# ARTIFICIAL INTELLIGENCE AND GEOSPATIAL TECHNOLOGIES FOR SUSTAINABLE MARITIME LOGISTICS.

# CASE STUDY: PORT OF CONSTANTA, ROMANIA

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1. **ABSTRACT:** This study analyzes the potential impact of Artificial Intelligence (AI) and geospatial technologies on maritime logistics, into guiding the industry towards unprecedented operational efficiency, precision, and sustainability. It highlights the critical role these technologies play in optimizing maritime operations, including demand forecasting, route optimization, and enhancing operational visibility, thereby significantly boosting efficiency. With a focus on sustainability, the paper illustrates how AI and geospatial technologies contribute to emission reduction, energy efficiency, and the development of green infrastructure within ports, aligning with global sustainability objectives. By leveraging the analytical skills of AI alongside the detailed mapping capabilities of geospatial technologies, the research outlines a forward-looking approach to maritime logistics that not only addresses immediate operational benefits but also underscores a commitment to ethical and sustainable maritime practices. This integration marks a milestone in the maritime sector, redefining industry standards and paving the way for a more sustainable and efficient future in maritime logistics.

## 2. INTRODUCTION

In the rapidly evolving landscape of maritime infrastructure and logistics, the industry faces significant challenges in enhancing sustainability and resilience. These challenges include reducing greenhouse gas emissions, improving energy efficiency, and developing green infrastructure within ports and logistics networks (Sharma et al. 2022). Amid these challenges, Artificial Intelligence (AI) and geospatial technologies emerge as important tools (Gandhi et al. 2020), offering innovative solutions to optimize operations, reduce environmental impact, and foster sustainable development.

This article aims to explore the integration and application of these technologies within the maritime sector, highlighting their role in transforming ports and logistics into more efficient, sustainable systems. As ports serve as critical nodes in global supply chains, their transition towards greener practices is not only essential for environmental efforts but also for maintaining economic competitiveness (Fu et al. 2022). AI and geospatial technologies, with their capacity to analyze vast datasets and provide actionable insights, are at the lead of this transition, enabling smarter decision-making and resource management.

## 3. BACKGROUD

The evolution of AI and geospatial technologies in maritime applications has significantly transformed the industry, enhancing navigational precision, operational efficiency, and environmental sustainability. These advancements have the potential to facilitate the development of advanced route optimization algorithms and autonomous navigation systems, enabling vessels to navigate more safely and efficiently while minimizing their environmental impact. This technological progression underscores a shift towards more intelligent and sustainable maritime logistics practices(Raza et al. 2023).

The integration of AI and geospatial technologies has the potential to improve operational efficiency in maritime logistics. By optimizing route planning and automating navigation, these technologies reduce fuel consumption and voyage times, directly impacting cost savings and resource utilization (Scarlat, Ioanid, and Andrei 2023). Their application streamlines operations, enhances decision-making processes, and supports more agile responses to changing environmental and market conditions, demonstrating a profound impact on the maritime industry's operational dynamics.

AI and geospatial technologies offer significant potential in enhancing climate resilience in maritime operations through advanced navigation systems, enabling ships to avoid hazardous weather and optimize routes for safety and fuel efficiency (Farzadmehr, Carlan, and Vanelslander 2023). These technologies can also play a crucial role in risk management, providing predictive analytics that help in anticipating and mitigating potential disruptions caused by climate-related events. By AI's ability to process vast datasets, identifying potential threats and enabling proactive measures will result in safer, more reliable maritime operations, even in the face of increasing climate variability. Furthermore, environmental monitoring benefits from these innovations, as they allow for real-time tracking of emissions and the environmental impact of maritime activities, supporting efforts to reduce the carbon footprint resulted from shipping operations and contribute to global sustainability goals.

## 4. AI AND GEOSPATIAL TECHNOLOGIES IN SUSTAINABLE MARITIME OPERATIONS

In the contemporary global market, integrating AI and geospatial technologies might revolutionize maritime operations. This integration sets the conditions for a new era of operational efficiency, precision, and sustainability within the maritime sector (Aiello, Giallanza, and Mascarella 2020). The analytical effectiveness of AI, when paired with the detailed mapping capabilities of geospatial technologies, empowers organizations to effectively optimize maritime logistics and operations.

In maritime operations, AI and geospatial technologies can facilitate precision in demand forecasting, route optimization, and operational visibility, significantly enhancing efficiency (Guo, Li, and Huang 2023). These technologies are especially critical for maritime navigation, where they enable the deployment of autonomous navigation solutions, providing real-time, data-driven guidance for vessels navigating complex routes (Scarlat, Ioanid, and Andrei 2023).

An analysis of the capabilities of AI and geospatial technologies reveals that their application brings more than short term operational benefits, marking progress toward more sustainable and ethical maritime operations (Alsolbi et al. 2023). This shift is vital in a period where environmental sustainability is as crucial as operational efficiency, redefining industry standards for managing maritime logistics in a rapidly evolving global context.

### *4.1 AI and Geospatial Technologies in emission reduction*

AI plays a crucial role in enhancing port operations to significantly reduce emissions by optimizing logistics and operational workflows. Such workflow optimization is depicted in Figure 1. Simultaneously, geospatial data empowers precise environmental impact assessments, enabling targeted interventions that diminish the maritime sector's ecological footprint. These technologies together offer a path toward greener maritime activities, aligning with global sustainability goals.

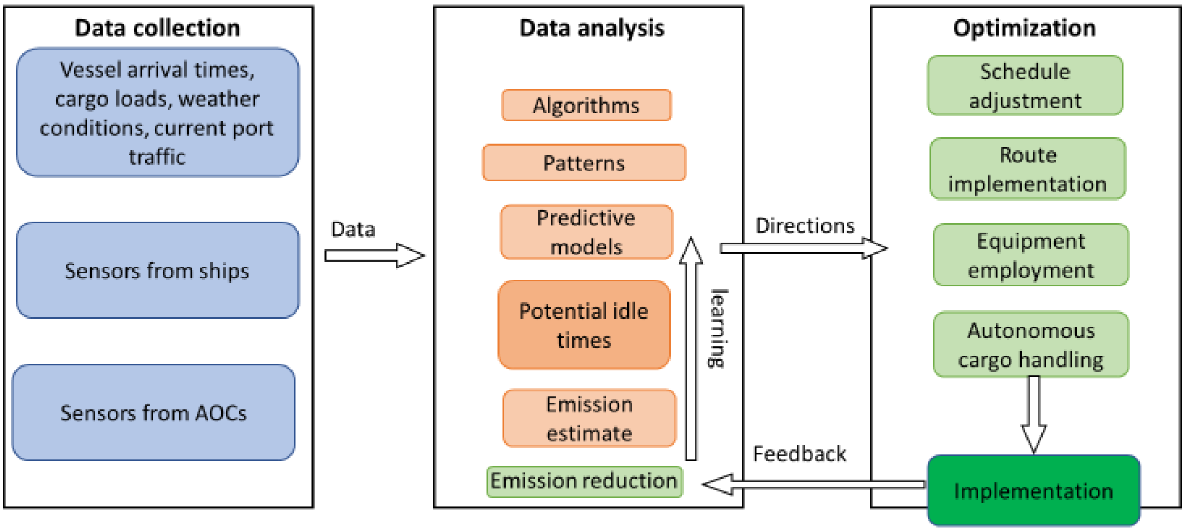


**Figure 1**: AI-Driven Emission Reduction in Port Operations Flowchart.

AI can significantly enhance the efficiency of port operations by analyzing patterns and predicting peak operational times, allowing for the adjustment of activities to minimize emissions. Through machine learning algorithms, AI can identify the most efficient workflows, reducing idle times for ships and equipment that contribute to greenhouse gas emissions (Tan et al. 2023). This optimization leads to a notable decrease in the carbon footprint of maritime logistics, showcasing AI's role in promoting environmental sustainability.

Geospatial technologies offer a precise tool for monitoring the environmental impacts of maritime activities. By utilizing satellite imagery and GIS data, stakeholders can track pollution levels, the movement of vessels, and their ecological footprints in real-time (Zeng, Yuan, and Hou 2023). This data is crucial for implementing targeted actions aimed at reducing emissions and mitigating the impact on marine ecosystems, enabling a more responsible management of maritime operations.

The integration of AI and geospatial data can represent the best answer in the fight against pollution in maritime contexts. By leveraging AI's predictive analytics with geospatial detailed environmental monitoring, ports can proactively manage operations in ways that significantly cut emissions. This combined approach not only aids in achieving regulatory compliance but also sets a new benchmark for environmental stewardship in the maritime industry, paving the way for cleaner, more sustainable maritime logistics.

The integration of AI and geospatial technologies facilitates the development of an autonomous cargo vessel system, closely coordinated with Ashore Operations Centers (AOCs). This proposed system aims to streamline maritime logistics, enhancing efficiency and safety while significantly reducing human error in navigation and operations. Through precise route optimization and real-time data analysis, the system ensures optimal vessel performance, contributing to smoother port operations and better utilization of maritime resources.

Dividing large port areas into sectors for managing autonomous cargo vessel operations enhances efficiency and safety. This segmentation allows for smoother handover and takeover as vessels navigate through different zones, minimizing congestion and optimizing traffic flow (Scarlat, Ioanid, and Andrei 2023). Such organization can significantly contribute to emission reduction by ensuring vessels operate at optimal speeds and routes, reducing unnecessary fuel consumption and lowering greenhouse gas emissions.

### *4.2 Enhancing energy efficiency in ports*

AI-driven energy management systems in ports optimize operations for maximum energy efficiency. These systems analyze energy consumption patterns to automate and optimize energy use, reducing costs and environmental impact. Geospatial technologies support this by aiding in the layout planning of renewable energy installations, such as solar panels and wind turbines, ensuring they are placed in optimal locations for energy generation. This combination of AI and geospatial technologies enables ports to significantly enhance energy efficiency, contributing to the sustainability of port operations and the broader goal of reducing the carbon footprint of maritime activities (Iris and Lam 2019).

Automated routing tools, powered by real-time geospatial data, enhance maritime logistics planning. This synergy between tech and expertise not only boosts efficiency and safety but also supports eco-friendly operations. Autonomous collision-avoidance strategies can further refine this by employing AI and mathematical models for safer navigation in busy waters, optimizing vessel routes for both safety and efficiency (Acciaro and Wilmsmeier 2015). Adjusting course and speed dynamically, based on real-time insights and standard procedures, minimizes collision risks, and improves travel efficiency, marking a step towards more sustainable maritime practices.

Modern ports are increasingly turning to smart grid technologies, integrated with AI and geospatial systems, to manage their energy needs more efficiently. Smart grids enable a more dynamic supply and demand management, leveraging renewable energy sources more effectively (Longarela-Ares, Calvo-Silvosa, and Pérez-López 2023). By using AI to predict energy demand peaks and troughs, ports can optimize their energy consumption, reducing reliance on non-renewable energy sources. Geospatial data aids in the strategic placement of energy resources, including the integration of electric charging stations for electric vehicles and equipment, further promoting the electrification of port machinery, and reducing greenhouse gas emissions.

Advanced energy monitoring systems, equipped with AI algorithms, offer real-time tracking of energy use across port operations. These systems can identify inefficiencies and suggest immediate adjustments, such as automating lighting and heating, ventilation and air conditioning (HVAC) systems based on geospatially mapped activity patterns within the port (Tanganelli and Mingozzi 2019). By analyzing data collected from sensors and IoT devices, ports can implement targeted energy-saving measures, contributing significantly to overall energy efficiency goals. Figure 2 presents a flowchart for how it can be achieved energy efficiency in port operations.

AI and geospatial technologies are useful in optimizing the mix of renewable energy sources in ports. AI algorithms can forecast weather conditions and analyze geographical data to determine the most efficient mix of solar, wind, and other renewable energy sources. This optimization ensures that ports can rely on a steady supply of green energy, minimizing their carbon footprint. Geospatial analysis helps in mapping out the best locations for renewable energy installations, considering factors such as sunlight exposure and wind patterns, to maximize energy generation from these sources.

The planning and development of sustainable port infrastructure can benefit significantly from the use of AI and geospatial technologies. By analyzing geospatial data, planners can design port layouts that optimize natural ventilation and lighting, reducing the energy consumption of port buildings and facilities. AI-powered simulation models can predict the long-term benefits of such designs, helping to make the case for investment in sustainable infrastructure.

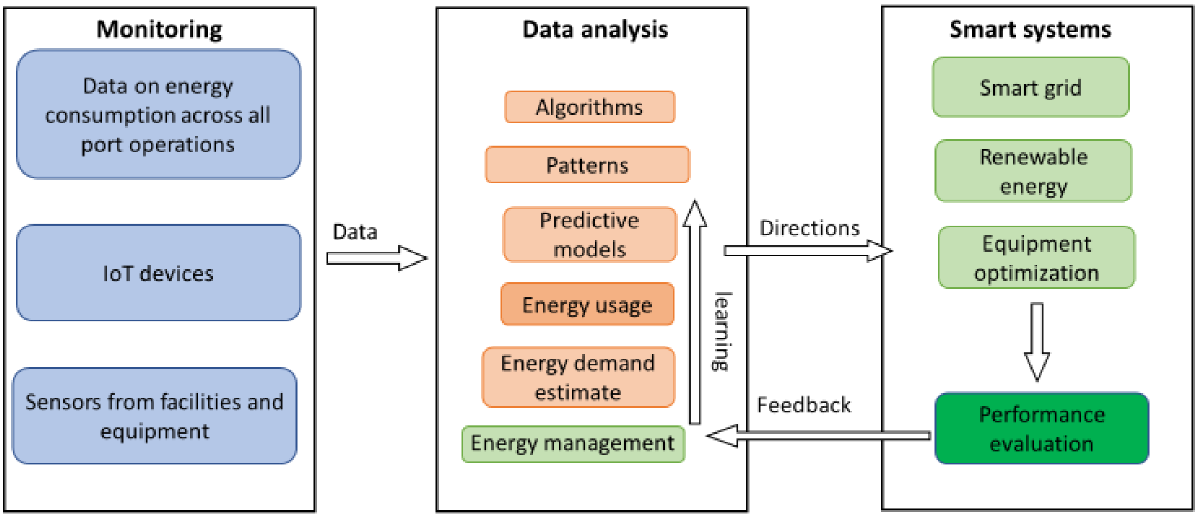


**Figure 2**: AI-Driven Energy consumption management in Port Operations Flowchart.

Collaboration between ports, technology providers, and energy companies is essential to leverage AI and geospatial technologies fully. Sharing data and best practices can accelerate the adoption of energy-efficient solutions across the maritime industry. International initiatives and partnerships can foster the development of standards and frameworks for energy management in ports, encouraging a unified approach to sustainability.

### *4.3 Creating sustainable supply chains*

AI and geospatial technologies combined have the potential to transform supply chain transparency and visibility. These technologies analyze extensive datasets to deliver insights and forecasts in real-time. By joining AI with geospatial information, they offer a detailed perspective of the supply chain, enhancing goods tracking, equipment maintenance forecasting, and route optimization. This synergy ensures inventory levels are accurately matched with current demand and supply, markedly boosting inventory management efficiency.

Improving supply chain visibility with AI and geospatial technologies significantly aids in identifying and mitigating risks early by offering instant data and foresight. This is key for navigating unexpected situations like natural disasters or market shifts. Moreover, this enhanced oversight supports faster, more informed decisions, heightening adaptability to market changes and boosting customer satisfaction through more responsive service.

Integrating blockchain into supply chain visibility enhances security and trust by providing an immutable record of all transactions, crucial for compliance and quality assurance. This transparent tracking from production to end-user marks a leap towards sustainable and ethical supply chains. Research highlights blockchain's role in Industry 4.0, enhancing traceability and process visibility, significantly influencing sustainable practices and addressing environmental and resource optimization challenges (Kuo, Huang, and Chen 2022). This underscores blockchain's critical role in transforming supply chain management towards sustainability.

As supply chains adapt and grow, merging AI, geospatial technologies, and blockchain brings both prospects and challenges. The key challenge is integrating these technologies smoothly into existing frameworks and achieving system compatibility. Moving forward, continual refinement and embracing these innovations are crucial for crafting supply chains that are more robust, effective, and sustainable, matching the increasing emphasis on global environmental and ethical norms.

### *4.4 Developing green infrastructure*

Artificial intelligence plays a critical role in enhancing the longevity and efficiency of port infrastructure through predictive maintenance. By analyzing vast datasets, including historical maintenance records, sensor outputs, and operational parameters, AI algorithms can predict equipment failures before they occur. This predictive capability allows for timely maintenance actions that prevent costly downtime and extend the infrastructure's lifespan. AI's analytical power ensures resources are allocated efficiently, prioritizing critical maintenance tasks, and optimizing the use of materials and human resources. This approach not only supports the sustainability of port operations by reducing waste and unnecessary consumption but also significantly lowers the environmental impact of maintenance activities.

Geospatial technologies offer invaluable insights into the planning and development of sustainable facilities within ports. Through the analysis of geographic and spatial data, these technologies enable planners to identify the best locations for new infrastructure projects, considering environmental sensitivities, land use compatibility, and renewable energy potential (Oloruntobi et al. 2023). For example, geospatial analysis can determine the most effective placement for solar panels and wind turbines, considering factors such as solar insolation and wind patterns. Additionally, these technologies can help design green spaces within port areas, enhancing biodiversity and providing natural solutions for stormwater management and cooling, thereby reducing the urban heat island effect often associated with port areas.

The integration of AI and geospatial technologies facilitates more effective resource allocation in the development of green infrastructure. AI can analyze geospatial data to optimize the layout of green spaces, renewable energy installations, and other sustainable facilities, ensuring they deliver maximum environmental and economic benefits (Wang, Cheng, and Zhen 2023). For instance, AI algorithms can predict the growth of vegetation in green spaces, allowing for the strategic placement of plants and trees to maximize carbon sequestration and air quality improvement. This integrated approach not only enhances the sustainability of port operations but also contributes to the well-being of the surrounding communities by providing cleaner air and more accessible green spaces.

Leveraging AI and geospatial technologies in developing green infrastructure represents a forward-thinking approach to sustainability in maritime settings. By harnessing the predictive power of AI and the spatial analysis capabilities of geospatial technologies, ports can create resilient, efficient, and environmentally friendly infrastructure. This commitment to green infrastructure development not only aligns with global sustainability goals but also positions ports as leaders in environmental stewardship, setting a benchmark for sustainable practices in the maritime industry.

## 5. CHALLENGES AND FUTURE DIRECTIONS

Integrating advanced AI and geospatial technologies into maritime infrastructure represents a substantial financial undertaking, necessitating a significant initial investment. This cost barrier encompasses not only the direct expenses of acquiring the technologies themselves but also extends to the costs associated with training personnel to proficiently use these advanced tools (Aslam, Michaelides, and Herodotou 2020). Moreover, the integration process may uncover the need for modifications or upgrades to existing infrastructure to accommodate the new technologies effectively. These financial considerations can deter ports and maritime logistics operations from adopting these innovative solutions, despite their potential to significantly enhance efficiency, sustainability, and safety.

The adoption of AI and geospatial technologies in the maritime sector raises pressing concerns regarding data privacy and security. These technologies rely on the collection, analysis, and storage of vast quantities of sensitive geospatial and operational data. The handling of such data introduces risks of unauthorized access and data breaches, which could have severe implications for port operations and security (Cho et al. 2022; Progoulakis et al. 2022; Tam, Jones, and Papadaki 2012). Therefore, there is a critical need for implementing robust cybersecurity measures and protocols to protect this sensitive information. Ensuring the integrity and security of data is paramount to building trust in these technologies and their broader acceptance within the maritime industry.

A significant challenge facing the integration of AI and geospatial technologies in maritime infrastructure is the issue of interoperability and standardization. The maritime sector utilizes a diverse array of technologies and systems, each with its own set of standards and protocols. This diversity can delay or even block seamless integration and data exchange between different systems, hindering the effective deployment of AI and geospatial solutions. Overcoming this challenge requires concerted efforts to develop and adopt international standards that ensure compatibility and facilitate smooth interoperability among the vast number of technologies employed in maritime logistics and operations.

The pace at which regulatory and legal frameworks adapt to technological advancements is often slow, presenting a considerable hurdle to the implementation of AI and geospatial technologies in maritime infrastructure. Regulatory challenges can include issues related to the use of autonomous systems, data privacy regulations, and the certification of new technologies for maritime use. This slow adaptation can delay the deployment of innovative solutions that have the potential to revolutionize maritime operations. Addressing these regulatory and legal hurdles is essential for creating an enabling environment that supports technological innovation while ensuring safety, privacy, and compliance.

Further research into cost-effective implementation strategies and comprehensive return on investment (ROI) analyses for AI and geospatial technologies in maritime settings is crucial. Such research can provide valuable insights into how these technologies can be deployed more affordably and effectively, encouraging their wider adoption. By demonstrating the long-term financial benefits and operational efficiencies that these technologies can bring, stakeholders can make more informed decisions, potentially accelerating the integration of AI and geospatial solutions across the maritime industry. Tailored studies that consider the specific needs and constraints of various port sizes and locations can help identify scalable and adaptable solutions, ensuring that the benefits of technological advancements are accessible to all.

The exploration of advancements in encryption and blockchain technology is vital for enhancing data security and privacy within the maritime sector. These technologies offer robust solutions for protecting sensitive operational and geospatial data, ensuring that information is shared securely and efficiently among stakeholders. By adopting these advanced security measures, ports and logistics operations can mitigate the risks of data breaches and cyberattacks, fostering a more secure digital environment. Investment in and adoption of such technologies are imperative for building trust and confidence in digital maritime operations, making the case for their broader implementation across the industry.

The development of international standards and protocols is recommended to ensure interoperability among different systems and technologies within the maritime industry. Establishing a unified set of guidelines can significantly facilitate the integration of AI and geospatial technologies, enhancing data sharing and operational efficiency across global supply chains. Such standards would not only streamline technological adoption but also foster innovation by providing a clear framework within which new solutions can be developed and implemented. Collaborative efforts among industry stakeholders, technology providers, and regulatory bodies are essential to create and maintain these standards, ensuring they remain relevant and adaptable to emerging technological trends.

Advocacy for policy changes and the adaptation of legal frameworks is crucial to accommodate the unique needs and potential of AI and geospatial technologies in maritime infrastructure. Engaging with policymakers, industry leaders, and legal experts to update existing regulations and create new policies that reflect the realities of modern technology can significantly accelerate its adoption. Such efforts should aim to address the challenges of privacy, security, interoperability, and the equitable deployment of technologies, ensuring that the legal and regulatory environment supports innovation while protecting the interests of all stakeholders. Through proactive advocacy and collaboration, the maritime industry can help shape an ecosystem that is conducive to a sustainable approach in maritime industry.

## 6. CONSTANȚA PORT CASE STUDY

This research aims at understanding what are the issues faced by the biggest port in Romania in developing its importance in the region and what the business representatives with operations through this port think could be improved.

Firstly, a documentation was done to better understand the growth of maritime transport in the last years through the Constanța port using official public reports.

Secondly, the authors conducted a series of interviews with 10 owners or managers of companies with operations in Romania that import or export goods through this port.

The interviews taking place in December 2023 had the purpose of understanding what could be done to improve the services offered by the port to be competitive on the global market. And, if the situation in Ukraine and the fact that part of the Odessa Port maritime traffic moved to Constanța, could lead to a better positioning of Romania in the maritime global transport industry?

### 6.1 Constanța Port current situation

The Port of Constanța represents the most important maritime port of Romania, its favorable geographical position being emphasized by the Pan-European Corridors IV and VII.

The total merchandise traffic of the port in 2022 was of 75,5 million tons, with a growth of 12% compared to the previous year. The data provided in the table below highlights the traffic for the period 2017-2022.

**Table 1**. Total merchandise traffic in the Port of Costanța (Tons). Source: ("Portul Constanta" 2023).

| *Traffic* | *2017* | *2018* | *2019* | *2020* | *2021* | *2022* |
|---|---|---|---|---|---|---|
| Total Traffic (tons) | 58.379.154 | 61.303.774 | 66.603.292 | 60.375.799 | 67.483.435 | 75.537.687 |

The increase in maritime operations through Romania is partly attributed to the conflict in Ukraine, with an estimated 15% of total growth resulting from ships redirecting their activities. Commodities experiencing significant surges due to this shift include oily seeds, such as sunflower seeds, witnessing a near 70% rise in 2022, and iron ore along with scrap iron, which saw close to a 50% increase, both impacts of the war situation.

The data from the Port of Constanța website showcases the diversity and volume of sea-going vessel calls at the Port of Constanța from 2017 to 2022, highlighting a trend of growth in maritime traffic (see Table 2). Notably, cargo ships and tankers have seen significant fluctuations, with cargo ship visits peaking in 2022. The report also indicates a dramatic rise in tanker traffic, underscoring the port's expanding role in liquid bulk cargo. Despite variations in container and bulk carrier movements, the overall increase in vessel calls reflects the port's rising importance in regional maritime logistics.

**Table 2**. Calls on sea-going vessels, by type of ship. Source: ("Portul Constanta" 2023).

| *Type of Ship* | *2017* | *2018* | *2019* | *2020* | *2021* | *2022* |
|---|---|---|---|---|---|---|
| Cargo | 1,815 | 1,785 | 1,807 | 1,927 | 1,751 | 1,969 |
| Passenger | 13 | 11 | 17 | 0 | 3 | 16 |
| Portcontainer | 592 | 524 | 510 | 475 | 494 | 435 |
| Tank | 608 | 670 | 687 | 581 | 587 | 798 |
| Bulk Carrier | 574 | 628 | 622 | 558 | 645 | 741 |
| Others | 491 | 521 | 533 | 490 | 505 | 539 |
| **Total** | 4,093 | 4,139 | 4,176 | 4,031 | 3,985 | 4,498 |

Table 3 provides a rough estimate of fuel consumption based on vessel type and data comprised in other studies (Albo-López, Carrillo, and Díaz-Dorado 2023; Marius 2014). Actual consumption can vary widely due to factors such as vessel size, speed, engine type, and operational conditions. The estimates for "Others" category can vary significantly based on the specific types of vessels included, and therefore, an average consumption was considered.

**Table 3**. Average fuel consumption (Tons/Day). Source: ("Portul Constanta" 2023).

| *Type of Ship* | *Avg. Fuel Consumption (Tons/Day)* |
|---|---|
| Cargo | 100-200 |
| Passenger | 100-200 |
| Portcontainer | 100-200 |
| Tank | 20-40 |
| Bulk Carrier | 20-40 |
| Others | Varies (considered an average of 40) |
| **Total** | N/A |

As the demand is continuously growing, the port is in a continuous search for modernization solutions to become more competitive in the region. Taking into account the example of Port of Rotterdam ("The Digital Port | Port of Rotterdam," n.d.) and following the flowchart from Figure 1. It is possible to project the fuel savings achieved by ships docking at Port of Constanța. We can estimate a fuel reduction of approximately 10-20%. The estimated reductions (%) are roughly approximated and based on the assumption that implementing AI and geospatial technologies can achieve similar outcomes to those observed in other ports like Rotterdam. Actual percentages would require detailed calculations based on specific emission factors for each cargo type and operational efficiencies gained through technology adoption.

If the expetations mentioned previously are met, this would result in savings of 43,073 to 86,146 tons of fuel in a year with similar traffic as 2022.

Table 4 presents a range of estimated fuel savings for each vessel type, showing the potential reduction in fuel consumption achievable with a 10% to 20% efficiency improvement in operations at the Port of Constanța for one year, taking as a reference year 2022. As the traffic projections are indicating a conisderable increase in the port activity, we can safely assume that the potential savings are substantial, making the impact on the environment substantially reduced also.

**Table 4**. Rough estimate of the fuel consumption in 2022 (Tons). Source: ("Portul Constanta" 2023).

| *Vessel Type* | *Fuel Consumption 2022 (Tons)* | *Fuel Savings 10% (Tons)* |
|---|---|---|
| Cargo | 295,350 | 29,535-59,070 |
| Passenger | 2,400 | 240-480 |
| Portcontainer | 65,250 | 6,525-13,050 |
| Tank | 23,940 | 2,394-4,788 |
| Bulk Carrier | 22,230 | 2,223-4,446 |
| Others | 21,560 | 2,156-4,312 |

Currently, the VTMIS Constanța, a maritime traffic management system, ensures navigation and traffic management in the Port of Constanța. It operates under the Maritime Coordination Center and the Romanian Naval Authority, providing 24/7 surveillance for enhancing navigation safety, traffic efficiency, and environmental protection. The VTS area, a crucial zone for VTMIS operations, includes maritime zones defined by specific coordinates. The system facilitates various services, including traffic information and assistance, ensuring compliance with navigation rules and aiding in the effective organization of maritime traffic within its jurisdiction. Figure 3 depicts a screenshot of the output of the monitoring system.

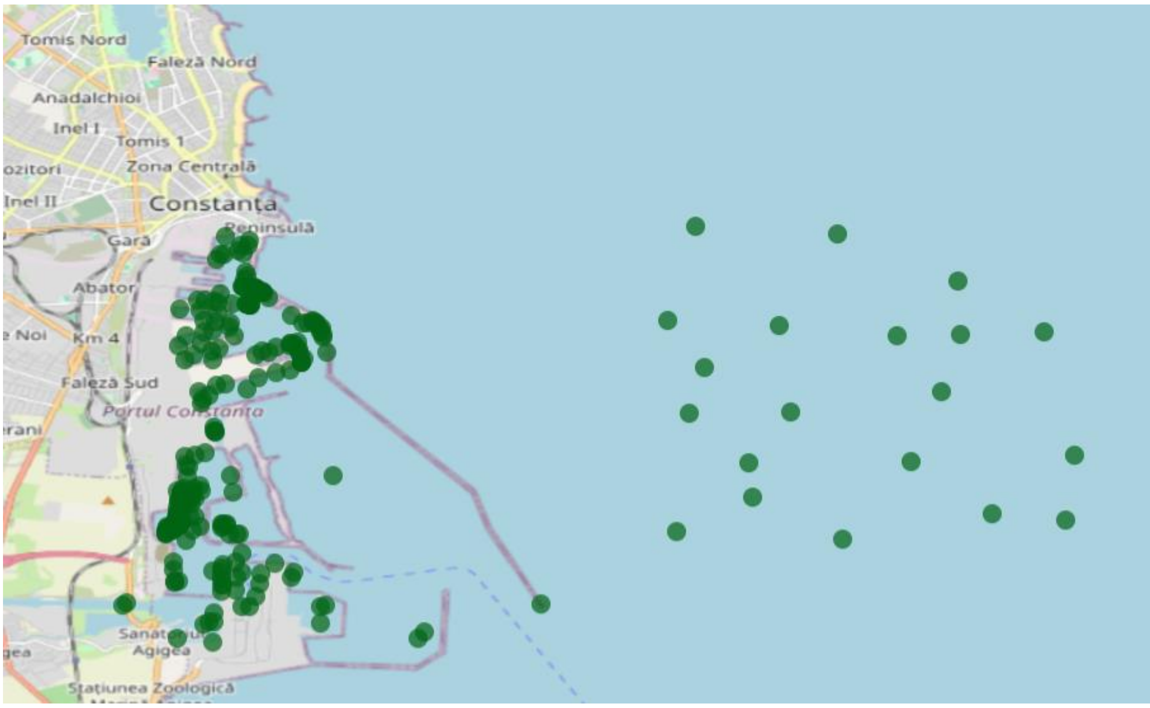


**Figure 3**: Port of Constanta GIS system showing the location of vessels. Source: ("Portul Constanta," n.d.)

Almost all the data about traffic information and ship's crew is transmitted by voice. Adopting a digital solution akin to the Port of Rotterdam could significantly enhance operational efficiency at the Port of Constanța. Such a transformation might lead to optimized traffic management, improved safety, and better environmental protection through advanced analytics and real-time data processing. Additionally, it could foster seamless communication within maritime operations, streamline navigation assistance, and effectively manage vessel traffic, ensuring a more sustainable and efficient maritime logistics hub.

### 6.2 Research methodology and results

During December 2023, the authors contacted several company representatives that use the port of Constanța to import or export goods. The aim of the research was to understand what could be done to improve the services offered by the port to be competitive on the global market and how could Romanian port increase its operations after part of the maritime transport done through Odessa port shifted to Constanța.

The results of the study show that the biggest problems companies with operations in Romania face is the lack of *railway and road infrastructure* within the country. All 10 company representatives that accepted to participate in the interviews mentioned this problem as a serios one, affecting the decision to use the port of Constanța. For example, unless the business is located in Dobrogea, so close enough to the port, the delays are almost impossible to avoid otherwise. So, this is the reason why some investors choose directly the Western part of Romania when deciding where to open their factories, as in a short time they can cross the border to Hungary, and the infrastructure in Hungary is perceived as significantly better.

The Danube river links Romania to many European countries. But there are certain limitations especially on the capacity of the ships passing through the Danube Delta canals. This is an area of critical importance to Romania from the natural ecosistem point of view, as a lot of turists visit every year the delta. The transporters' associations have sometimes a different perspective then the ecological associations when it comes to the navigating canals and to the Danube ecosystem, but due to the legal regulations, navigation can be done to a certain amount so that it does not distroy the natural environment of the delta.

Another problem mentioned by the business representatives we could talk to is the improvement needed in the digitalization of the port. The trucks waiting to enter the port don't have an exact estimation of the time until they are able to discharge or charge the merchandise. The transportation companies have high costs due to these waiting times , so the modern technologies, including AI could be used to create automatized systems within the port.

In conclusion, the port of Constanța increased its operations, but the infrastructure and the digitalization did not improve at the same pace. Business representatives of companies that transport their goods through the port, as well as the transporters' associations, consider that the port needs further investments in order to increase its operations and decrease the waiting times.

## 7. CONCLUSIONS

In conclusion, the integration of AI and geospatial technologies within maritime logistics represents an important shift towards enhancing operational efficiency, sustainability, and resilience. These technologies have demonstrated potential in optimizing operations, reducing emissions, and facilitating the development of green infrastructure. By leveraging AI's predictive analytics and the detailed mapping capabilities of geospatial technologies, maritime operations can be significantly more sustainable, reducing the industry's carbon footprint and aligning with global environmental goals.

The case study of the Port of Constanța underscores the transformative potential of adopting digital solutions similar to the Port of Rotterdam. Through the integration of AI and geospatial technologies, the port has a clear pathway to significantly enhance operational efficiency, reduce environmental impact, and bolster maritime safety. The expected fuel savings, calculated to range from 10% to 20% for different vessel types, highlight the substantial economic and environmental benefits of modernization. This forward-looking approach not only aligns with the global push towards sustainability but also positions the Port of Constanța as a regional leader in maritime logistics innovation. The case study reinforces the conclusions drawn about the industry-wide shift towards technology-driven operations, emphasizing the critical need for collaboration, investment, and regulatory adaptation to realize these advancements fully.

The future of maritime logistics lies in the continued innovation and application of these technologies, fostering a collaborative environment that encourages sharing best practices and data. However, the industry faces challenges, including high implementation costs, data security concerns, and regulatory hurdles, which must be addressed to fully realize the potential of these technologies. Moving forward, a sustained effort from all stakeholders is essential to overcome these barriers, ensuring that maritime logistics continues to evolve in an environmentally responsible and efficient manner. This journey towards a more sustainable and efficient maritime sector is not only crucial for the industry but also for the global community, as it aligns with broader goals of environmental sustainability and economic resilience.

## 7. CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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