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# e-Navigation vs. Autonomous Navigation – Challenges for Marine Pilots

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ABSTRACT: Maritime navigation is currently evolving along two parallel paths: e-Navigation, designed to integrate and harmonize ship- and shore-based information for enhanced decision-making, and Autonomous Navigation, which seeks to transfer these decisions to automated and remotely supervised systems. This paper explores how these two trajectories align and diverge, focusing on their impact on marine pilots. The e-Navigation concept, including the IMO-endorsed S-Mode interface standardization, has demonstrated tangible benefits for pilotage by improving situational awareness, operational safety, and data exchange through standardized user interfaces and information flows. In contrast, the transition toward autonomous vessels raises significant technological, operational, legal, and human-factor challenges, including redefined pilot roles, liability issues, mixed-fleet operations, and cybersecurity risks. While both approaches rely on similar enabling technologies, their design philosophies differ fundamentally: e-Navigation augments human expertise, whereas Autonomous Navigation seeks to reduce or replace it. The paper concludes with recommendations for pilot training, competencies, and regulatory frameworks, emphasizing human-machine collaboration and staged implementation.

## 1 INTRODUCTION

A marine pilot, also called maritime pilot, port pilot, harbour pilot, ship pilot, or simply pilot, is a mariner who makeovers ships through dangerous or congested waters, such as harbours or river mouths. The terms maritime pilot and marine pilot are essentially interchangeable and refer to the same profession: a mariner with specialized knowledge of a specific waterway, often dangerous or congested, like harbours or river mouths. They guide ships safely through these areas, providing expert local knowledge to ship captains and crews.

While the ship's captain holds overall command, the role of a maritime pilot is equally critical, though distinct. Maritime pilots are specialists in manoeuvring vessels during arrivals and departures from ports, particularly in challenging or high-risk conditions. Their responsibilities can be summarized as follows:

– Advisory role during complex manoeuvres: Although the captain is responsible for the vessel's navigation at sea, pilots provide expert advice on the safest routes and manoeuvring strategies when entering or leaving a port, where precision is essential.
– Expertise with large and heavily loaded vessels: The larger the ship, the more difficult it is to handle. Cargo carriers and oil tankers, due to their size and inertia, require the skills of a pilot to ensure safe passage, protecting not only the vessel and crew but also the marine environment.
– Specialized knowledge of restricted waters: In ports with narrow channels or complex approaches,

pilots possess the local knowledge needed to guide vessels safely through confined waters without incident.

For these reasons, maritime pilots are employed locally and are intimately familiar with the waterways in which they operate. Effective cooperation and clear communication between the pilot and the ship's captain are essential, as any misunderstanding can result in serious operational or environmental consequences.

## 2 E-NAVIGATION

### 2.1 *What is a e-Navigation?*

In general terms, e-Navigation refers to the integration of modern electronic tools and systems aimed at improving the safety and efficiency of maritime navigation. It is an IMO initiative defined as *"the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment."* The IMO has stipulated that e-Navigation must be driven by user needs and fully account for the human element. As highlighted in [2], the effectiveness of e-Navigation in enhancing safety, security, and environmental protection depends not only on the supporting technologies but also on the establishment of robust operational procedures and comprehensive training for decision-makers..

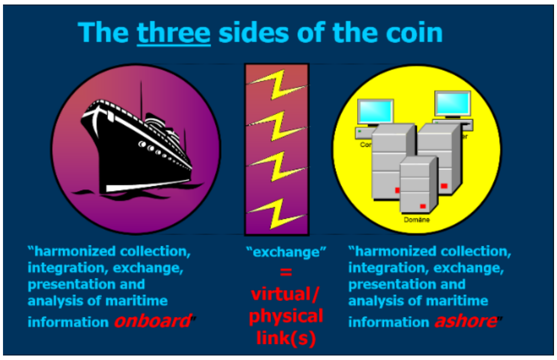


Figure 1. Definition of e-Navigation – the three sides of the same coin [5]

The advantages of the latest developments in computer science, automation, electronics, telecommunications, telematics, geomatics, and global positioning technologies, as well as advances in data storage, processing, analysis, transfer, and visualization—should be fully considered and applied within maritime technology [7].

Key features of e-Navigation:
- Use of ECDIS (Electronic Chart Display and Information System),
- AIS (Automatic Identification System),
- Enhanced communication and decision support systems.

Main benefits of e-Navigation:
- Improved situational awareness,
- Real-time data sharing,
- Human control remains central.

### 2.2 *The e-Navigation Concept*

Thanks to advances in information technology, seamless communication between sea and shore is now possible, enabling the maritime community to actively promote e-Navigation as a means of preventing accidents, improving transport efficiency, conserving energy, and protecting the marine environment. Large-scale implementation of e-Navigation features appears inevitable [4]. The impact of electronics and computers on ships' bridges has been evident for at least three decades; nevertheless, there remains considerable debate about whether these systems have truly improved navigational safety. As the future of shipping is closely tied to e-Navigation, it is imperative to prepare students to meet the challenges posed by the growing volume of navigational information that must be effectively selected, processed, and analysed in order to support correct decision-making.

To achieve this, traditional methods of teaching navigation must be complemented by modules that integrate data from multiple navigational sources and sensors. Students should be trained to build a comprehensive situational awareness based on all available information. They must also develop a safety-oriented mindset and the ability to self-educate when faced with unfamiliar navigational equipment or new configurations of integrated bridge systems (INS/IBS). Proper onboard training is essential, beginning with sufficient time to familiarize themselves with user manuals and operational procedures for the installed systems.

e-Navigation is envisioned as a "living" concept that will evolve over time. As technologies, political priorities, and commercial objectives change, so too will the information and tasks involved. However, the need for safe and efficient maritime transport is unlikely to change. Future decision-making will increasingly depend on technology, but human judgment will remain indispensable. Therefore, the human element must be fully considered at every stage of the design, development, implementation, and operation of e-Navigation systems.

To support this vision, new and modified education and training programmes dedicated to e-Navigation are required, along with well-standardised international procedures for marine navigation. While the full details of how e-Navigation will be realized are not yet fully defined, its presence on the maritime horizon is unmistakable. Ship transport has long been the original Intelligent Transport System (ITS), and developments in this sector are of clear relevance to ITS research in other modes. The IMO's e-Navigation initiative and the EU's e-Maritime programme both underscore this point, having identified information architecture as a critical factor for the future development of maritime transport. This architecture must account for legacy systems, the international nature of shipping, applicable legislation and standards, and the variable quality of available communication channels [5].

Before the concept of e-Navigation can be fully implemented, it is essential to ensure that ongoing projects, testbeds, and emerging standards are indeed moving in the right direction. We must ask whether the current vision of e-Navigation is truly sufficient and aligned with industry needs and expectations.

### 2.3 *S-Mode*

S-Mode, a standardized navigation display mode, offers significant benefits for maritime pilots by improving consistency and ease of use across different Electronic Chart Display and Information Systems (ECDIS), ultimately enhancing safety and efficiency.

This standardization reduces the learning curve for pilots, especially when transitioning between vessels, as they can rely on a familiar interface regardless of the specific ECDIS model.

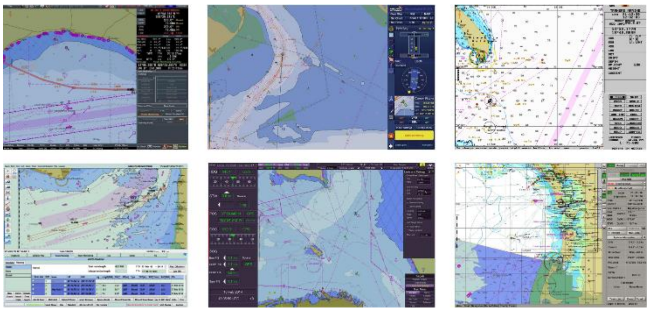

Figure 2. At least dozens of different models of ECDIS available on the market [5]

The IMO has adopted guidance on the standardization of the design of navigation and communication systems, including displays, interfaces, and functionalities, to ensure that bridge teams and pilots have timely access to essential information required for safe navigation throughout the entire voyage, from berth to berth.

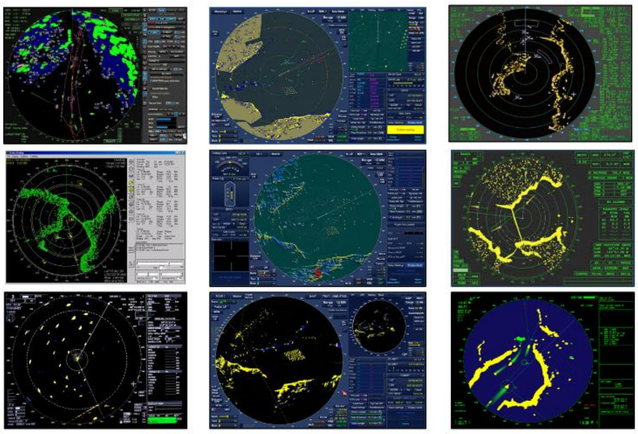

Figure 3. At least dozens of different models of marine radars available on the market [5]

S-Mode is intended to reduce variability in navigation systems and equipment by standardizing key aspects of user interfaces. This standardization will enable users to access essential information and functions more quickly, thereby supporting safer navigation. The guidance is driven by a strong user need for consistency in the presentation of critical information required to perform key navigational tasks, regardless of the equipment manufacturer.

### 2.4 *Key Benefits of e-Navigation for Marine Pilots*

There are the following key benefits of e-Navigation for marine pilots:

1. Enhanced Situational Awareness:
   - Real-time data from AIS, radar, and ECDIS provides a clearer picture of the navigational environment.
   - Access to dynamic and up-to-date charts, tidal data, and weather forecasts improves decision-making.
   - Integration of information reduces the need for manual cross-checking between systems.
2. Improved Safety:
   - Better collision and grounding avoidance through predictive tools and real-time monitoring.
   - Alerts and alarms provide early warnings about navigational hazards.
   - Enhanced visibility in low-light or poor weather conditions through augmented systems.
3. Much Better Communication and Coordination:
   - Standardized data exchange with VTS (Vessel Traffic Services) and port authorities improves coordination.
   - Digital route sharing and updates minimize misunderstandings.
   - Reduces reliance on voice communication, decreasing the risk of miscommunication.
4. Efficient Voyage Planning and Execution:
   - Seamless integration with Port Management Information Systems (PMIS) allows better timing and manoeuvring.
   - Pre-arrival planning and route optimization tools save time and fuel.
   - Pilots can review and adjust routes before boarding, increasing preparedness.
5. Support for Portable Pilot Units (PPUs):
   - e-Navigation systems support PPUs, which pilots use to bring their own high-accuracy navigation equipment.
   - PPUs provide independent and reliable data that can be more precise than the ship's equipment.
   - Enhanced autonomy in decision-making, especially during tight manoeuvres.
6. Data Logging and Post-Event Analysis:
   - Automatic recording of navigational data supports incident investigation and training.
   - Enhances transparency and accountability in pilotage operations.
7. Regulatory Compliance and Standardization:
   - Helps pilots and shipping companies stay compliant with IMO regulations and SOLAS e-Navigation mandates.
   - Facilitates standard operating procedures and interoperability across different ships and regions.

Apart from that e-Navigation with S-Mode it is huge benefit for Marine Pilots it is in 100% dedicated for Marine Pilots.

## 3 WHAT DOES THE FUTURE HOLD FOR SHIPPING?

If we are talking about the future the most important is the time horizon - one year, five years, ten, twenty years or next century.

Figure 4. If we are talking about the future – the most important is the time horizon

Current marine technology developments are focused in increased reliance on data analytics, remote operations, and autonomous ships. Technologies which are mainly in focus:
- Importance of navigation technology in modern maritime operations;
- Automation in vessel operations;
- Artificial Intelligence (AI) and machine learning in Navigation;
- Digital twins and real-time monitoring systems;
- Advances in sustainable energy (e.g., electric/ hybrid vessels).

So, what does the future hold for shipping? In the Author opinion there are seven magnificent trends in international shipping [6]:
- Alternative Marine Fuels (LNG, Hydrogen, etc.);
- Green Propulsion (e.g. Wind, Solar);
- Smart Shipping Technologies (Internet of Things (IoT) applications, advanced sensors, and big data for real-time operational monitoring, Predictive maintenance to prevent mechanical failures, 3D printing);
- Digitalization (e.g. Electronic Charts/ECDIS);
- GNSS/PNT;
- e-Navigation, and
- Autonomous Ships.

Figure 5. Perfect pair introduced to marine navigation: GNSS and ECDIS [3]

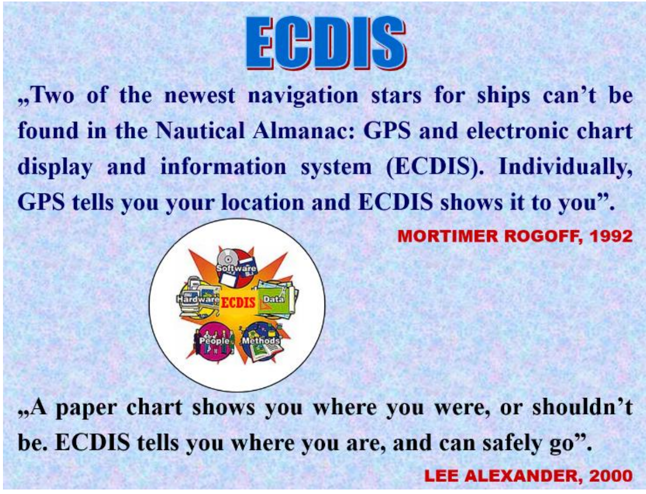

Figure 6. The two most important sentences about the revolution that took place in maritime navigation relating to ECDIS [3]

Figure 7. The seven great trends observed in technology development for international shipping can be reduced to three main trends: digitalization, intelligentization and decarbonisation

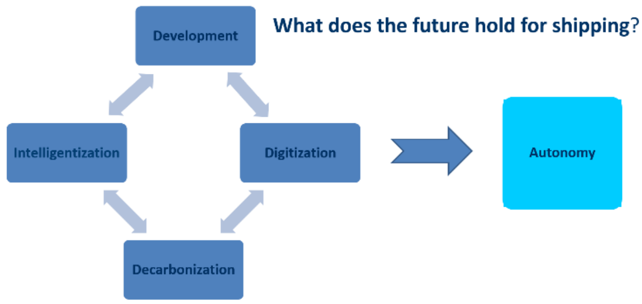

Figure 8. The technology development, digitalization, intelligentization and decarbonization inevitably lead to autonomy of international shipping [6]

The most important question: are e-Navigation and Autonomous Navigation heading in the same direction? Really? Are they? I don't think so. They're two completely different directions. This is the final moment to decide which direction is most appropriate and attractive at this moment.

## 4 AUTONOMOUS NAVIGATION

Definition of Autonomous Navigation is clear. It is navigation carried out by AI and sensors without human intervention. Technologies involved: sensors, AI, machine learning, remote operations centres [1].

There are defined levels of autonomy (based on IMO's MASS framework):

– Manned ships with automated processes,
– Remotely controlled ships,
– Fully autonomous ships.

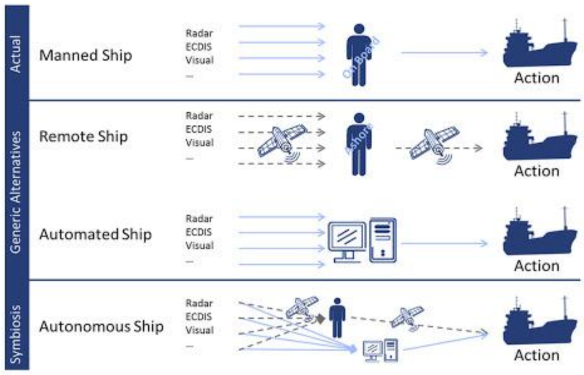


Figure 9. Degrees of autonomy according to IMO [http://www.unmanned-ship.org/munin/about/the-autonomus-ship]

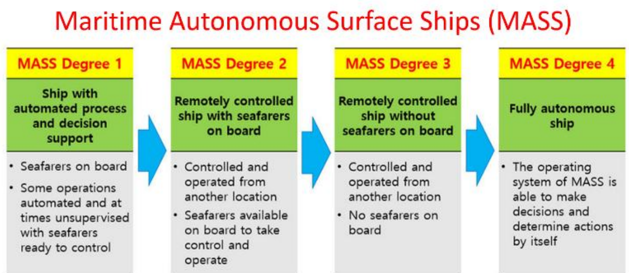


Figure 10. Degrees of autonomy according to IMO [8]

Current marine technology developments are focused in increased reliance on data analytics, remote operations, and autonomous ships. Technologies which are mainly in focus.

Autonomous shipping vessels pose major challenges for science and education:

– levels of autonomy and their implementation
– operating conditions
– changes in the labour market
– education in response to the needs of the labour market.

Figure 11. Autonomous vessel [http://emag.nauticexpo.com/article-long/rolls-royces-vision-of-autonomous-vessels]

But we must realize that an autonomous ship does not yet mean autonomous shipping and autonomous navigation. Building an autonomous ship is no longer a major technological challenge; it's only a matter of a few years of advanced work. However, autonomous shipping is a major international challenge in legal, operational, and organizational terms, requiring at least a dozen years of intensive, coordinated work under the auspices of the IMO.

There is a long and winding road ahead of us from autonomous ship to autonomous shipping.


Figure 12. There is a long and winding road ahead of us from autonomous ship to autonomous shipping

## 4.1 *Degrees of Ships Autonomy*

The IMO isn't the only one that has established degrees of ship autonomy. There are at least a few other similar classifications.

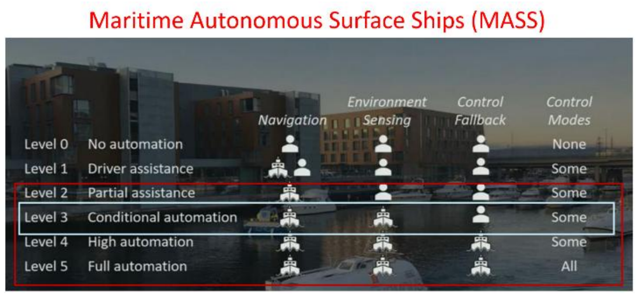


Figure 13. The IMO regulations for the four levels of MASS

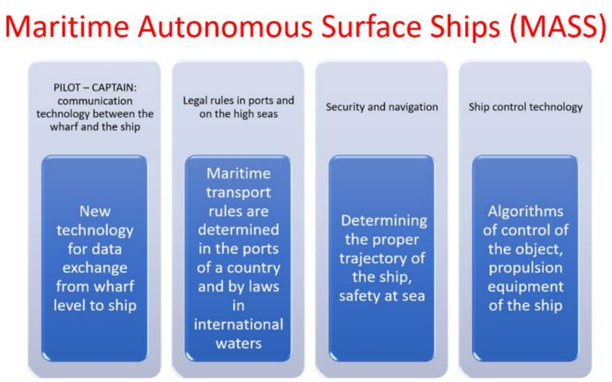


Figure 14. Degrees of autonomy according to NTNU (Norwegian University of Science and Technology)

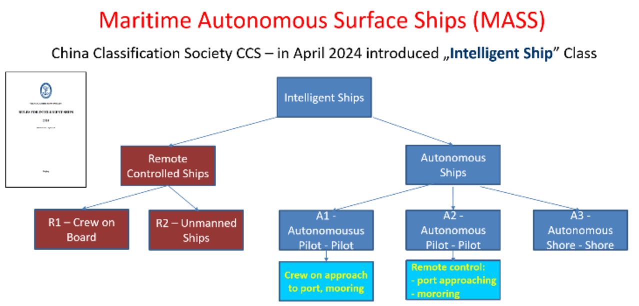


Figure 15. Degrees of ships autonomy according to China Classification Society CCS adopted in 2024 for „Intelligent Ship" Class

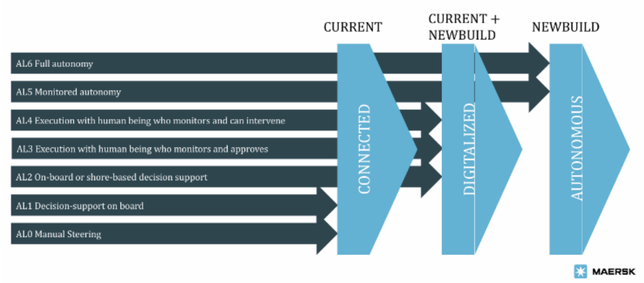


Figure 16. The journey towards full autonomy by Maersk

## 5 CHALLENGES FOR MARITIME PILOTS IN E-NAVIGATION

Maritime pilots play a critical role in ensuring the safe navigation of ships, particularly in challenging or congested waters like harbours, straits, or canals. With the emergence of e-Navigation—a concept promoted by the International Maritime Organization (IMO) to enhance marine navigation through harmonized data exchange and integrated systems—maritime pilots face several new challenges:

1. Integration of New Technologies:
   - Challenge: Pilots must adapt to a wide range of new technologies, such as Electronic Chart Display and Information Systems (ECDIS), Automatic Identification Systems (AIS), and advanced decision-support tools.
   - Impact: Some pilots may struggle with training gaps or inconsistent implementation across ships.
2. Interoperability and Standardization Issues:
   - Challenge: Different ships and systems may use varying standards and versions of electronic navigation tools.
   - Impact: Pilots must quickly adapt to unfamiliar systems during each new pilotage, increasing cognitive load and risk of error.
3. Data Overload and Situational Awareness:
   - Challenge: e-Navigation systems generate large volumes of real-time data.
   - Impact: Pilots may experience information overload, potentially distracting from core navigational duties and reducing situational awareness.
4. Cybersecurity Risks:
   - Challenge: Increased digital integration makes navigation systems vulnerable to cyberattacks.
   - Impact: Pilots must now consider the reliability and security of the data they depend on, which could be compromised or manipulated.
5. Human-Machine Interface (HMI) Complexity:
   - Challenge: Interfaces of navigation systems can be non-intuitive or vary between manufacturers.
   - Impact: A poor interface design can impair the pilot's ability to quickly interpret data and make decisions.
6. Challenge:
   - Over-reliance on digital systems may erode traditional seamanship and manual navigation skills.
   - Impact: In the event of system failure, pilots must still be able to navigate using conventional methods like paper charts, radar, or visual cues.
7. Limited Authority Over Ship Systems:
   - Challenge: Maritime pilots are temporary navigators on ships they do not control.
   - Impact: They may not be allowed or able to integrate or fully utilize e-Navigation tools, such as ship-specific ECDIS or route optimization software.
8. Training and Competency Gaps:
   - Challenge: Continuous updates to e-Navigation tools require ongoing education.
   - Impact: There may be inconsistent training standards for pilots globally, leading to a gap in technological proficiency.
9. Communication and Coordination:
   - Challenge: e-Navigation encourages increased information sharing between ships and shore-based authorities.
   - Impact: Pilots must coordinate not only with the ship's crew but also with port authorities, VTS (Vessel Traffic Services), and digital platforms, increasing complexity.
10. Legal and Liability Concerns:
    - Challenge: The use of automated or decision-support systems raises questions about legal responsibility during incidents.
    - Impact: Pilots may face uncertainties around accountability when relying on digital systems for navigational decisions.

## 6 CHALLENGES FOR MARITIME PILOTS IN AUTONOMOUS NAVIGATION

As the maritime industry moves toward increased automation and autonomy, maritime pilots—who traditionally play a critical role in navigating ships through congested or challenging waters—face several key challenges. These can be grouped into technical, operational, legal, and human-factor categories:

1. Redefinition of the Pilot's Role:
   - Loss of traditional function: Pilots may no longer board autonomous ships in the traditional way, reducing their hands-on navigational role.
   - Remote guidance limitations: Transitioning to remote piloting or supervisory roles may reduce their ability to assess real-time conditions and make fine-tuned decisions.
   - Skills shift: Pilots will need to acquire skills in monitoring AI systems, interpreting sensor data, and managing remote-control interfaces.
2. Communication & Coordination:
   - Human-machine interface (HMI): Ensuring intuitive and reliable interfaces for pilots to communicate with autonomous systems is complex.
   - Unclear authority: There may be ambiguity in command hierarchies between pilots, remote operators, and onboard autonomous systems.
   - Situational awareness: Without being physically onboard, pilots may struggle to maintain situational awareness, particularly in complex or dynamic environments.
3. Integration with Legacy Systems:
   - Mixed fleets: Pilots will need to manage navigation for both traditional manned ships and varying levels of autonomous vessels, complicating operations.
   - Port infrastructure: Ports may not be uniformly equipped to accommodate autonomous vessels, limiting pilot effectiveness
4. Safety and Liability:
   - Accountability issues: Legal frameworks for responsibility in case of accidents involving autonomous ships are still evolving.
   - Decision-making responsibility: Determining who is liable when an autonomous system makes a poor decision—pilot, shipowner, or software provider—remains unclear.
5. Training and Regulation:
   - Lack of standardized training: There is currently no global standard for training pilots in dealing with autonomous vessels.
   - Regulatory lag: International maritime regulations (IMO, SOLAS, etc.) have yet to fully adapt to the presence of autonomy in pilotage.
6. Cybersecurity and System Reliability:
   - Vulnerability to cyberattacks: Autonomous systems are exposed to hacking risks, which could impact pilot operations.
   - System failures: Pilots may face critical situations due to malfunctioning AI, sensor errors, or software bugs without sufficient override capabilities.
7. Ethical and Employment Impacts:
   - Job displacement concerns: Automation may reduce the demand for traditional pilotage services, raising concerns about employment and role relevance.
   - Human oversight ethics: Determining how much human oversight should be maintained, and under what circumstances intervention is necessary, poses ethical dilemmas.

## 7 COMPARISON: E-NAVIGATION VS. AUTONOMOUS NAVIGATION

It is not at all easy to compare e-navigation with autonomous navigation. We should take for consideration the following aspects: definition, purpose, automation level, human role, technologies used, communication focus, regulatory driver, stage of implementation

1. Definition
   e-Navigation: A strategy led by the IMO to enhance maritime navigation through the integration of modern digital technologies.
   Autonomous Navigation: The use of AI, sensors, and automation to allow ships to operate with minimal or no human intervention.
2. Purpose
   e-Navigation: Improve safety, security, and efficiency by supporting the decision-making of human operators.
   Autonomous Navigation: Replace or reduce human decision-making with automated systems for navigation and ship operations.
3. Automation Level
   e-Navigation: Low to moderate – supports human operators (e.g., electronic charts, integrated bridge systems).
   Autonomous Navigation: High – includes decision-making by AI, remote or fully autonomous ship operation.
4. Human Role
   e-Navigation: Humans are always in control; e-Navigation tools aid decision-making.
   Autonomous Navigation: Human role varies: from remote monitoring (remote-controlled ships) to fully autonomous (no crew).
5. Technologies Used
   e-Navigation: ECDIS, AIS, VTS, GNSS, digital reporting, integrated bridge systems.
   Autonomous Navigation: AI, machine learning, computer vision, LiDAR, radar fusion, autonomous control systems.
6. Communication Focus
   Enhancing data exchange between ships, shore, and other entities.
   Autonomous Navigation: Real-time data processing for autonomous decision-making and self-navigation.
7. Regulatory Driver
   e-Navigation: the IMO e-Navigation Strategy Implementation Plan (SIP).
   Autonomous Navigation: Ongoing IMO MASS (Maritime Autonomous Surface Ships) regulatory development.
8. Stage of Implementation
   e-Navigation: Widely implemented; adopted globally.
   Autonomous Navigation: Emerging field; in experimental, pilot, or limited deployment stages.

Table 1. Comparison: e-Navigation vs. Autonomous Navigation - Summary Table.

| Criteria | e-Navigation | Autonomous Navigation |
|---|---|---|
| Scope | Digitally enhanced navigation support | Fully or partially self-navigating ships |
| Human Operator | Central role | Minimal to no role (varies by autonomy level) |
| Main Goal | Safer, more efficient decision-making | Reduce/eliminate human control of navigation |

| Automation Level | Supportive | High/full autonomy |
|---|---|---|

### 7.1 *Challenges for Marine Pilots*

The following challenges for maritime pilots come to the fore:

- Loss of traditional roles: In fully autonomous environments,
- New skill requirements: Data interpretation, system oversight, remote piloting,
- Legal & liability issues: who is responsible in case of failure?
- Situational awareness: reduced access to "feel" of the ship,
- Communication gaps: between autonomous systems and human-operated ones.

Table 2. Challenges for Marine Pilots.

| | |
|---|---|
| Loss of traditional roles | In fully autonomous environments |
| New skill requirements: | Data interpretation, system oversight, remote piloting |
| Legal & liability issues: | Who is responsible in case of failure? |
| Situational awareness: | Reduced access to "feel" of the ship |
| Communication gaps: | Between autonomous systems and human-operated ones |

The following new opportunities are emerging for maritime pilots:

- Leading roles in remote piloting centers,
- Advisory roles in system design and safety protocols,
- Training and simulation experts,
- Hybrid operations: assisting in the transition period.

Milestones actions on the way forward:

- Continuous training and upskilling for marine pilots,
- Standardization and regulation by IMO and national authorities,
- Human-machine cooperation: balancing tech with human experience,
- Advocacy by pilot associations.

Surprising and difficult to accept conclusions for marine pilots:

- Navigation is evolving, but the role of pilots remains critical,
- e-Navigation supports pilots, Autonomous Navigation challenges their role,
- Pilots must adapt to remain relevant in future maritime operations.

And finally, the most important sentence: ***"Technology will not replace marine pilots, but pilots who use technology will replace those who don't."***

Some have proposed that potential risks could be eliminated by removing masters, pilots, and officers of the watch (OOWs) altogether, relying solely on advanced automation technologies. Such ideas partly stem from the ubiquity of technology in modern life, but more fundamentally, they reflect a misunderstanding of the critical role marine pilots play and the limitations of technology.

During my nearly half-century as a marine navigator—and as an expert in maritime navigation and safety at sea—I have witnessed dramatic changes in maritime technology. These advances have profoundly altered the roles of both masters and pilots. Whereas entire sea passages were once navigated manually, today technology is used for most of the planned route, with manual navigation reserved primarily for port approaches, mooring, collision-avoidance situations, and complex manoeuvres such as turning.

What many outside the industry do not realize is that masters and pilots are always actively navigating the vessel. They are the ones who make all decisions regarding the voyage, including route selection and numerous other operational choices. Even when technology is used to manipulate controls, the vessel is continuously navigated in the minds of the masters and pilots.

Technology undoubtedly offers strengths: it can monitor conditions consistently over extended periods and is indispensable for tasks such as cargo and stability control. However, despite its ever-improving reliability, anyone who believes technology cannot fail at the most inopportune moment has likely never experienced a computer malfunction. Technology is inherently limited to performing functions that have been anticipated and programmed. There is, therefore, no substitute for human capabilities—particularly the ability to adapt and innovate in unforeseen circumstances.

## 8 CONCLUSIONS

The most important question still remains: e-navigation or autonomous navigation? We know already, they're not the same. e-navigation aims to unify information presentation, while autonomous navigation aims to completely eliminate the navigator's role on a navigational vessel. So who would benefit from unified bridge screens if, ultimately, there's no one there? What's the point of this work? Perhaps we should focus on the main goal of autonomous navigation right away? Well, that might be too risky, so let's do it step by step, first unifying within e-navigation concept, and then slowly but surely phasing out the benefits of e-navigation in favour of autonomous navigation. Yes, this can ultimately bring success, but it requires patience and time.

This decision, whether e-Navigation or Autonomous Navigation, should be made as soon as possible, but without undue haste, leaving a long *vacatio legis*. Let us remember that the design and construction cycle of a ship does not last a month or two. It's a process that takes about three years, and considering the need for a complete change in shipowners philosophy and policies, even up to ten years.

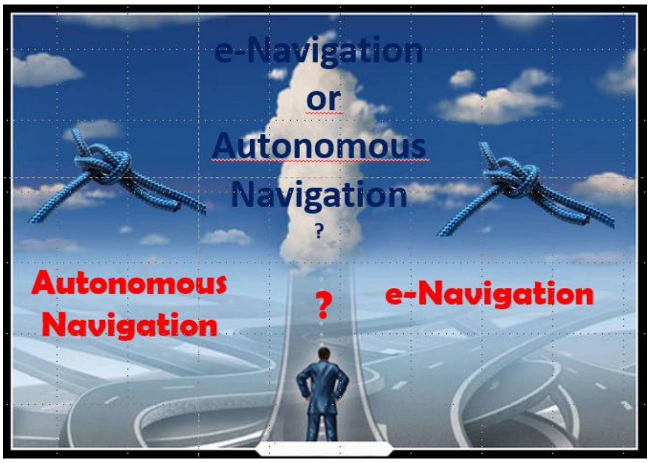


Figure 16. The most important question: e-Navigation or Autonomous Navigation?

This paper is intended for professionals and stakeholders engaged in, researching, or interested in the shipping industry, the broader maritime sector, and the development of autonomous shipping. The target audience includes regulators, educators, researchers, engineers, manufacturers, and seafarers, particularly master mariners, officers of the watch, and marine pilots.

## ACKNOWLEDGMENT

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## ABBREVIATIONS

| | |
|---|---|
| AI | Artificial Intelligence |
| AIS | Automatic Identification System |
| ECDIS | Electronic Chart Display and Information System |
| GNSS | Global Navigation Satellite System |
| HMI | Human-Machine Interface |
| IBS | Integrated Bridge System |
| IMO | International Maritime Organization |
| INS | Integrated navigation System |
| ITS | Intelligent Transportation System |
| LNG | Liquefied Natural Gas |
| MASS | Maritime Autonomous Surface Ships |
| OOW | Officer of the Watch |
| PMIS | Port Management Information Systems |
| PNT | Positioning, Navigation and Timing |
| PPU | Portable Pilot Unit |
| SOLAS | Safety of Life at Sea Convention |
| VTS | Vessel Traffic Service |

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