GenAI in Bridge's Ship Operation

Nikitas Nikitakos [(1)], Dimitrios Papachristos [(2)], Sofia Kallou [(3)]

(1) Professor, Department of Shipping Trade and Transport, University of the Aegean, Chios, Greece

(2) Postdoc fellow, Department of Port Management and Shipping, National and Kapodistrian University of Athens, Athens, Greece

(3) Researcher, Department of Tourism Management, University of West of Attica, Athens, Greece

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ABSTRACT: Generative artificial intelligence (GenAI) tools are an emerging class of new-age artificial intelligence algorithms capable of producing novel content — in varied formats such as text, audio, video, pictures, and code — based on user prompts. This key technology has demonstrated remarkable flexibility in analysing and structuring data and text into accessible information, vital for integrating humans, data, and systems. This paper presents its applications in the management of the ship's bridge, revealing the great potential of this new technology and the great potential for improving the operations and resource management of the bridge. It is a theoretical - bibliographical study of the subject of GenAI with a focus on the shipping industry and especially in Ship's Bridge Operation. It was found that the development of GenAI is rapid, and there are many areas of application in shipping and ship's bridge management. It provides greater flexibility, reliability and reduces the workload of Officers. However, not enough commercial applications were found, indicating that there is a large scope for future development.

2. INTRODUCTION

Artificial Intelligence (AI) is considered one of the newest scientific disciplines. It was first introduced in the 1950s, where a debate among scientists began, led by A. Turing. AI is a key branch of computer science concerned with the design and development of intelligent machines capable of performing tasks that could normally be performed solely by human intelligence as mentioned in [1].

AI systems either exploit symbolic rules or learn a numerical model and/or adapt their behaviour by analysing how the environment reacts to their previous actions. As a scientific field, it encompasses various approaches and techniques, such as machine learning, deep learning, machine reasoning and robotics as noted in [2].

Historically, AI was first formulated at Dartmouth College in 1956, at a conference of researchers from the fields of Mathematics, Electronics and Psychology to study the possibilities of using computers to simulate human intelligence. However, the term first appeared in a study by A. Turing (1912-1954), where he posed the question: "Can machines think?". Although his question cannot yet be answered with certainty, the investigation is continuing. Turing then defined a test (1950), in [3], which is a mimicry game, which went down in the history of computing as the Turing test. In 1950, in his paper entitled "Computing Machinery and Intelligence" he notes that by the year 2000 there will be machines so intelligent that the probability that an interrogator will make the mistake of mistaking an answer as coming from a natural person, when in fact it comes from a machine, will be over 30% as mentioned in [2].

In [2] the historical origins of AI are linked to the "syllogisms" of Aristotle (384-322 BC), which offered various models of expressions that always gave correct conclusions, based on correct hypotheses (classical Aristotelian syllogism). After the Renaissance, the first important moments were in 1854, when G. Boole laid the foundations of propositional logic, and in 1879, when G. Frege proposed a system of automated reasoning, laying the foundations of predicate calculus. Today, AI has been significantly advanced through advances in the fields of machine and deep learning, and neural networks.

Artificial Intelligence (AI) is poised to revolutionise the shipping sector, promising increased efficiency, safety, and environmental sustainability. however, as with any transformative technology, the integration of AI into shipping presents a complex array of benefits and challenges. AI technologies are increasingly being applied to the shipping industry to advance its development. Today, the global research community is looking for innovative methods in the field of AI technology, constantly exploring new research directions to improve the level of intelligence in all sectors of the economy and market. In particular, machine learning and deep learning are currently at the core of developments in artificial intelligence along with generative AI, as mentioned in [5]. Specifically, the machine learning and deep learning methods continue to mature, they are increasingly being utilized in the shipping industry.

Shipping navigation can be seen as a complex socio-technical system. It involving automation systems which are capable of sensing, producing and storing big data. According to [5], increasing automation solutions in turn pose challenges to navigators' situation awareness and workload. For all that, in this paper the new trend in AI technology and its possible applications in the management of the ship's bridge is presented. It is a theoretical - bibliographical study of the subject of GenAI with a focus on the shipping industry and especially in Ship's Bridge Operation. It provides greater flexibility, reliability and reduces the workload of Officers in Bridge.

3. METHODOLOGY APPROACH

This paper is based on a literature analysis of sources & material. The analysis followed the procedure:

- Use of the internet (official websites, international databases, search engines, i.e. Scholar, Scopus).
- Introduction of key words/phrases in English (GenAI and shipping, GenAI and Bridge operation, GenAI and ship bridge's personnel).
- Selection of articles, reports, studies, texts according to their relevance to: GenAI application in ship's bridge operations.
- Editing focusing on: conclusions, key points, theoretical concepts, technologies, applications in trial (TRL5/6) or full commercial use (TRL 7/8).
- Synthesis, extrapolation of conclusions.

The time of collection and analysis was October & November 2024.

4. GENERATIVE ARTIFICIAL INTELLIGENCE (GEN-AI)

Generative AI (GenAI) has invaded the consciousness of the public in late 2022 with the widespread availability of ChatGPT, the which became the fastest growing application in history. With the ability to mimic human abilities to produce text, images, video, music and code. Many people now use GenAI in their daily lives and the possibilities of adapting the models to applications to domain-specific AI applications seem limitless.

GenAI is an artificial intelligence (AI) technology that automatically generates content in response to prompts written in natural language chat environments. GenAI is actually producing new content. Content can appear in formats that include all symbolic representations of human thought: natural language text, images (including photographs, digital panels and animations), video, music and software code.

GenAI is trained using data that collected from websites, social media chats and other online media. It creates its content by statistically analyzing the distributions of words, pixels or other elements in the data it has ingested and by identifying and repeating common patterns (for example, which words usually follow which other words).

While GenAI can produce new content, it cannot produce new ideas or solutions to real-world challenges, as it does not understand real-world objects or the social relations that underlie language. Furthermore, despite its fluent and impressive output, GenAI cannot be relied upon for its accuracy.

GenAI's technological background is based on machine learning (ML), which uses algorithms to continuously and automatically improve its performance from data. ML algorithms are "trained" to find patterns and features in vast amounts of data in order to identify those patterns and make decisions and predictions with minimal human intervention based on new data as mentioned in [6]. The better the algorithm, the more accurate the decisions and predictions will become as it processes more data. The ML process includes the following features [6]: (a) execution in sequential steps, (b) human feature extraction, (c) automatic classification, and (d) operating with less data.

The type of ML (which has led to many of the advances in AI that we have seen in recent years such as the use of AI for facial recognition) is referred to as Artificial neural networks (ANNs). Artificial Neural networks (ANNs) have evolved with the increase in computing power with distributed computing frameworks. They are circuits of interconnected neurons whose goal is to solve a computational problem. The neurons are the building blocks of the network. There are three types of neurons: input neurons, output neurons and computational hidden neurons, as described in [7].

ANNs are inspired by the way the human brain works and help solve some very complex problems that cannot be solved by traditional mathematical models, as mentioneded in [8]. According to [9], neural networks have been shown to be very promising systems in many prediction and classification applications due to their ability to learn from data. The researchers found a direct correlation between the amount and level of connectivity between neurons and intelligence in different species that exchange input data with each other. Machine learning adapted this process and led to the development of artificial neural networks (ANNs), which can solve more complex problems, such as image recognition.

Neural networks can learn from huge amounts of data and take advantage of big data (images, text, transactions and social media data), creating models that perform better and better depending on the data stream they are fed with. Large companies such as Google, Facebook, Microsoft and IBM have been focusing on their development since early 2010, as noted in [10].

In [11], the GenAI refers to artificial intelligence systems with the ability to generate text, images or other forms of media through the use of generative models. These models gain an understanding of the patterns and structures within their training data, then generate new data with similar characteristics. GenAI includes several types, each of which is tailored for specific tasks or forms of media creation. Below are some of the most common types:

(1) *Generative Adversarial Network (GAN)* is a class of machine learning framework and a prominent framework for the GenAI approach. Moreover, the architecture it offers is quite unique from conventional deep neural networks. It consists of two main elements called Generator and Discriminator as noted in [12]. The overall system is based on the dynamics of the zero-sum game, the winner will remain unchanged and the loser's model each time it has

to modify its parameters, it will continue to do so until the discriminator is unable to detect whether the output of the generator is false or not as mentioneded in [13]. During the early stages of development, GAN-based models faced significant challenges in their training process.

(2) *Transformers,* further Generative AI techniques called Transformers were introduced by Vaswani *et al.,* [14]. This innovative architecture has been the focal point for a variety of work, including machine translation and language generation, and continues to drive the evolution of neural networks.

(3) *Variational Autoencoders (VAEs)*, introduced by Kingma *et al.,* [15]. It consists of an encoder and a decoder. The purpose of first element is to encode the given input in a lower dimension called latent space and the second element decodes that latent output into its original input shape. This provides a structured way of learning meaningful representations of the data and then generating new samples from this data distribution.

(4) The Diffusion Models have been designed to improve the performance of the Simple GAN, introduced by Salimans *et al.,* [16]. This is a type of generative model that aims to learn complex probability distributions by transforming a simple base distribution into the target distribution through a series of reversible transformations.

Finally, both text and image GenAI technologies are based on a set of AI technologies that have been available to researchers for several years. ChatGPT, for example, uses a generative pre-trained transformer (GPT), while image GenAI typically uses so-called generative adversarial networks (GANs). In particular:

(1) *GenAI in Image Translation*. It is becoming a rapidly growing technology, particularly within the realm of medical applications. This innovation holds remarkable potential, not only in terms of cost-saving implications related to equipment usage but also in the facilitation of informed medical decisions. The performance of generative AI models, particularly in the subfield of image translation, is typically assessed using specialized datasets. Among these, two notable datasets stand out: ImageNet [17], ClebA [18].

(2) *Generative AI for Video Synthesis and Generation.* Generative AI has transformative applications in video and animation, leading to the creation of visually stunning and dynamic content.

(3) *Generative AI for Natural Language Processing.* Gen AI models have demonstrated remarkable achievements across a spectrum of Natural Language Processing (NL) procedures. Such applications are language comprehension, logical reasoning, and text generation.

The following table (see Tab.1) illustrates Techniques used in generative artificial intelligence (GenAI):

Table 1. Techniques used in generative artificial intelligence (GenAI)

ML	A type of AI that uses data to automatically improve its performance	
ANN	A type of ML that is inspired by the structure and function of the human brain	
	General-purpose Transformers	A type of ANN that is capable of focusing on different parts of data to determine how they are related to each other
GenAI in Text	Large Language Models - LLM	A type of general-purpose transformer trained on Big data (Corpus)
	Generative pre-trained	A type of LLM that has been pre-trained on even larger amounts of data, which allows the model to capture the nuances of language

	transformers - GPT	and produce coherent text with context-awareness
GenAI in Image	GAN	Types of neural networks used to create images
	VAE	

5. BRIDGE'S SHIP OPERATION AND RESOURCES

Bridge of the ship or navigation bridge is the highest point or deck of the ship. It is essentially an elevated structure from which the command and control of the ship is carried out. Thanks to advances in technology, the bridge of a modern ship is now similar to the cockpit of an aeroplane. It is now a fully automated workplace in which the safety and performance of the ship is influenced by the skills and abilities of the Officer of the Watch (OoW), particularly his perceptive ability to analyse the data provided by the modern bridge systems in order to take optimal decisions on a case-by-case basis for the ship and crew. Thanks to technology, he is provided by information systems with a wealth of information in graphical (diagrammatic) or numerical form for better processing. The consequent increase in the volume of data and the technological power that accompanies this increase has led to an urgent need for faster information flow and more sophisticated process management aids.

Bridge Resource Management (BRM) can be a vessel's greatest strength or its weakest point, depending on how effective it is. Effective BRM helps a bridge team anticipate and respond correctly to their ship's changing situation. Successful management and utilisation of all available resources, human and technical, ensures the safe completion of the voyage. On the contrary, non-effective BRM can lead to loss of situational awareness. Thus, successful BRM focuses on team building, responsible challenge and response, closed loop communication, leadership and decision-making skills to help avoid these errors, like as inadequate monitoring, failure to set priorities, failure to assign responsibilities etc., as noted in [19] & [20].

Human resources are a key component of any organisation, or business unit. Thus, in the case of ship's bridge, for the effectiveness of the ship's bridge team, there are the following factors, as mentioned in [20] & [21]:

(1) *Organization characteristics*. It refers to the structure, culture, leadership, resources and technology, of the officers and other bridge employees, who follow the IMO regulatory framework (prison regulations) and the corresponding technology (compass, GPS etc.).
(2) *Task design and content*. There is a defined scope of work by discipline and officer.
(3) *Team characteristics*. Team structure, experience, skill level.
(4) *Team behaviour and functioning*. It depends mainly on the regulatory framework and the necessary skills and technology, while at the leadership level, the Bridge Officer and the Master have a dominant role.
(5) *Team effectiveness*. It concerns the successful completion of the trip with the necessary safety.

Overall, the roles of the bridge team members are not easy to define within a narrow framework, as they are influenced by the abilities/skills and personalities of the individuals involved. The most important element is that each team member has an understanding of his/her role and the roles of the other team members. The Master of the ship has a central role in the management of the bridge. The Master is the person who controls the movement of the ship in accordance with the applicable regulations and the recommended measures per area (traffic schemes), and regulates the course and speed and has the supervision for safe navigation combined with the keeping of watches.

Finally, the role of each member of the bridge team (except the Captain) can be summarised as follows:

(1) *Watch Officer*: He has the responsibility for safe navigation, along with keeping the Master informed, receiving his assurance that his reports have been understood. He/she supervises the helmsman, checks orders to the engine room, is responsible for coordinating communications while recording the log and carrying out any orders from the Master.
(2) *Look out Helmsman*: observation of the surrounding area - coxswaining.
(3) *Backup Officer*: support the Master (Captain) by providing information from the instruments and using the communication systems.

In addition, mental workload is associated with tasks related to information processing and any human activity that has some mental processing as its substrate. In shipping, an example of this could be the task of a navigator to pass a ship through a canal. The navigator should constantly monitor the passage of the vessel, observing both sides of the canal to avoid a side collision. The navigator could be more efficient, provided he reduced his mental load. Achieving this minimization of mental load is critical (particularly in ship's bridge management), since it is considered a key objective for the successful design of a ship's bridge resource management system. Therefore, the designer of such systems should be familiar with the principles of workload, and what constitutes an appropriate or optimal workload.

An example of mental task execution, combined with the flow of information between the Captain, Lieutenant Commander, Officer of the Watch and Helmsman, in the form of time milestones is shown in the following figure (as mentioned in [22]):

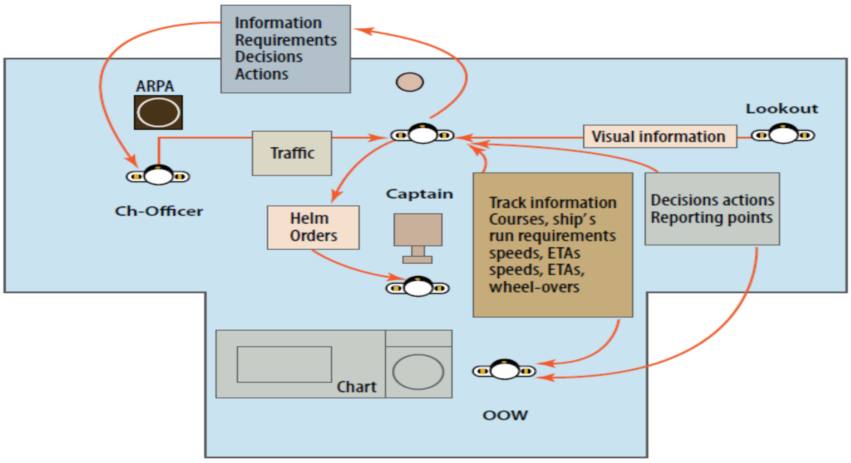

Figure 1: Diagrammatic representation of information flow on the bridge, waiting for a navigator to board [22]

6. GEN-AI APPLICATIONS IN SHIP'S BRIDGE

The shipping is a multifaceted sector. The shipping industry strives for ever more efficiency. For example, in 2024 the biggest Ships (i.e. *MSC Irina*, *OOCL Spain, One Innovation*) can each carry more than 24.000 container units per voyage. In addition, modern cruise ships continue to grow in size. Also, smart (or AI) shipping Tools for real-time tracking of the route, fuel consumption, trim, etc. are already used by 77% of shipping companies. AI technology can contribute to more sustainability above the water and in the ports. Also, it can deliver solutions to tackle staff shortage.

According to [23], in an analysis of 192 marine incidents by the Transportation Safety Board of

Canada (TSB) between 1998-2018, interface design as well as non-standard system layout was found to significantly influence the accidents that occurred. As a consequence of technological advances, the role of marine navigators is shifting from monitoring and planning to surveillance, with implementation in many cases now being carried out by automated or intelligent systems, as mentioned in [24].

According to [25] Bridge systems have an increased ability to integrate information, although the integration may not fully meet the requirements of the new role. Prior studies suggest that navigators can involve themselves into integration work as mentioned in [26]. In order to design future human-centric bridge systems, it is important to understand the underlying challenges of Human-Machine Interaction (HMI) on ship bridges, as well as the specific requirements and limitations of users and technology in the context of navigation, as noted in [5].

As well as everything else needed to support the ship's bridge team in performing their tasks reliably, safely and accurately. According to [5], the most important factors that will affect the work on the bridge of the ship are (see Fig.2):

(1) *Integrating Synthesizing and Prediction in a Dynamic Environment*. For example, An obvious interaction challenge on ships was found in dynamic environments where there are many ships in close proximity to each other. In these situations, the OOW must monitor the actions of vessels in the vicinity of his ship, anticipate the evolution of the situation based on various information, as well as his experience and navigation regulations, so that there is no collision or other safety hazard. This situation may require a high level of cognitive resources such as mental effort and attention from OOW in ship's bridge.

(2) *Distractive Work Environment with Fragmented Information and Controls*. Alarms can be an important source of information for Bridge officers (i.e. OOW), but they are also distractive by nature. In addition to the distracting alarm issues, the bridge has a need for interoperability. The tendency for large loads of information but increasingly dispersed and fragmented was found in related studies. The ship's bridge environment has many systems and equipment from different manufacturers that provide individual pieces of information related to the operation of the ship.

(3) *Trust Issues*. Trust issues are a difficult issue for ship's bridges, leading to reduced use or dependence on certain systems. During mooring, a captain was observed verbally communicating with another deck officer to confirm the distance from the correct berthing position. When asked if an automation system could replace this task, he expressed fears of possible failure of the machine at some point although the probability may be small. These trust related phenomenon are commonly seen in the maritime industry.

(4) *Usability Issues*. In related research, they showed that bridge officers have difficulty using bridge systems usually due to various usability issues. In general, it has been found that systems on the bridge of ships lack a high level of interaction

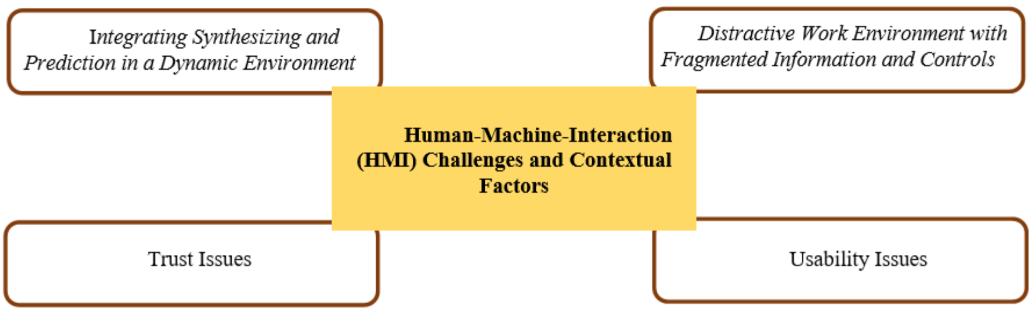

Figure 2: HMI Challenges & Contextual Factors

In the case of GenAI there are three major areas of application in resource management on the ship's bridge:

(1) *Ship's Bridge documents management:* Intelligent Document Processing (IDP) (by using ChatGT & LLM) can automate the processing of various ship's Bridge related documents such as records, packing lists, and delivery details etc. GPT extracts of key data, enables efficient document organization and retrieval, and enhances visibility and control on overall shipping operations (see Fig.3). Specifically, IDP is a technological solution that automates the processing of documents using Optical Character Recognition (OCR), GenAI and ML techniques. Using NLP and machine learning techniques, it can extract user-defined data or information sets or information to process them from unstructured, semi-structured and structured documents and digitise them for further analysis and storage. NLP also helps to understand the context and semantics of the extracted data, resolving ambiguities and validating information against the context within the document. LLMs have advanced NL capabilities, enabling them to understand the content of unstructured documents. GPT models excel at extracting relevant data & information by recognizing entities and key data points, allowing accurate, reliable and efficient data extraction. In addition, GPT models aid in document classification, sorting documents based on their content and structure, streamlining document handling processes in IDP systems [27].

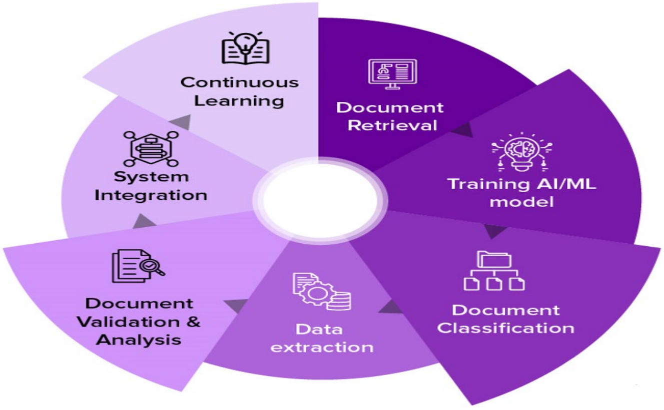

Figure 3: IDP process (https://www.bridgenext.com/blog/transforming-logistics-how-generative-ai-gpt-augments-intelligent-document-processing/)

(2) *Decision-making support (DMS)*. For example, an application of DMS in ship's bridge operation is GenAI, OpenText^{TM} Operations Bridge. It offers two powerful new capabilities:

- *Event-driven remediation suggestions.* When a deck officer or OOW encounter an event in the Operations Bridge event console, this software tool can intelligently analyze the context and suggest remediation steps (DMS process). The officer receives actionable recommendations to help him resolve issues quickly, reliable and efficiently.
- *Intelligent documentation querying.* The ship's bridge officer can ask a question about a situation on the bridge, and the tool will search its documentation repository, extracting information and providing comprehensive answers to help make decisions.

Now GenAI (by using LLM, Machine learning / deep learning) can bring new capabilities to existing causal and predictive AI capabilities, expanding the capabilities of a ship's bridge officer, but also improving the performance of the team.

(3) *Training with Bridge's Simulators by using GenAI.* The advent of AI and Machine / Deep learning has provided sophisticated functions for fusing sensors and object detection and classification that have accelerated the development of highly automated and autonomous ships as well as decision support systems for shipping navigation. However, it is difficult to assess how the implementation of these systems affects the safety of ship operation. Using GenAI, marine training simulators can be folded to conduct controlled, repeatable experiments that allow us to compare and evaluate functionality for new systems on the ship's bridge. Navigation and decision support affect navigation performance and safety. On other hand, although shipping training simulators are realistic for human navigators, it cannot be assumed that simulators are realistic enough for object detection and classification functionality and, therefore, the use of GenAI in image processing in naval bridge simulators would help in this direction. One such example, in [28], the authors proposed the using Cycle-Consistent Adversarial Networks (Cycle-GANs) to transform the simulator data before detecting and classifying objects. Once an object is detected and classification is completed, the result is transferred back to the simulator environment. Based on this result, decision support functionality is increased with realistic accuracy and robustness.

7. DISCUSSIONS AND CONCLUSIONS

AI algorithms and technologies are increasingly being applied to the shipping sector to advance its development. Generative artificial intelligence (GenAI), in turn, has a myriad of possible uses. It can automate the processing of information and presentation of results in all the basic symbolic representations of human thought. Enables the delivery of final results by providing incomplete knowledge products. Frees people from certain categories of lower-level thinking skills.

This new generation of AI tools can have a profound impact on shipping and in particular on the management of operations and resources on the bridge. It can help in several areas of engagement for bridge workers on the bridge of the ship, support indecisive decisions and also better train them. Specifically:

(1) Ship's Bridge documents management;
(2) Decision-making support (DMS);
(3) Training with Bridge's Simulators by using GenAI.

In general, GenAI has significant advantages. For example, the benefits of the autonomous shipping it can offer are multiple. First, AI navigation systems have the ability to optimise routes at sea more efficiently than human operators, as they can factor in real-time parameters such as weather conditions, sea states and traffic congestion on shipping routes. This optimisation results in reduced fuel consumption and a low level of emissions. This contributes to the adoption of green shipping. Secondly, autonomous vessels can operate continuously as they are crewless, which improves operational efficiency and reduces transit times during voyages. In addition, its application to autonomous systems enhances safety by minimising human error, which is the main cause of maritime accidents. Advanced Gen AI algorithms can detect and respond to potential hazards faster and more reliably than human operators. This capability is considered critical to avoiding collisions, and other incidents that can cause significant environmental damage [28].

Gen AI has a major impact on logistics and supply chain management within the maritime industry, and in particular, on the ship's bridge, because it is a sector from where cargo management on the ship takes place. It is driving in significant improvements in efficiency and sustainability. Gen AI algorithms can analyze vast datasets from various sources (Big Data Analytics), including shipping schedules, cargo volumes, and port traffic, to optimize logistics operations and supply chain workflows. Also, with the support of Starlink, there is cross-communication between the Gen AI tools and they can thus carry out analyses of large volumes of data on a regular basis [29].

However, Gen AI tools differ due to some of their characteristics, and their interface, and the specific training algorithms used by each of them are also different. There are also slight differences in their strengths and weaknesses. Table 2 provides a summary of the comparison of Gen AI tools [30].

Table 2. Comparing the Different Generative AI Tools (evaluating advantages vs. disadvantages)

	Description	Advantages - Disadvantages	Capability for Ship's Bridge Operations
ChatGPT	GPT-3.5 GPT-4. 0(can used in the paid version) Supervised, Reinforced Learning from Human Feedback Proximal Policy Optimization	• It can generate highly human-like responses& be fine-tuned for specific tasks. • handle input sequences of variable length • needs large amounts of pretraining data and can be computationally expensive.	• It can be widely used on the ship's bridge and in autonomous navigation for decision support Score : 4.5/5
Perplexity	Deep learning, Undisclosed to the public	• It sites the sources it uses to provide answers to questions. • Produces a very concise and unambiguous response • Not always accurate and input text must be very clear (not ambiguity)	• It can be used on the ship's bridge and in autonomous navigation for decision support Score : 3.5/5
YouChat	Deep learning, Undisclosed to the public	• Easy to use and deploy and can be customized • It sometimes displays irrelevant links • It is in its beta stage	• It can be used on the ship's bridge and in autonomous navigation for decision support Score : 3/5
Chatsonic	Deep learning, Undisclosed to the public	• Offers several advanced AI capabilities • Can generate images from text • Only available in English • The free version limits users to 10000 words (up limit)	• It can be used on the ship's bridge and in autonomous navigation for decision support Score : 3/5
Microsoft Bing Chat	Supervised learning Backpropagation	• Responses have a high degree of accuracy. • It cites sources for its responses. • It can generate images. • You can only generate 30 responses per session. • Slightly slower response time/	• It can be used on the ship's bridge and in autonomous navigation for decision support Score : 3/5

Finally, it was found that the development of GenAI is rapid, and there are many areas of application in shipping and ship's bridge management. It provides greater flexibility, reliability and reduces the workload of Officers. However, not enough commercial applications were found, indicating that there is a large scope for future development.

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