0	0%
No	12	100%
Total		

None of the 12 respondents had used a PPU prior to becoming a pilot, this suggests that the PPU is a tool for pilots and it is not used in the other sectors of the maritime space like normal navigation on board vessels.

3.13.1 Time duration of using Pilot Portable Units (PPU)

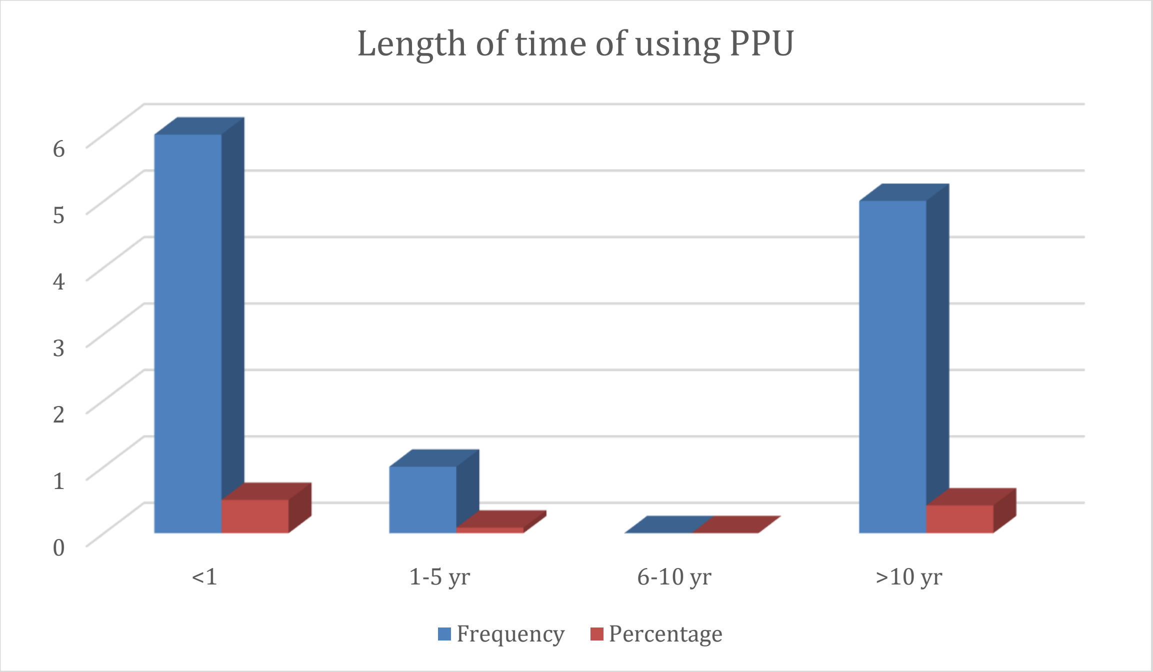


Figure 111: Number of years of using Pilot Portable Units

Based on the data, it appears that 50% of respondents have been using PPUs for less than a year, while 8.30% have been using them for 1-5 years. The remaining 41.7% of respondents have been using PPUs for more than 10 years. One respondent reported using the PPU exclusively when handling large vessels, while six respondents use the

PPU whenever they're working, except for simple manoeuvres with clear visibility. Finally, five respondents use the PPU for every manoeuvre as part of their standard operating procedures and must provide justification if they choose not to use it.

3.13.2 Training on the use of the PPU

Training on the use of Portable Pilot Units (PPUs) is crucial to ensure that maritime pilots and navigators can effectively utilize this technology for safe and efficient vessel maneuvering. The training helps familiarize users on how to navigate the PPU software, access various functions, and interpret the information displayed on the PPU screen. This includes understanding the user interface, menus and icons.

Table 8: Training on the use of the PPU

	Frequency	Percentage
Yes	12	100%
No	0	0
Total	12	100%

Out of the 12 respondents, all of them (12 respondents) were trained in the use of the PPUs. Training marine pilots on the use of PPUs is essential for safety, efficiency, and compliance in modern maritime navigation. It equips pilots with the skills and knowledge needed to effectively leverage these advanced tools, ultimately benefiting the entire maritime industry

Training was provided by the suppliers of the PPU via Zoom. The training span was within a day. However, there were instances where the training took two days. After the supplier training, there was a CBT training that took about two hours. It was it was conducted by the safe pilot company. The duration was enough as there were opportunities to ask questions and also follow-ups whenever there was a difficulty.

Regarding the sufficiency of the training period, a majority of the respondents believed that it was adequate as they had received training on the use of ECDIS while sailing. This training provided them with a solid foundation to further develop their skills in using PPU.

3.13.3 Information provided by the PPU

The various information about the ship’s characteristics includes the ship's length overall, beam, and draft. In navigation of the vessel, information such as the ship’s course, speed of the vessel, rate of turn, heading of the vessel, and rate of drift at every point in time, and also get predicted ranges to obstacle or object. This information are made known within a reasonable space of time so as to facilitate ideal decisions making.

This device helps create your own routes of passage during the pilotage. It also provides AIS information from other vessels.

The PPU gives an opportunity to track the sailings performed, and this is uploaded automatically to a shore-based server. It is easy to access the recordings and use them as a reference in times of claims from ship owners or insurance companies and can be used as an internal sharing of knowledge.

3.13.4 Adequacy of information provided by the PPUs

The adequacy of information provided by the Portable Pilot Unit (PPU) for decision-making in maritime navigation largely depends on the quality and accuracy of the data, as well as the capabilities of the PPU system.

Table 9: Adequacy of information provided by the PPU

	Frequency	Percentage
Yes	10	83.33%
Somehow	2	16.67
No	0	0%
Total	12	100%

Out of the 12 respondents, the majority of them (10 respondent), which accounts for 83.3%, stated that the information obtained from the PPUs are adequate for decision-making, while the remaining 16.7% had a neutral stance. The respondents with neutral viewpoints gave the following reasons:

- I cannot say it is adequate because this only gives a 2-D view, which is not enough for full accuracy.
- Sometimes, settings on the ship's AIS led to an offset which if not applied results in positional errors
- spoofing or jamming of the satellite navigation system also affects the accuracy of the positioning in the PPU, however, this applies to the vessel's equipment which use satellite-based positioning

3.13.5 Integrity of the information from the PPU

It is well known that electronics or devices are made by man and have a high tendency to failure. As a result, it is always important to check for the integrity of all information obtained from the PPU in order to ensure the safety of pilotage. Primarily, the use of visuals to ensure that the information received is right. In so doing, you compare the information you have with that of the ship using visuals. In addition, the PPU comes with a portable GPS system, which enhances the GPS position of the PPU.

Also, information can be confirmed with some known parameters of the vessel shown on the wheelhouse poster, which gives you the dimensions the speed, and the turning circle, among other parameters. The GPS, radar and the ECDIS can also be used to ascertain the credibility of the information. Finally, the crew at either the forward station or the aft station can give clearance from various obstacles.

3.14 Relation between PPU display and the surrounding environment

PPUs are primarily used for providing the range and bearing of the first visual object in the line of sight, especially in low-visibility conditions. This information is crucial for pilots to assess their position relative to visual landmarks or navigation aids. One respondent cited a situation where he had to slot a vessel in between two other vessels, mooring men ashore were giving the clearances for forward and astern. He used the information from the mooring men to corroborate the information given on the PPU. This led to a reduction in verbal communication when the information displayed by the PPU was found to be accurate. Double-checking of the information from AIS with the visual or land, land-fixed objects was important.

PPUs are valued for their portability, allowing pilots to carry them outside to the bridge wings, which is the preferred position when approaching and leaving berth. This mobility contrasts with fixed radar systems that require communication with personnel inside the bridge. PPUs provide real-time information in a format that allows pilots to access data independently. PPUs basically come in the form of iPads that are very mobile, when approaching a breakwater, the PPU is able to give you the range and bearing from the breakwater, and a visual picture of exactly the angle at which the tug is pushing. So, you are able to actually ask the tug to push you at one angle or to pull you at another angle.

While the PPU offers valuable data, experienced pilots emphasize the importance of cross-referencing PPU information with other sources. These may include visual cues, feedback from mooring teams or tugboat crews, and radar data. This verification process ensures that the information provided by the PPU aligns with the actual conditions.

PPUs are particularly beneficial during close-quarters manoeuvring, such as when docking or undocking in confined spaces. They provide data on distances from obstacles, rates of turn, and angles, aiding pilots in making precise navigational decisions.

PPUs offer predictive positioning capabilities, which project the vessel's future position based on its current course and speed. This feature assists in planning the manoeuvre and anticipating the vessel's position under various scenarios.

PPUs can be used in conjunction with other navigation tools, such as radar, electronic chart display systems (ECDIS), and AIS integrating data from these sources enhances situational awareness and decision-making.

3.14.1 The PPUs assistance in projecting the vessel’s future position

The predictive capabilities of Portable Pilot Units make them significant in aiding decision-making during vessel manoeuvres. It gives the chart representation and the vessel's dimension by calculating and displaying the future positions of vessels based on their current course and speed. This predictive function aids navigators in understanding how their vessel's movement will unfold over the next minutes or seconds. So, during your approach and swinging of the vessel, it gives the distance to the nearest object and the predicted position.

While PPUs help predict how the manoeuvre would be proceeding, they do not make decisions for pilots. It increases pilots’ awareness of the likely consequences of their actions, as they retain control over manoeuvring decisions. Predictive capabilities are particularly valuable during complex manoeuvres, such as turning a vessel within a confined space or navigating through channels. PPUs assist in assessing the feasibility and safety of these manoeuvres.

PPUs rely on data from Automatic Identification Systems (AIS) for vessel positions and Global Positioning Systems (GPS) for location information. The accuracy of these data sources is crucial to the reliability of the predictions generated by PPUs. PPUs contribute to safer navigation by enabling navigators to anticipate and prevent potential collisions, groundings, or unsafe situations. It serves as an additional layer of situational awareness. PPUs remain useful even in adverse weather conditions like fog. They provide navigators with predictive data that can compensate for reduced visibility, allowing for safer navigation.

The calculation of the rate of turn of the ship by the PPU is independent of the ship’s AIS system, and this is one of the absolute best functions of the PPU that can help pilot to monitor the swing of the vessel, enabling him or her take decision in case the manoeuvre is not going as expected. Predictive information gives pilots confidence in their manoeuvres, especially during complex and confined space operations. It allows them to visualize the vessel's path and make real-time adjustments as needed. Proper training and familiarity with the PPU system are essential for pilots to effectively utilize the PPUs.

3.15 The inherent challenges in pilotage districts

PPUs are indispensable tools for pilots at all Ports. The advantages and relevance of Portable Pilot Units (PPUs) in maritime navigation are below.

Primarily, the respondents stated that the layout at some ports (Tema Port) is challenging and difficult. This underscores the need for advanced navigation tools like PPUs to assist pilots in manoeuvring vessels safely within the port.

In addition, the potential for inaccuracies when relying solely on human communication for information. As can be inferred from the literature that human error is the number one cause of maritime-related accidents or incidents, PPUs offer a reliable source of real-time data, reducing the risk of errors and misunderstandings.

Again, PPUs have the ability to provide crucial information on vessel position, depth, hazards, and restrictions, enabling informed decision-making of pilots, thereby making it handy.

Also, the PPUs enhance safety by providing accurate information, particularly in close-quarter situations within the port. This data includes range and clearance from obstacles, predicted positions, and distances from obstacles, all of which contribute to better situational awareness.

Further, the importance of technology, especially given the increasing size of vessels, has made the adoption and use of PPUs essential for managing large vessels efficiently, reducing the need for physical communication and streamlining decision-making. This contributes to the pilot's confidence and awareness by providing real-time and predictive information. This is particularly valuable when navigating in challenging conditions or congested waterways.

3.15.1 Critical use of the PPU during pilotage

The critical areas where PPUs are relevant includes

1. Passing through the port waters and channels with limited space. A case in point is when a vessel is coming alongside the quay or is casting off. The distances that the PPU is able to give to the wharf whilst coming closer and the speeds, bow speed, stern speed and ahead or astern speed, also help in the safe manoeuvring of the vessel.
2. Use of PPU during the pilotage, especially with large vessels, thus, when slotting in a large vessel between other two vessels, the PPU can guide to ascertain the distances and rate of turn in the approaches.
3. Manoeuvring in shallow waters is guided by the use of PPUs, which gives the depths of the area and indicate buoyage systems.
4. When the vessels are large, the PPU helps the pilots monitor the turn, when swinging within a very small or confined area.
5. Accurate navigation is crucial when handling barges, towing jack-up rigs or towing FPSOs for scrapping. These operations require precision as the vessels involved are quite large and the navigable width of water is often restricted. To improve accuracy in maneuvering, PPUs are placed onboard.

The PPUs improve situational awareness for pilots, and assists in decision making during the pilotage. It also means that jobs that can be done during daylight can also be done at night-time, weather conditions being only the limiting factor.

3.15.2 Incidents or accidents whilst using the PPU

To minimize the risk of incidents or accidents when using PPUs, maritime authorities, vessel operators, and pilots should prioritize thorough training, regular equipment maintenance and updates, adherence to safety protocols, and effective communication between all parties involved in navigation. Additionally, pilots should use PPUs as valuable aids to decision-making rather than as replacements for judgment and seamanship skills.

Table 10: Incidents or accidents experience whilst using the PPU

	Frequency	Percentage
Yes	4	33.3%

No	8	66.7%
Total	12	100%

Out of the 12 respondent, majority of them (8 respondent) which accounts for 66.7% stated that they have never been involved in any incidents or accidents whilst using the PPU while remaining 33.3% stated that they have been involved in incidents or accidents whilst using the PPU, but further stated that the accident was not attributable to the PPU.

3.16 Optimization of the use of PPU to enhance navigational safety

Optimizing the use of Portable Pilot Units (PPUs) is essential to enhance navigational safety in the maritime industry. PPUs offer valuable tools for improving situational awareness and decision-making during vessel operations. Some respondents wanted to be able to simulate the impending manoeuvre on the PPU, as it could help the Shipmaster be fully appraised and have confidence having known how the manoeuvre will be carried and thus build more cooperation among the bridge team. Others were of the view that the AIS plug should be enhanced to provide additional information beyond its initial objective of information sharing to provide access for pilots to exchange information without the use of VHF.

3.16.1 Technical Challenges associated with the use of PPU

The use of Portable Pilot Units (PPUs) in maritime navigation brings some technical challenges. The results from the respondents on the technical challenges are below.

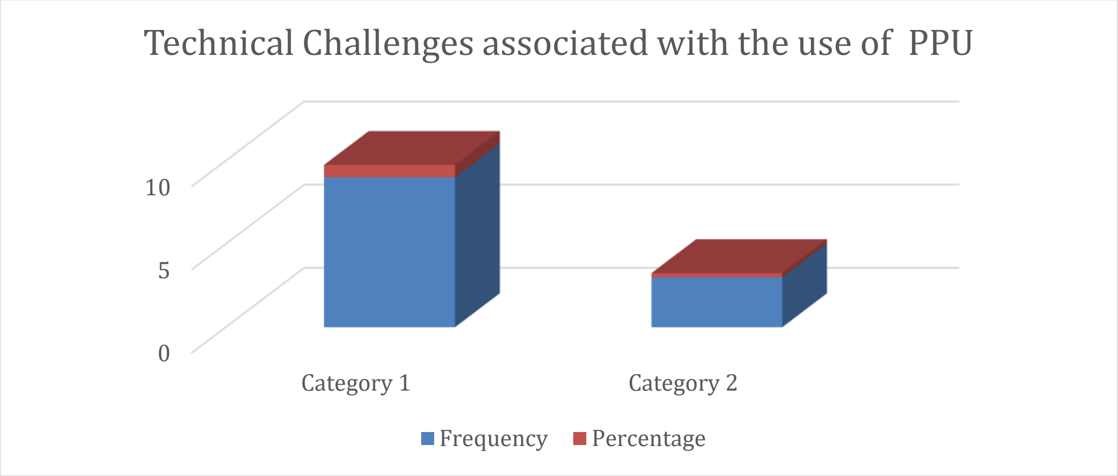


Figure 12: Technical Challenges associated with the use of PPU

Out of the 12 respondent, majority of them (9 respondent) which accounts for 75% stated that there are technical challenges associated with the use of PPUs while remaining 25% stated that they do not encounter technical challenges.

Some technical challenges associated with the use of PPUs include:

1. PPUs rely on GPS technology for positioning, and accuracy can be affected by factors such as satellite signal blockage and atmospheric conditions. This affects precise positioning, especially in narrow or congested waterways, can be challenging.
2. PPUs need to interface with various onboard systems, such as, Automatic Identification System (AIS), and Electronic Chart Display and Information System (ECDIS). Ensuring seamless integration and data synchronization can be technically complex.
3. PPUs are typically battery-powered. Prolonging battery life while ensuring continuous operation during long pilotage tasks can be a technical challenge.
4. Ensuring redundancy and system reliability is crucial for safety. Therefore, PPUs need backup systems and fail-safe mechanisms to handle technical failures.
5. Software Updates: Keeping PPU software up to date is essential. Managing software updates and ensuring compatibility with other onboard systems can be technically complex.

6. Protecting sensitive navigation data from cyber threats is a growing concern. Ensuring the cybersecurity of PPUs and associated systems is a technical challenge.
7. Interference and Jamming: PPUs can be vulnerable to intentional or unintentional interference and jamming of GPS signals. Implementing measures to detect and mitigate interference is technically challenging.
8. Environmental Factors: Harsh maritime environments, including exposure to saltwater, vibration, and extreme temperatures, pose technical challenges for the durability and reliability of PPUs.
9. Ensuring that pilots and navigators are adequately trained and familiar with PPU operation is a technical challenge. Effective training programs and ongoing support are essential.

3.16.2 Limitations on the use of the PPU

The PPU becomes useless when is connected to the vessel's AIS and its gives inaccurate information

- The PPUs becomes useless when is connected to the vessel's AIS and its gives inaccurate information.
- When AIS signal is unstable and the vessel is little far from the coast, it is difficult to register the vessel details.
- The other accessories of PPUs are separated, making it bulky to carry.
- Some of the PPU are not configured with information needed, when that happens, the pilot is expected to fix it all by himself before he continues his maneuver which inconveniences pilots when they are time-restricted
- When it comes to the weather, some ships do not have sheds on the bridge wings. So, when it rains, the equipment has no protection from the rain, or when it is very sunny, considering the part of the world we are in, you basically have to leave the PPU in the sun, and it gets a bit hot and might shut down.
- During jamming of GPS reception, the PPU becomes limited and unreliable

4 Discussions

This dissertation provides insight into maritime pilots' cognitive processes with respect to situation awareness and decision-making. The aim to investigate the impact of the PPU on the situation awareness of pilots has been met.

The theory of situation awareness, as espoused by Endsley (1995), has 3 levels, level one being perception, level 2- comprehension and level 3 projection. The discussion shows how the PPU impacts these levels of situational awareness.

Level 1- Perception of the elements involves discerning the status, qualities and dynamics of task-related components in the surrounding environment (Melnyk et al., 2022).According to one respondent, the PPU (Portable Pilot Unit) provides important information such as the course over the ground, the heading, speed, and drift of the ship. It also offers a sky view of the situation, enabling the pilot to have an overview of the vessel's movement inside the channel and while entering the port. Additionally, it helps the pilot determine the passing clearance from other vessels and obstructions, thereby confirming the PPU's ability to assist the pilot in achieving a Level 1 situational awareness. One respondent said in support of the ability of the PPU to aid in perception that

> "The port is really, really small and we are trying to take big vessels. So, when you are inside the bridge and you are entering, even with vessel, you know this Maersk vessels, these 250 meters with 40 meters 42 meters wide. When you are entering the port, you have the feeling that you are touching the breakwater from both sides from Starboard and port sides So you have to be exactly in the middle and also in the big vessel you are turning the vessel but you don't see anything you don't see anything the visibility is really horrible with some big vessels. So, in this case, what we what we used to do before we asked forward officer to report the distance of the vessel from the other vessel and same for aft but most of the time the bridge is in the aft we can see the aft but for forward

> some officer you know, when the vessels bow is 150 meter from the from the obstruction he will say 50 method and if you trust what he's saying you will start using engine unnecessarily so with the PPU if you checked him before and you know that is correct even if he's giving wrong the wrong distance you can tell Captain your officer is not so accurate. He is saying bullshit. So, this is the situation where PPU is very useful. So, to see even when we go outside the bridge, we cannot see exactly the situation. So when you have PPU, you can see exactly, you know, not exactly but you know almost how, how you are, are you in the middle of the basin? Or are you going too fast or too slowly and then you don't have to stress because even if the guy is saying 10 meters ahead, and you know that you are more than 100 meters you have nothing to do, our port is very, very small."

The assertion that the PPU aids in comprehending the pertinent elements required for manoeuvring is supported by all other respondents, albeit to varying degrees depending on the individual circumstances of their pilotage district. The use of PPU reduces the reliance on other human subjects for accurate reporting of the situation and is therefore valuable in situations where an all-around view of the situation is not readily available, such as in very large vessels where Pilots may not be able to see everything due to the vessel's dimensions.

Level 2 – Comprehension: It's important to understand the relevance of the data to the task and goals ahead when trying to comprehend the current situation (Melnyk et al., 2022). This level of understanding was not explicitly stated by the respondents but mostly implied as these processes are not discrete processes, as confirmed by Endsley (2004) that levels of situation awareness are not linear nor discrete processes. Many survey respondents reported comparing the window view (visual) to the display of the PPU. If there was a discrepancy between the two, they tried to understand the reason behind it. For instance, one respondent who was transiting a channel noticed that the PPU displayed the vessel as being outside the channel, even though visually, the vessel was within the channel. To investigate further, the respondent checked with other equipment onboard and found that the vessel was properly positioned as seen visually. Therefore, the respondent concluded that the PPU signal might have been spoofed since the VTS station also observed the same situation.

> The PPU displays the speed of the vessel, as well as the drift of the bow and stern, heading, and course. This helps the pilot to understand how the weather is affecting the ship. It is clear from these scenarios that the PPU aids in level 2 situational awareness, which is comprehension.

Level 3 – Looking ahead and anticipating future system states is like sailing ahead of the ship. The operator's mental models are created by mapping features in the environment and are used to develop situation awareness. This process involves intense thinking and assessment to determine future states of the system and its elements. In complex decision-making processes, this is crucial to achieve the desired goal in future events (Melnyk et al., 2022). According to Jones (2015), the three-pronged SA design approach begins with a user-centred analysis to define users' goals and information requirements. UI displays are grouped according to goals, and functionality is provided to achieve those goals. This approach ensures that the system provides the necessary information in a format that supports higher levels of SA, promoting better decision-making. Supporting higher-level SA in one of the most effective resources a system can provide a user, the user will still need to access the underlying information that the system integrated to provide the projection support.

The PPU therefore satisfies the above design criteria, that is the prediction function supports higher levels of SA, particularly level three SA this evidenced by most of the respondents’ answers, one respondent said he believes that the PPU can provide you with the expected direction or the probable path that the vessel is going to take in the near future, which helps to plan your landing accordingly. This information includes the course, speed, and any actions you take, like swinging or moving forward. It gives you predictions that aid in positive decision making. Another respondent had this to say

> “Depending on the settings, so, if you have a speed and then you are swinging or you're approaching the berth depending on the ship the PPU actually positions the vessels dimension in advance ahead of you. So, you know, that within this time this is where the vessel will be so, based on that if that is not the desired the required position you want the vessels to be then is telling you that you have to take action to correct or not to get to that predicted position”

All other respondents expressed similar sentiments showing that when it comes to level 3 SA, projection, the PPU comes into its own.

From the above submission, it is clear that the PPU positively impacts the situation awareness of maritime pilots, and when used in conjunction with the other tools available to the Pilot such as the onboard equipment and other tools like weather forecast and tidal information provides better outcomes in navigational situations.

Finally, this discussion chapter highlights two accidents where the use of PPU could have averted the accident. In the Federal Kivalina case (AIBN, 2010), the Pilot was unable to connect his PPU, and the charts for the area were received quite late. As a result, the navigation officer did not plot the tracks on the chart, and they had to navigate solely by sight. If the Pilot had been able to connect his PPU, he would have had access to the latest local chart, and the monitoring would have been more effective. According to most of the respondents, the PPU is the equipment that the Pilot is most familiar with and will tend to rely on it more, as the equipment on board ships can vary from ship to ship.

The Milano Bridge incident (KMST, 2021) is an incident worth noting. It was concluded that the vessel deviated from its planned route and got into an accident when it made a turn at excessive speed while berthing. This happened because the master and pilot of the ship failed to fully consider navigation risks, such as manoeuvrability, which was hindered by an exceptionally low draft. Additionally, there was insufficient communication and no proper manoeuvring or pilotage plan agreed upon in advance between the master and the pilot for berthing. From the investigations, the Pilot was not using a PPU and was estimating that the vessel turn was slow, with the PPU however, the predictor function will have shown exactly how the manoeuvre will proceed in the future allowing the Pilot to make better and informed decision to avoid the accident. This position is corroborated by Stanley (2020) when he wrote that an accurate ROT is crucial for electronic charting systems to facilitate pilotage, especially when software can use it together with position and course/speed over the ground to predict future positions while turning. While high-level PPUs have this capability, not all Electronic Chart Display and Information Systems (ECDIS) possess it, and some older ships' gyros do not generate ROT. In the earlier groundings mentioned, PPUs would have provided early warning signs, as was the case with CMA CGM Vasco de Gama and Leda Maersk, but unfortunately, nobody seems to have taken notice.

Pilots make all the decisions during the pilotage manoeuvre. However, PPUs help them make informed decisions by providing high levels of situational awareness. The PPUs have a playback function that can record and store all manoeuvres, which can be used to share knowledge and increase the mental models of pilots. This can enhance their expertise and improve their decision-making abilities. Rasmussen (1997) suggests that in familiar situations, simple skill and rule-based choices among familiar action alternatives can replace analytical reasoning and planning, which are time-consuming

5 Conclusion and Recommendations

5.1 Introduction

This chapter consists of the conclusions drawn from the findings with respect to the objectives for this study. It also contains the recommendations from the researcher based on the results of the research conducted.

5.2 Summary of Findings

i. How marine pilots make navigational decisions during pilotage

Ideally, the primary information required by the pilot to make decisions that will ensure safe pilotage is to know the ship that is bound to take a berth, this includes basic characteristics of the ship such as the type of ship, draft, length overall, beam and the type of engine. Also, whether there are some limitations on the ship, for example, the number of consecutive starts of the engine and the air draft, so as to understand how the vessel will behave in the channel.

Information regarding the vessel is obtained from the vessel itself, particularly during discussions with the master. Some information is also obtained from the pilot card, and these include the vessel’s dimensions and manoeuvring characteristics. Information about the weather and tides is obtained from the port authorities or weather service organizations via the Internet.

The tugboat crew also provide some information, such as clearances when passing close to the breakwater, and also distances from any obstructions until the vessel is alongside.

Usually, raw data is obtained by the Pilot concerning the weather and environmental elements such as wind, current and tide. The Pilot uses this raw data to determine what effects these elements will be having on the ship. The pilot card is the standard where all ships are supposed to present some information. As a result, information from the vessel and other additional information required are obtained easily.

Although majority of the respondents stated that the information provided is reliable, it is impossible to say all information obtained for safe decision-making during pilotage is 100% reliable.

Working with humans and equipment makes room for errors or mistakes, and these errors affect operational performance. There are instances where information on decision-making fail pilots. Sometimes, one source of information becomes scanty and might not be the best to influence your judgments. So even though some information is handed over to the pilot, the onus lies on him to ascertain the reliability or otherwise of the information.

ii. The decision-support systems and tools used during pilotage

In the past, visuals and second opinions were obtained in order to ascertain important information that supports decision-making during pilotage. However, in recent times, the use of electronic navigational aids and ECDIS, radar, wind indicator and parallel index variable range markers ARPA, which provides information that will determine the decisions and actions. In addition to that, PPUs are useful in assessing information and also enhance operations as they give a bird eye view of the environment within which manoeuvring is being carried out.

iii. The impact of PPU on pilots' situational awareness and decision-making

All respondents stated that they use PPUs during navigation. The PPU is the mini form of the (ECDIS) electronic navigational aid, which has a chart display with AIS incorporated and provides guidelines information about the vessel and other vessels in the vicinity for routing during the piloting.

Training of pilots was provided by the suppliers of the PPU. The training span within a day, however, there were instances where the training took two days. After the supplier training, there was an in-house training that took about two hours.

The PPUs are used daily on all work schedules while on board all vessels , except those that are small enabling the Pilot to have an all-round view (basically the PPU enables the pilot to have a bird’s view of the vessel s/he is manoeuvring) or those which do not have the pilot plug through which the PPU is connected to the vessel’s systems. The PPU gives an opportunity to track the sailings performed, and this is uploaded automatically to a shore-based server.

The various information about the ship’s characteristics includes the ship's overall length, beam, and draft. In navigation of the vessel, information such as the course of navigating, speed of the vessel, rate of turn, heading of the vessel, rate of drift at every point in time and also get predicted ranges to obstacle or object. This information is made known within a reasonable space of time so as to facilitate ideal decisions making.

iv. Optimising the use of PPU to enhance navigational safety

In order for the PPU to be optimized, there is a need to educate and sensitise all ports and mariners to adopt and use this system to ensure safety. Also, the system should be upgraded to include a traffic collision avoidance system, which is based on GPS reception like a TCAS system in aviation, so that when you have a situation with two vessels, the system will advise on the actions necessary to avoid a collision.

5.3 Conclusions

In order to obtain entry to the ports and conduct business, ships require the assistance of marine pilots who are trained to safely navigate hazardous marine environments. The International Maritime Organization's main focus has always been on improving maritime safety, considering accidents and incidents that continue to take place. Several researches have established that human error is responsible for about 85% (Acejo et al., 2018; Galieriková, 2019) of the causes of these mishaps. Working with humans and equipment make room for errors or mistakes, and these errors affect operational performance. It is important to reiterate that majority of accidents and allisions that happen in pilotage waters was attributed to a pilot who was in command of either one or both of the vessels involved. There are instances where information on decision making fail pilots. Sometimes, one source of information becomes scanty and might not be the best to influence your judgments. So even though some information is handed over to the pilot, the onus lies on him to ascertain the reliability or otherwise of the information.

The outcome of the research shows that most ports around the world have adopted technologies such as ECDIS and PPUs to ensure navigational safety during pilotage. All respondents stated that they know what PPUs are and their essence during navigation. The PPU, a condensed version of the ECDIS, features a chart display integrated with AIS capabilities. It furnishes essential vessel information and guidelines for routing during piloting operations. Pilots in various countries were trained prior to the adoption and use of the PPUs.

Pilot training was facilitated by the PPU suppliers, typically spanning a single day, although there were instances where it extended to two days. Subsequent to the supplier-led training, there was an in-house training session lasting approximately two hours.

PPUs are incorporated into daily operations across all work schedules aboard all vessels, except for those involving minimal manoeuvring or minimal complexity. The PPU enables the tracking of sailings, with data automatically uploaded to a shore-based server. PPUs are critical tools for ensuring the safe navigation of vessels, especially in complex and congested waterways. Proper training ensures that pilots can effectively use PPUs to assess and mitigate risks, avoid collisions, and respond to emergencies.

Nonetheless, some measures have been suggested by the respondents for optimizing the use of PPUs for safety of navigation during pilotage.

5.4 Recommendations

Ways of improving PPUs to enhance navigational safety:

1. The PPU and its accessories should be integrated into one unit to facilitate the ease of setting it up and also prevent loss of the accessories.

2. The system should be designed in such a way that the pilot can simulate the manoeuvre as part of the Master Pilot exchange. This will give a pictorial view of the proposed manoeuvre thus allowing for effective monitoring.
3. The PPU should be updated from a 2D to a 3D display function
4. The battery health should be improved in order that they can be used for long periods before charging it
5. The gadget should be constructed to suit the geographical region in which it is to be used considering the environmental aspects such as temperature, humidity and rain. Some respondents in the tropics complained of overheating if it's used outside the bridge, when it's sunny, it gets hot and it's shut down or something like that. The need to shut it down or something like that.
6. The redundancy in the system should be monitored and controlled by employing more sophisticated technologies, especially with regards to the instability in the alarm signal system
7. Cybersecurity needs to be strengthened in the maritime industry so that false AIS targets do not control with actual targets.
8. The system should be upgraded to include a traffic collision avoidance system, which is based on GPS reception like a TCAS system in aviation, so that when you have a situation with two vessels, the system will advise on the actions necessary to avoid a collision.

In this dissertation, the focus was on examining the effect of PPU on the situation awareness (SA) of maritime pilots using qualitative research methods. As these findings cannot be applied to all pilots, there is a scope for future research to investigate the frequency of PPU usage and its effectiveness in reducing accidents during pilotage.

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Appendix A

Consent Form

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfillment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is “The Impact of Pilot Portable Units on Maritime Pilots’ Situational Awareness and Decision-making”

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will later be published online in WMU's digital repository (maritime commons) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student’s name	Bernard Kuwornu
Specialization	Maritime Safety & Environmental Administration
Email address	w1012541@wmu.se

* * *

I consent to my personal data, as outlined above, being used for this study. I understand that all personal data relating to participants is held and processed in the strictest confidence, and will be deleted at the end of the researcher’s enrolment.

Name: ………………………………………………………………………

Signature: ………………………………………………………………………

Date: ………………………………………………………………………

Rev August 2021

Appendix B

REC DECISION # REC-23-036(M)

Email, PhD <PhD@wmu.se> (sent by cef@wmu.se) Jun 20, 2023, 2:37 PM

to me, Dimitrios

Dear Bernard Kuwornu,

I am pleased to let you know that the members of the WMU Research Ethics Committee (REC) have now unanimously **approved** the research related documents that you submitted to this office on 14 June 2023 concerning your research study involving human participation.

You are now free to start your data collection work in consultation with your supervisor.

With kind regards,

Carla Fischer
REC Secretary
Faculty Support Officer
Research Projects and Doctoral Programs
World Maritime University
Malmö, Sweden
Tel: +46 40 35 63 91
Fax: +46 40 12 84 42
E-mail: phd@wmu.se

Appendix C

Interview guide

Please feel free to seek clarification on any issue

SECTION A: PERSONAL INFORMATION (tick as appropriate)

1. Gender
   Male [ ]   Female [ ]

2. Age
   18-35 [ ]   36-49 [ ]   50 years and above [ ]

3. Highest level of education?

Training College [ ]   Diploma [ ]   First Degree [ ]   Master's [ ]   Other [ ]

4. If Other please specify
   ……………………………………………………………….

5. Certificate of Competency   Yes [ ]   No [ ]

   Class III [ ].   Class II [ ].   Class I [ ]

6. What kind of Pilotage do you perform?

   ………………………………………………………………………………………..

7. How long have you been working as a Pilot?
   Below 1 year [ ]   1-5year [ ]   6-10years [ ]   Above 10 years [ ]

8. What are the basic tasks and responsibilities you perform in your current role?

   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………

SECTION B: MARITIME PILOTS NAVIGATIONAL DECISIONS DURING PILOTAGE

9. What information do you need to make decisions that will ensure safe pilotage?

   …………………………………………………………………………………
   ……………………………………………………………………………………………………

10. Where do you get the information used in decision-making?

………………………………………………………………………………

………………………………………………………………………………

11. How is this information presented to you?

………………………………………………………………………………

………………………………………………………………………………

12. Is the information reliable?

Yes [ ] No [ ]

If No, why?

………………………………………………………………………………

………………………………………………………………………………

13. How do you check the reliability of this information?

………………………………………………………………………………

………

14. Has the information ever failed you?

Yes [ ] No [ ]

If yes, how did you solve it?

………………………………………………………………………………

………………………………………………………………………………

SECTION C: DECISION SUPPORT SYSTEMS AND TOOLS USED IN DECISION-MAKING

15. In making navigational decisions, do you use any tools?

Yes [ ] No [ ]

16. What tools do you use to support your decision-making?

………………………………………………………………………………

………………………………………………………………………………

………………

SECTION D: IMPACT OF THE USE OF PPU ON PILOTS' SITUATIONAL AWARENESS AND DECISION MAKING

17. Do you know anything about Pilot Portable Units (PPUs)?

Yes [ ] No [ ]

If yes, what do you know about PPUs?

…………………………………………………………………………………
…………………………………………………………………………………
………………..

18. Have you used Pilot Portable Units before?

Yes [ ] No [.]

19. How long have you used Pilot Portable Units (PPU)

…………………………………………………………………………………

…………………………………………………………………………………

………………..

20. Did you receive training on the use of the PPU?

Yes [ ] No [ ]

If Yes, how long was the training?

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…………………………………………………………………………………

………………

21. How often do you use the PPU?

…………………………………………………………………………………
…………………………………………………………………………………
………………

22. What information is provided to you from the PPU?

…………………………………………………………………………………
…………………………………………………………………………………
……………….

23. Is the information adequate for your decision-making?

Yes [ ] Somehow [ ] No [ ]

24. How do you check the integrity of the information from the PPU?

…………………………………………………………………………………

…………………………………………………………………………………

………………

25. How do you relate the information from the PPU to the situation pertaining around you?

……………………………………………………………………………………
……………………………………………………………………………………
………………

26. How does the PPU assist you in projecting the vessel's future position?

……………………………………………………………………………………
……………………………………………………………………………………
………………

27. What are the inherent challenges in your pilotage district that make the use of the PPU beneficial?

……………………………………………………………………………………
……………………………………………………………………………………
……………….

28. In what situations will you find the use of the PPU critical during pilotage?

……………………………………………………………………………………
……………………………………………………………………………………
………………..

29. Have you had any incidents or accidents whilst using the PPU?

Yes [ ]   No [ ]

If Yes was the PPU a contributory factor?

……………………………………………………………………………………
……………………………………………………………………………………
………………

SECTION D: OPTIMIZATION OF THE USE OF PPU TO ENHANCE NAVIGATIONAL SAFETY

30. Do you have any technical challenges with the use of the PPU?

Yes [ ]   No [ ]

If Yes, what are some of the challenges associated with the use of PPU?

…………………………………………………………………………………

…………………………………………………………………………………

………………

31. What limitations have you experienced in your use of the PPU?

…………………………………………………………………………………

…………………………………………………………………………………

………………

32. What improvements does the PPU need to enhance navigational safety?

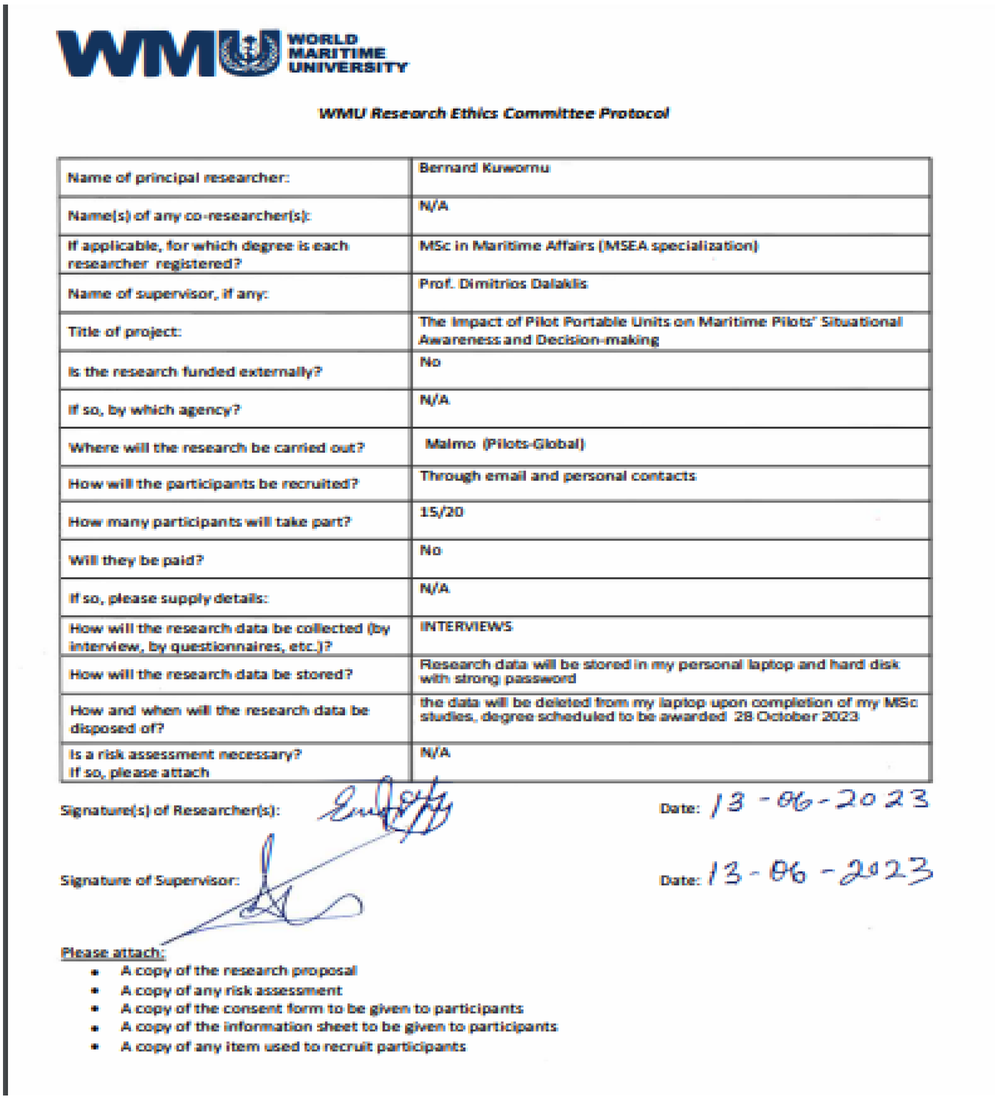
…………………………………………………………………………………

…………………………………………………………………………………

………………

Appendix D

Ethic Committee Protocol



WORLD MARITIME UNIVERSITY

WMU Research Ethics Committee Protocol

Name of principal researcher:	Bernard Kuwornu
Name(s) of any co-researcher(s):	N/A
If applicable, for which degree is each researcher registered?	MSc in Maritime Affairs (MSEA specialization)
Name of supervisor, if any:	Prof. Dimitrios Dalaklis
Title of project:	The Impact of Pilot Portable Units on Maritime Pilots' Situational Awareness and Decision-making
Is the research funded externally?	No
If so, by which agency?	N/A
Where will the research be carried out?	Malmo (Pilots-Global)
How will the participants be recruited?	Through email and personal contacts
How many participants will take part?	15/20
Will they be paid?	No
If so, please supply details:	N/A
How will the research data be collected (by interview, by questionnaires, etc.)?	INTERVIEWS
How will the research data be stored?	Research data will be stored in my personal laptop and hard disk with strong password
How and when will the research data be disposed of?	the data will be deleted from my laptop upon completion of my MSc studies, degree scheduled to be awarded 28 October 2023
Is a risk assessment necessary? If so, please attach	N/A

Signature(s) of Researcher(s): Date: 13-06-2023

Signature of Supervisor: Date: 13-06-2023

Please attach:

- A copy of the research proposal
- A copy of any risk assessment
- A copy of the consent form to be given to participants
- A copy of the information sheet to be given to participants
- A copy of any item used to recruit participants