California Review Management

INTERNATIONAL BUSINESS

# Utilizing AI for Maritime Transport Optimization

by Ryan Pannell and J. Mark Munoz

Image Credit | YarM

*The maritime transport industry plays a key role in global trade, and AI advancements are bound to boost performance.*

INSIGHT | FRONTIER 19 Dec 2024

# Introduction

While the automobile industry is no stranger to Artificial Intelligence (AI), with 80% of global trade transported by maritime shipping, application of AI (both predictive and generative) in the maritime space is relatively new. In 2021, over 850 million twenty-foot equivalent units were transported worldwide (UNCTAD, 2023) making the industry an important contributor to global business. The marine economy contributes to nearly 2% of the US GDP leading to over $700 billion in sales and impacting 2.4 million jobs (National Oceanic and Atmospheric Administration, 2024). Within this environment, emerging opportunities for the use of AI in areas such as fleet management, navigation, predictive maintenance, and environmental monitoring can potentially transform the industry in significant ways.

RELATED CMR ARTICLES

Konstantin Hopf, Oliver Müller, Arisa Shollo, and Tiemo Thiess, **"Organizational Implementation of AI: Craft and Mechanical Work,"** 66/1 (Fall 2023): 23-47.

Vegard Kolbjørnsrud, **"Designing the Intelligent Organization: Six Principles for Human-AI Collaboration,"** 66/2 (Winter 2024): 44-64.

# New Horizons

Changes in the maritime industry can open pathways to productivity enhancements (Tenold, 2019). Currently, technological enhancements and AI-driven innovation are unfolding in seven (7) important areas in the maritime transport industry:

**1. Autonomous Ships and Navigation Systems**

- **Autonomous Vessels:** The industry is exploring and testing fully autonomous ships, which rely on AI for navigation, obstacle detection, route optimization, and decision-making in real-time. While most vessels still require human oversight, some companies, like Rolls-Royce and Wärtsilä, have developed autonomous systems capable of short, uncrewed voyages. These systems rely on sensors, LIDAR, radar, and satellite data to create a virtual environment and enable autonomous navigation.
- **Dynamic Route Optimization:** AI helps optimize routes based on weather, sea conditions, fuel efficiency, and other real-time factors. This optimization can significantly reduce fuel consumption, transit time, and greenhouse gas emissions. Companies like Wärtsilä's Eniram use AI-powered software to recommend optimal routes.
- **Collision Avoidance Systems:** AI-based collision avoidance systems analyze radar and AIS (Automatic Identification System) data to predict potential hazards and recommend maneuvers. These systems, developed by firms like Kongsberg, assist human crews by providing an added layer of safety.
- **AI-Driven Operational Dashboards:** Many operators now use AI-integrated dashboards that offer real-time insights into various aspects of vessel performance, including fuel usage, emissions, crew efficiency, and route management. These dashboards help decision-makers make more informed choices and quickly adapt to changing conditions.

**2. Predictive Maintenance and Equipment Monitoring**

- **Condition Monitoring:** AI-driven predictive maintenance solutions are increasingly popular for monitoring the health of critical equipment onboard, such as engines, pumps, and generators. By analyzing sensor data, AI can detect early signs of wear or failure, allowing for proactive repairs and minimizing unexpected breakdowns. This leads to significant cost savings and enhances fleet availability.
- **Machine Learning Models for Failure Prediction:** Machine learning models trained on historical data are used to predict equipment failures before they happen. These models factor in variables like vibration, temperature, and pressure to assess component health and recommend maintenance schedules. Companies like Rolls-Royce and Maersk employ these AI models in their fleet management systems.
- **Remote Diagnostics and Monitoring:** AI-driven remote monitoring systems enable shore-based teams to keep an eye on a vessel's health by providing real-time data from onboard sensors. This allows for proactive decision-making and faster responses to maintenance needs. Companies such as ABB have developed platforms that provide real-time diagnostics, which have been especially useful for managing fleets with reduced onboard personnel.

**3. Risk Management**

- **Risk Assessment and Incident Prediction:** AI is used to assess operational risks by analyzing historical incidents and near-miss data. This helps companies identify high-risk scenarios and implement preventive measures to improve safety and reliability across their fleets.

**4. Fuel Efficiency and Emissions Reduction**

- **Energy Optimization Systems:** AI algorithms optimize energy usage across various ship functions, including propulsion, lighting, and HVAC (heating, ventilation, and air conditioning). By continuously analyzing operational data, these systems reduce fuel consumption, which in turn lowers emissions. The Eniram platform, for example, monitors energy efficiency and suggests adjustments to minimize fuel usage.

**5. Port Operations and Logistics Optimization**

- **Port Traffic Management:** AI is transforming port logistics through predictive models that manage the inflow and outflow of vessels. By forecasting arrival times and berthing schedules, AI can minimize port congestion, reduce waiting times, and enable smoother transitions from sea to land transport.
- **Supply Chain and Inventory Management:** AI-driven solutions help ports and shipping companies optimize supply chains by predicting delays, managing inventory more accurately, and aligning port resources with incoming shipments. This ensures efficient cargo handling and reduces dwell time for goods at ports.

**6. Crew Management and Safety**

- **Safety Monitoring:** AI-based surveillance systems monitor crew behavior and work conditions to detect signs of fatigue or potential hazards, reducing the risk of accidents. Advanced AI-powered cameras can monitor compliance with safety protocols, such as wearing personal protective equipment (PPE).
- **Crew Training and Simulation:** AI-powered simulators are increasingly used to train crew members by mimicking real-life scenarios, such as adverse weather, equipment failure, and emergency protocols. This helps crews develop critical skills in a safe, controlled environment.

**7. Inspection and Quality Control**

- **Automated Inspections:** Drones equipped with AI-driven image recognition are used to inspect hard-to-reach areas of vessels, such as the hull or cargo holds. AI software analyzes these images to detect cracks, rust, or other forms of damage that require repair.
- **Quality Assurance in Shipbuilding:** AI is also used in shipyards for quality control during vessel construction, ensuring components meet specifications and detecting defects in materials, welding, and other critical areas.

These AI enhancements have boosted operational efficiencies in numerous ways and have set the stage for disruptive industry breakthroughs in the future.

## Rough Seas Ahead

The maritime industry has experienced highs and lows in past years (Stopford, 2009). This fluctuation in industry performance has impacted investments as well as operational approaches and the utilization of technology. While AI offers several improvement pathways in the maritime transport industry, there are challenges that have to be carefully navigated. These challenges include:

**1. Data Quality and Standardization Concerns** – the industry needs to be prepared for data fragmentation given that the maritime industry is a complex ecosystem with various stakeholders, such as vessel operators, port authorities, and logistics providers, each using different data systems and standards. This lack of uniformity makes it difficult to consolidate data, hindering AI's ability to analyze comprehensive datasets for accurate insights. In addition, data accuracy and completeness has to be taken into account. Sensors on vessels and port equipment can sometimes be inaccurate or have gaps in data collection, affecting the reliability of AI models. Poor-quality data impacts the accuracy of AI-driven decisions, such as maintenance predictions and navigation.

**2. Regulatory and Legal Challenges** – there is absence of clear regulations for autonomous ships. While autonomous shipping technology has advanced, regulations have not kept pace. International Maritime Organization (IMO) guidelines for autonomous vessels are still in development, and there is limited clarity around responsibilities and liabilities in case of incidents involving AI-driven vessels. Data privacy and security regulations have to be better managed. AI solutions often require real-time tracking and analysis of crew behavior, vessel movement, and operational data. Compliance with data privacy laws, such as GDPR in the EU, becomes challenging, especially when data crosses international borders.

**3. Cybersecurity Risks** – the industry is vulnerable to cyber attacks like other industries. As more AI-enabled systems become networked, ships and ports are increasingly vulnerable to cyber threats. A cyberattack on an AI-powered navigation or maintenance system can lead to severe operational disruptions and even accidents, raising concerns about the resilience of these systems. Also, the protection of AI models can be complex. AI systems, especially those relying on machine learning, can be compromised by malicious actors through attacks like data poisoning, where the training data is manipulated. This can result in flawed predictions and unsafe operations, highlighting the need for robust cybersecurity protocols tailored to AI.

**4. Operational Complexity and Reliability Issues** – there is complexity in the integration with existing systems. Many legacy systems on vessels are not built to support AI-driven applications, making it challenging to integrate modern technology into older fleets. This incompatibility can lead to high costs in upgrading or retrofitting existing equipment for AI compatibility. Furthermore, reliability of systems in unpredictable conditions is a cause of concern. AI models, particularly for navigation and maintenance, can struggle to handle highly unpredictable scenarios, such as severe weather or sudden equipment failures. These limitations necessitate human oversight, as fully autonomous operation remains unfeasible in complex, high-risk environments like open seas.

**5. High Initial Costs and Skill Gaps** – the implementation of AI architecture can be expensive. Developing and deploying AI systems in the maritime industry involves significant capital investment. This includes the cost of hardware, software, sensors, and maintenance, which can be prohibitive for smaller operators. Also, the lack of skilled personnel can derail projects and plans. The maritime industry faces a shortage of workers skilled in AI, data science, and cybersecurity. Effective implementation and maintenance of AI systems require specialized knowledge, and the industry is still building its talent pool to support these advanced technologies.

While these challenges are significant, careful planning and preparation can help address key areas of concern.

## Navigating Towards Success

The authors recommend five (5) approaches companies in the maritime industry can use to optimize AI utilization:

**1. Improve Data Quality and Standardization** – incorporating industry-wide data standards in business operations is key. This would help streamline data-sharing across the maritime ecosystem. Organizations such as the International Maritime Organization (IMO) and the Digital Container Shipping Association (DCSA) can play a role in setting these standards, making data more compatible and reliable for AI applications. There is benefit in pursuing data quality improvement initiatives. Regular sensor calibration, data cleaning protocols, and continuous monitoring of data integrity can help improve data accuracy. Investing in high-quality sensors and monitoring systems that can self-diagnose and report data issues can further enhance data reliability for AI-driven insights.

**2. Strengthen Regulatory and Legal Frameworks for AI and Autonomy** – there is benefit in accelerating regulatory development. Collaborations between regulatory bodies, maritime companies, and technology providers can expedite the creation of guidelines for AI and autonomous shipping. A framework for “levels of autonomy” (similar to the automotive industry) could help determine liability and responsibilities for different types of AI-assisted and autonomous operations. Furthermore, prioritizing data privacy and security compliance can have a positive impact. In order to address data privacy concerns, maritime companies can develop data anonymization and encryption protocols that comply with international regulations. In addition, having in place transparent data policies can reassure stakeholders that their data is handled responsibly and in compliance with privacy laws.

**3. Enhance Cybersecurity Protocols** – companies in the industry should adopt maritime cybersecurity standards. Adhering to standards like the International Maritime Organization's (IMO) Cyber Risk Management Guidelines can help mitigate cybersecurity risks. Maritime companies should adopt a "defense-in-depth" approach, implementing layers of security, including firewalls, intrusion detection systems, and endpoint security. AI-specific cybersecurity measures should be planned for. Protecting AI models against data manipulation requires unique protocols. Regular model training with updated, verified data can help defend against data poisoning. Conducting "red teaming" exercises, where cybersecurity experts attempt to exploit vulnerabilities in AI systems, can help identify and address potential weaknesses before malicious actors do.

**4. Plan for Operational Complexity and Reliability** – maritime companies should create hybrid AI-Human systems. Until fully autonomous vessels are viable, a hybrid approach where AI works alongside skilled human operators can be effective. For example, AI can handle repetitive or data-intensive tasks (such as route optimization), while humans oversee high-stakes decisions or intervene during anomalies. There is value in doing simulation and testing in diverse scenarios. AI models should be trained in simulations that cover diverse maritime conditions, from calm waters to extreme weather. High-fidelity simulators can help develop robust AI systems by exposing them to various challenges, allowing them to handle a broader range of conditions reliably.

**5. Reduce Costs and Bridge Skill Gaps** – companies in the industry would benefit from a phased AI implementation and cost-sharing approach. For cost-effective AI adoption, companies can start with smaller, more affordable pilot projects. Additionally, industry consortiums could facilitate cost-sharing for research and AI technology deployment, helping smaller companies access advanced tools and reducing individual investment costs. Furthermore, training and upskilling programs can make all the difference. Investment in specialized training programs is essential to build a workforce proficient in AI, data science, and maritime-specific technologies. Partnerships with academic institutions, online courses, and industry certifications in maritime AI can all help bridge the skill gap, ensuring there's a talent pool capable of supporting AI's growth in the sector.

A well-thought and holistic approach that considers the needs not just of the company but the entire ecosystem sets the foundation for sustainable and long-term success.

## Concluding thoughts

AI presents both challenges and opportunities for the maritime transport industry. With the right set of strategic actions, operational enhancement in predictive maintenance, fuel and route optimization, and real-time operational monitoring can be gained.

**1. Predictive Maintenance**: AI-driven predictive maintenance uses machine learning algorithms to analyze data from vessel sensors, monitoring equipment like engines, pumps, and generators. This allows operators to detect potential issues early, reducing unexpected failures and enabling timely repairs. The impact is significant: reduced maintenance costs, minimized downtime, and extended equipment lifespan, all of which contribute to smoother and more cost-effective operations.

**2. Fuel and Route Optimization**: AI-powered route optimization tools can recommend the most fuel-efficient routes by analyzing factors like weather patterns, ocean currents, and real-time fuel costs. Similarly, AI can adjust vessel speeds to minimize fuel consumption without compromising arrival times. This application directly benefits both operational budgets and environmental goals, as reduced fuel usage translates to lower greenhouse gas emissions and significant fuel savings.

**3. Real-Time Operational Monitoring**: AI-enabled dashboards aggregate data from various onboard sources to offer real-time insights into metrics such as fuel usage, crew efficiency, and vessel performance. By providing operators with a comprehensive, data-driven view, these systems support smarter, faster decision-making and allow crews to adapt quickly to changing conditions. The immediate impact includes improved operational efficiency, better resource allocation, and enhanced safety protocols.

A well thought and implemented AI strategic plan is poised to offer the maritime transport industry transformative operational benefits, from cost savings and improved efficiency to stronger compliance with environmental standards. It serves as a compass for the way ahead and a successful AI journey.

## References


National Oceanic and Atmospheric Administration (2024). US marine economy continues upward trand. Accessed Nov 8, 2024. Available at: **https://www.noaa.gov/news-release/us-marine-economy-continues-upward-trend**

Stopford, M. (2009) Maritime economics. New York: Routledge Press

Tenold, S. (2019) Norwegian shipping in the 20th century. London: Palgrave Macmillan.

UNCTAD (2023). Maritime transport indicators. Accessed Nov 6, 2024. Available at : **https://hbs.unctad.org/maritime-transport-indicators/**


---


Ryan Pannell Follow

Ryan Pannell is the CEO and Global Chair of Kaiju Worldwide, an ecosystem of technology research companies specializing in Predictive AI-based financial products. As a former asset manager with a background in cryptography, pattern recognition, and theoretical physics, Ryan believes that Predictive AI can transform industries for the benefit of investors and consumers.


J. Mark Munoz Follow

Dr. J. Mark Munoz is a tenured Full Professor of Management at Millikin University, and a former Visiting Fellow at the Kennedy School of Government at Harvard University. Aside from top-tier journal publications, he has authored/edited/co-edited more than 20 books such as: Global Business Intelligence and The AI Leader.