Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2023, 75 (147), 68–78
ISSN 2392-0378 (Online)
DOI: 10.17402/575

Received: 11.06.2023
Accepted: 26.06.2023
Published: 30.09.2023

Analysis of passenger ships activity in the oil and gas offshore shipping sector in the North Sea

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Keywords: offshore fleet, offshore sector, AIS, passenger shipping, oil & gas offshore sector, ship utilization efficiency

JEL Classification: R4, D470, L91, 0320

Abstract

Maritime and coastal areas are the lifeblood of many countries. They are vital to the prosperity of countries because they provide trade routes, regulate the climate, are a source of organic and inorganic resources and energy, and provide a place for the public to live and relax. Increasingly, however, there are divergences and barriers to the use of marine areas. On the one hand, available and developed technology and knowledge enable increasingly improved use of the sea. On the other hand, the combined effect of these activities leads to conflicts of interest and the deterioration of the marine environment. The purpose of this study is to analyze the feasibility of using automatic identification system (AIS) maritime traffic data, in terms of its suitability, to correctly assess the utilization of the potential of a specific fleet within the offshore shipping industry. In addition, the authors undertake the task of determining to what extent activities relating to the GPS position of the ship, ship type (i.e., cargo or passenger), ship status (i.e., aground, anchored, moored, not under command, restricted maneuverability, underway sailing, or underway using its engine), ship draught, service speed, total engine power, and deadweight constitute areas and methods for optimizing the use of the offshore fleet under all the conditions previously described that limit this optimization. Given the stated goal, this paper uses both a literature review procedure and statistical methods to conduct a comparative analysis.

Introduction

The offshore shipping sector is a specialized segment of the shipping industry that focuses on supporting offshore activities and operations such as oil and gas exploration and extraction, offshore wind farms, and other marine projects (including research and aquaculture). The sector has its own unique characteristics and requirements that distinguish it from other shipping segments. These specificities certainly include geographical location. It must be considered that coastal shipping operations occur in remote and often difficult environments such as open seas, deep waters, and offshore installations. This requires specialized vessels and equipment capable of operating in these specific conditions, including ice-class vessels, jack-ups, heavy lift vessels (HLVs), anchor handling tugs (AHTSs), platform supply vessels (PSVs), cable laying vessels (CLVs), crew transport vessels (CTVs), and accommodation vessels. In addition, there are a number of other highly specialized offshore vessels with smaller applications. Another function supporting offshore activities is the offshore vessels, which play a key role in supporting various offshore activities. They transport personnel and equipment and deliver all kinds of structural components, parts, and machinery to and from offshore installations, including oil rigs, platforms, and wind farms. These vessels may also provide support services such as anchor handling, towing, subsea construction, and maintenance. In addition, maritime shipping often involves dynamic operations that require flexibility and adaptability. Ships may have to perform multiple tasks in a single operation, such as resupply, crew transfer, and emergency response. They need to be equipped with specialized equipment, including cranes, winches, and wheelhouses, to facilitate these operations, as well as to provide the crew with appropriate services – i.e., accommodation and transport capacity. Due to the remote and demanding nature of offshore operations, safety, security, and environmental issues are of primary importance. Offshore companies must comply with strict safety regulations and implement robust safety management systems to protect personnel, assets, and the environment. Vessels must be equipped with safety equipment and emergency response capabilities, and must comply with international maritime and marine standards, as well as ships' flag obligations.

The shipping industry has witnessed significant technological advances that meet the changing demands of offshore operations. This includes the development of specialized vessels, advanced navigation and positioning systems, remotely operated vehicles (ROVs) for subsea operations, and improved communication and monitoring systems. Seasonality and cyclicality are other factors that determine the specificity of shipping. Shipping activities can be affected by seasonal (mainly yearly-based) and cyclical factors (repeatable works and services to be delivered to the marine constructions). For example, in the oil and gas industry, exploration and extraction activities can vary according to oil prices, market demand, and resource availability. On the other hand, once oil or gas production has started, it cannot be easily discontinued before the oil or natural gas field is depleted. The construction and maintenance of offshore wind farms is highly dependent on weather conditions and the project schedule. While the construction phase requires less daily transfer of technicians (most are accommodated on board SOVs or accommodation vessels), it is already important for the operation and maintenance (O&M) phase of the daily transfer of crew with respect to weather conditions and forecasts. Consideration should also be given to a time charter-based form of cooperation between an offshore developer and a shipowner who provides the services of a specific vessel, which ensures that the vessel is adequately crewed and in proper working order but with authority to delegate all operational decisions (i.e., current destination, embarkation and disembarkation of passengers, port of departure and/or arrival, cargo taken on board, speed, waiting at quay or jetty, etc.) to the master by a representative (often referred to as the 'marine operations center') of the charterer (i.e., the developer).

These specificities highlight the unique challenges and requirements of the shipping sector. Companies operating in this sector must have the expertise, equipment, and a strong focus on safety, security, quality, and environmental sustainability to successfully support offshore operations.

Voyage optimization methods as key tools for improving the economic efficiency of shipowner operations

In the area of ship operational optimization, several methods and procedures are now known, the application of which leads to specific optimization goals, with the reduction of operational costs as the primary objective and, less frequently, the reduction of negative environmental impacts, especially by reducing atmospheric emissions. The main solution that has been used for decades is slow steaming, i.e., the operation of ships by reducing speed and, thus, progressively reducing fuel consumption (and, therefore, fuel costs). This is the use of a function of fuel consumption and ship speed that is similar to a logarithmic function; hence, in the upper-speed ranges, it enables a significant reduction in fuel consumption at the expense of a relatively small reduction in speed (Cariou, 2011). The question then arises: Is slow steaming applicable to offshore shipping?

In addition to this solution, there are also more complex solutions based on information systems. As Czermański has shown, there are now solutions whose application leads to both objectives by reducing fuel consumption (Czermański, 2019). From a financial point of view, lower fuel consumption generates lower voyage costs for the ship but also results in lower greenhouse gas (GHG) emissions into the atmosphere. An important aspect that cannot be overlooked is the reduction of bunker fuel consumption costs since bunker fuel consumption costs typically account for 50% (Notteboom, 2006), or even more than 60% (Golias et al., 2009), of a container ship's total operating costs. These include various types of navigation systems that optimize the sea voyage considering navigational and market conditions (e.g., fuel management, voyage weather planning, and crew eco-driving training). The process of weather optimization of a sea route involves considering all historical data and forecasts for a given sea body of the future sea voyage to best align the route with the main objective of minimizing energy (fuel) consumption, including, in particular, consideration of wind strength and direction and wave action. The influence of sailing speed on bunker fuel consumption in shipping analysis has been written about, for example, by Christiansen et al. (Christiansen et al., 2013), Meng et al. (Meng et al., 2013), and Brouer et al. (Brouer, Desaulniers & Pisinger, 2014), including when considering fleet deployment (Álvarez, 2009). In practice, this refers to avoiding storms, strong winds, and high waves, which increase the vessel's resistance to motion and result in either a reduction in speed at the same engine rpm or the need to increase engine rpm to maintain a constant cruising speed. Methods for selecting the optimum speed were described by Mulder and Dekker (Mulder & Dekker, 2014) in their study. Tests performed over an entire year on a specific vessel showed that, by using a suitable weather optimization system, it was possible to reduce fuel consumption by 4% over the year, with the potential to increase this reduction to 8%. An extension of this technology also involves considering sea currents, which are fairly well-known and described by oceanographers. In extreme cases, this can help to increase speed by 3 kn while maintaining the same number of propeller revolutions, compared to traveling in the same conditions but without the help of a sea current in the direction of the voyage.

However, offshore shipping also shows significant differences from other shipping segments in this respect, since it is based on a separation of decision-making between the ship's captain, representing the interests of the shipowner and the developer acting in his own interests. In addition, there is the factor of entanglement in space. This is because offshore shipping, as a shipowner service provider, has a complementary function to the offshore investment in progress – an extraction platform or wind farm that has a fixed location, which prevents or significantly limits the use of maritime space for alternative navigation solutions. In addition, this effect is reinforced by the economic factor of fuel minimization, which is imposed by the developer (as he is the one who most often, according to the time charter, bears its costs) and thus, in most cases, does not allow a significant deviation from the course that is the shortest. Another factor exacerbates the issue – namely, the relatively short distances of the location of developments from land and ports (in the offshore wind sector, it is in the range of 20–80 Nm, slightly more in the oil and gas sector). The short distances also generate further logistical challenges, namely, the numerous deliveries of construction components and workers for the construction or servicing of the offshore installations concerned, whose sea transit times are strongly determined by the paradigm of being as short as possible. This does not offer many opportunities to adjust the courses (and, thus, lengthen them) of ships for fuel reduction effects, since both the goods carried to the installation and the workers sent to it cost the developer the same or more in terms of hours.

Noteworthy at this point is that one of the most important factors for the ship owner, as well as for the offshore developer, is the efficiency of the fleet involved in a project. Research on economic efficiency in relation to shipping only started to be conducted in the early 1990s. This was when the first studies of this issue in shipping appeared, in which the applicability of revenue management to freight or vessel capacity and price in liner shipping was investigated (Brooks & Button, 1994; Maragos, 1994). The main obstacle to revenue management in liner shipping is that container ship capacity is a complex function of stowage rules, cargo composition, and port call sequence (Jensen & Ajspur, 2022). Indeed, operational constraints significantly limit vessel capacity, as pointed out by Delgado (Delgado, 2013). Currently, many studies on revenue management in liner shipping focus on container slot allocation, i.e., the allocation of available container slots of a container ship fleet to incoming container traffic demand (Wang, Meng & Du, 2015, p. 142). As such, revenue management includes elements of demand forecasting, service pricing, and capacity allocation to different routes to facilitate transport. It even includes designing the correct network to maximize profit or deciding the size of the fleet already at a strategic level (Ting & Tzeng, 2004; Song & Dong, 2012). The service network should consist of a set of routes, the allocation of ships to routes, the sailing speed of ships on each route, and the allocation of cargo on the routes. Mulder and Dekker presented a cost-saving model that is obtainable by solving the network design problem in an integrated manner (Mulder & Dekker, 2014). The disadvantage of this method is the dependence on the global economy since the shipowners' margins are strongly dependent on the current market situation. In microeconomic terms, it is not uncommon for shipowners to undertake charters at, or even slightly below, the break-even point but with other objectives in mind – e.g., the transfer of a vessel to a more attractive region with greater economic potential (and the shipowner then minimizes the costs of this transfer by receiving partial coverage of these costs from the shipper), or when the freight market is in crisis and losses are minimized (i.e., in the zone between the company's closure point and the BEP).

Characters of the offshore industry

The offshore market is driven by high oil prices and investment in offshore oil exploration and extraction. Existing resources, i.e., onshore and in shallow waters, are depleting, and new discoveries are being made in deeper and more challenging environments, such as Brazil, West and East Africa, the Arctic, and Southeast Asia. Compared to many cargo ships, offshore support vessels need to have good seaworthiness and maneuverability. Therefore, they tend to be small, have low cargo capacity, and operate close to their land base, making frequent voyages (Erikstad & Levander, 2012). Overall investment in offshore operations is estimated to increase over the next 10–20 years and is expected to grow by an average of 10–15% per year. The segment is also influenced by new demand for specialized vessels, for example, the construction of offshore wind farms. Demand for larger offshore vessels and more technically advanced, high-performance vessels to support safe operations in harsh environments is also expected to increase. Currently, offshore support vessels are the fastest-growing vessel type in the offshore segment. Strong global pressure and attention to environmental protection, as well as regulations to reduce greenhouse gas emissions, are likely to increase demand in this market and accelerate technology development (Report Shipping, 2020). It is important to bear in mind that, in line with the general trend, the offshore industry, such as other industries, will focus on reducing energy demand, using alternative energy sources, and employing energy more efficiently. This will result in several changes in the structure of the fleet and outline the direction in which they are heading. In terms of clean energy and energy security, it is necessary to look for new innovative solutions (Oniszczuk-Jastrząbek, Czermański & Kowalik, 2021). The development of the offshore fleet in 2012 and 2020 is shown in Figure 1.

There are many different types of boats that provide services to the offshore industry. Among these are (Barrett, 2008):

- Anchor handling, towing, and supply. Anchor handling towing supply (AHTS) vessels tow drilling rigs from one location to another and are equipped with powerful winches that are used to lift and position the rig's anchors. In addition, many can carry moderate quantities of consumables, such as drilling fluid or drill pipe, and support offshore construction projects.
- Offshore supply vessels. Offshore supply vessels (OSVs) deliver drilling materials such as mud,

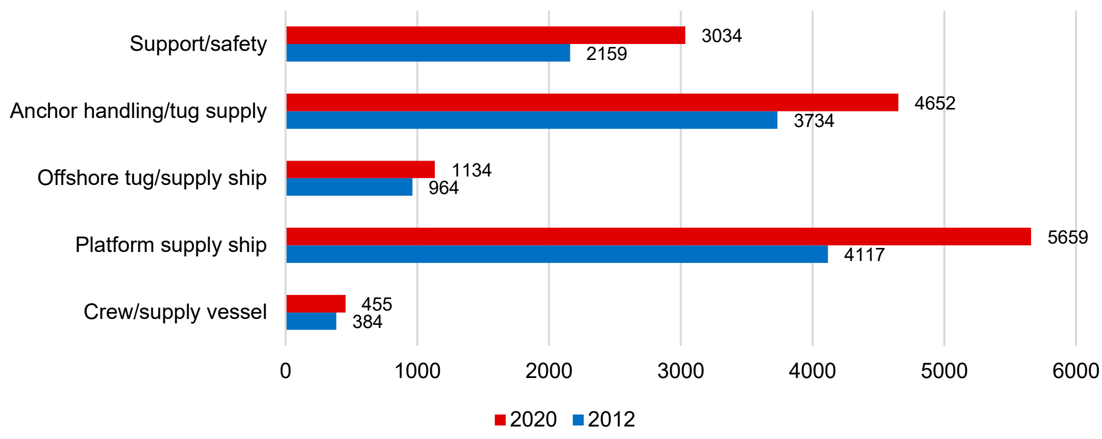

Figure 1. Development of the offshore fleet (forecast included) (Report shipping 2020, p. 14)

dry cement, fuel, potable water, drill pipe, casing pipe, and many other materials to drilling rigs.
- Crew boats transport personnel to, from, and between oil rigs and offshore platforms.
- Standby/rescue vessels. These typically operate in the North Sea due to regulatory requirements. These vessels are required to remain in the vicinity of rigs and platforms to provide emergency response services such as personnel rescue, firefighting, and first aid.
- Other types of vessels. There are a variety of other types of vessels used by the oil and gas industry: Utility/Workboats (which perform a great deal of work in support of offshore construction projects), survey vessels (which collect geophysical data), well stimulation vessels (which perform fracturing and acidizing of producing wells), and multi-purpose supply vessels (MPSV) that can provide a combination of remote subsea intervention services, remote operated vehicle (ROV) operations, deep-water lifting and installations, delivery of supplies, firefighting, and oil spill recovery.

In addition, there are other boats that perform maintenance work, pollution control, and diving support.

Tools for tracking ship traffic

Infomatics tools, including AIS, act as the most relevant means of measuring and monitoring vessels in motion and, on this basis, produce analyses, inferences, and recommendations for optimization. The primary purpose of developing ship guidance and traffic management systems is to improve the safety level of shipping and inland navigation. All tools and systems are based on precise ship data from the time of operation, such as position and direction of voyage, speed, draught, trim, wind strength and direction, and sea state. As written in the majority of works, in addition to improved safety levels, an increase in the fluidity of ship traffic has been achieved and, therefore, significant financial benefits resulting from the port's fast handling of ships (Galor, 2013). The European vessel traffic monitoring and information system (VTMIS) covers all sea areas of the member states and consists of the VTMIS systems of the European Union's member states. VTMIS consists of several systems that are its components, namely, vessel traffic surveillance systems (VTS), automatic identification systems (AIS), ship reporting systems (SRS), maritime assistance systems (MAS), long-range identification and tracking (LRIT), and a computerized information exchange system (SafeSeaNet) (Kopacz, Morgaś & Urbański, 2007).

Coastal radar stations are the primary source of information on the traffic situation in port areas. The basic prerequisite for radar guidance in a VTS system is the ability to detect an object by radar and then distinguish it against echoes from fixed objects, other vessels, and interference. If these conditions are not met, information on the movement of vessels will be insufficient for the system to function correctly. The ability to accurately detect and distinguish a maneuvering object in a port consists of several elements. The greatest problem for port systems based on radar technologies is object detection (Galor, 2013).

According to the International Convention for the Safety of Life at Sea: SOLAS 74, which entered into force on 1 July 2002, all ships that are 300 tonnes displacement and above must be equipped with shipboard automatic ship identification system kits. The basic components of such an AIS system are: the AIS coastal stations; the AIS ship stations, which should transmit information automatically to an appropriately equipped shore station, to another ship and to an aircraft, which includes data identifying the ship, i.e., its type, position, course and speed, navigational status, type of cargo carried, and safety data, which includes automatically receiving the same type of information from other AIS-equipped ships, monitoring their positions, tracking their movements, and exchanging information with shore stations; the AIS local area network information center (C. AIS); the stations of AIS supporting systems (GNSS and GMDSS stations) (Kopacz, Morgaś & Urbański, 2007).

The ship reporting system (SRS) requires well-defined procedures for reporting a ship, i.e., transmitting information to the coastal marine services (the port, VTS, SRS reporting system stations, etc.). They define when and to whom reports should be transmitted, what they should contain, and how their content should be structured (formatted). These systems contribute to the safety of shipping, and their purpose is to watch over maritime traffic. Ship reporting is a prerequisite for assistance – depending on the laws of the country, ship reporting may be voluntary or mandatory (Kopacz, Morgaś & Urbański, 2007).

The purpose of the maritime assistance system (MAS) is to: receive reports, recommendations, and notifications resulting from requirements established by the IMO; monitor the situation of a ship if its report indicates that an incident involving this ship may result in the need to assist it; act as a point of contact between the master of the ship and the coastal state concerned. The ship's situation, in which MAS should participate, does not require the rescue of people. The need for MAS participation is generated by the following events: the ship has been involved in a maritime incident that should have been reported, but the ship's seaworthiness to continue its voyage has been preserved; the ship requires assistance but is not in distress; the ship is in distress, but the people on board have already been rescued (Kopacz, Morgaś & Urbański, 2007).

The immediate cause of the LRIT long-range identification and tracking system was the 11 September 2001 terrorist attack on the World Trade Center. The United States Coast Guard (USCG) proposed the idea of LRIT to simultaneously track 50,000 different ships worldwide. The system was developed at the initiative of the IMO to facilitate control, international cooperation, and vessel traffic management. A message from a ship is received by a telecommunications satellite. The communication networks used in the operation of the LRIT are Iridium and Inmarsat (C and D+). The communications service provider is responsible for the operation of the satellites, the infrastructure necessary for the system to function properly, and its maintenance (Szcześniak & Weintrit, 2012, pp. 83–84).

SafeSeaNet is a maritime information exchange system for the EU's member states, consisting of a network of national SafeSeaNet systems interconnected through the central SafeSeaNet system. It has been developed to facilitate the exchange of data relevant to maritime safety, security of ships and port facilities, protection of the marine environment, efficiency of vessel traffic, and maritime transport between member states in electronic form. The collection and exchange of information is mainly, but not exclusively, about entries and exits to ports and the movements of certain types of ships (AIS). These include all ships of more than 300 gross tonnage (GT), fishing, tourist, and cargo ships that are 45 m in length and over, and all ships carrying dangerous cargo regardless of size (Pietrzykowski & Nozdrzykowski, 2013).

Analysis of the size and structure of the fleet – own research

Purpose of the study

The purpose of this study is to analyze the feasibility of using automatic identification system (AIS) maritime traffic data in terms of its suitability to accurately assess the utilization of the potential of a specific fleet within the offshore shipping industry. This assessment includes a typology of the operational parameters of a given ship, or the entire fleet of a shipowner in relation to the potential they present and in relation to other periods and assignments the ships have previously performed. It is the differences in the way that these vessels operate that provide the starting point for conclusions regarding areas and methods of optimizing the use of the offshore fleet under all the conditions previously described that limit this optimization.

The research was conducted based on selected features from the two databases described below. The authors' interest focused on the following features: GPS position of the ship, ship type (cargo or passenger), ship status (aground, anchored, moored, not under command, restricted maneuverability, underway sailing, or underway using its engine), ship draught, service speed, total engine power, and deadweight. Features were aggregated in different ways, for example, the status of the ship with total hours spent during status or GPS position and actual speed.

Research methodology and data sources

The analysis was performed with the use of two databases. The first one is the AIS database of maritime traffic in the North Sea, prepared by S&P Global. The database contains 32,390,057 records of information on vessel GPS position, ship type, IMO ship number, movement date, speed, draught, heading, destination, and move status. The second one is a database of technical parameters of offshore vessels prepared by scientists from the University of Gdańsk. The database contains 145,318 records and includes information such as shipowner, deadweight, service speed, main engine total power, type and subtype of vessels, and IMO ship number. These two databases were joined by the IMO ship number.

The data verification was performed on both databases while empty cells, NA (not available) values, and values out of range were not considered.

The primary analysis of data was focused on:

- geospatial data analysis for vessel movement with the different aggregation factors, i.e., ship type (cargo or passenger), draught, speed, service speed, and main engine total power;
- data aggregation for statistics of the operation types with, for example, moored, underway using its engine, etc.

For the analysis, the R language was used with the following libraries: sp – classes and methods for spatial data; dplyr – for working with data frame-like objects and filtering the data; ggplot2 – for creating the graphics; geosphere – for computing distances and related measures for angular (longitude/latitude) locations; ggmap – for spatial visualization with ggplot2.

Evaluation of the transport of passengers

The first group of considered ships was offshore passenger ships. The routes in which the passenger ships are traveling on the North Sea are shown in Figure 2. We can easily notice that there are some characteristic points for the ships that are moving. These are the routes that passengers (pax) travel to locations of oil rigs, platforms, and wind farms.

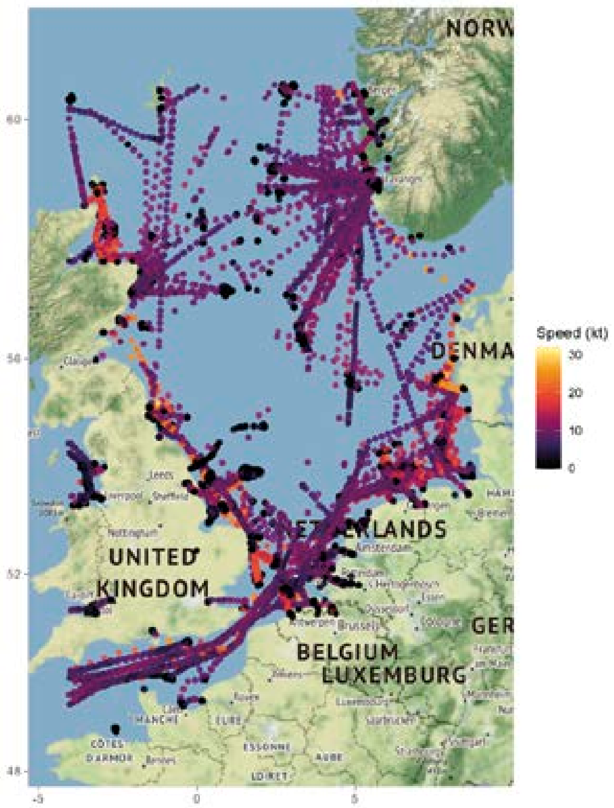

Figure 2. Routes of the passenger ships with their speed marked in color

The transport of pax was analyzed by filtering the data with ship type equal to "*Passenger*". It provides the total number of records equal to 372,334. Next, the records were aggregated by the field "*Ship status*" and the results were presented in Table 1.

Additionally, the owners of the ships were checked and aggregated. The most frequent movements of the ships were observed in the case of owners Orsted A/S (87,457 hours), Acta Marine Holding BV (81,222 hours), Repsol Oil & Gas Canada Inc. (38,238 hours), Chevalier Floatels BV (36,823 hours), Amasus Shipping BV (16,652 hours), Northern Offshore Services AB (10,983 hours), and World Marine Offshore A/S (10,814 hours). The total number of ship owners in the filtered data is equal to 110.

Table 1. Number of hours spent by passenger ships with different ship status

No.	Ship status	Hours
1	Aground	302
2	Anchored	4,102
3	Moored	201,124
4	Not under command	4
5	Power-driven towing astern	3
6	Restricted maneuverability	11,399
7	Underway sailing	2,042
8	Underway using engine	153,357

Considering the time spent at sea by the ships, there are only 9 group owners with a result above 2% (see Figure 3). The percentage of group owner time was calculated as the total group time divided by the total time of all ships spend on the sea. The top 9 ship group owners comprise 80.5% of the total time.

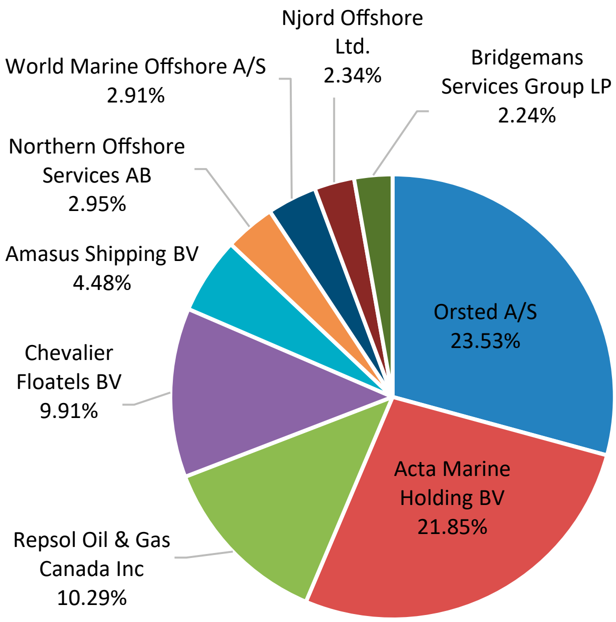

Figure 3. Passenger ship group owners with a total time result higher or equal to 2%

The pathways of ships aggregated by ship group owners, limited to the 9 groups described above, are shown in Figure 4. We notice that some paths

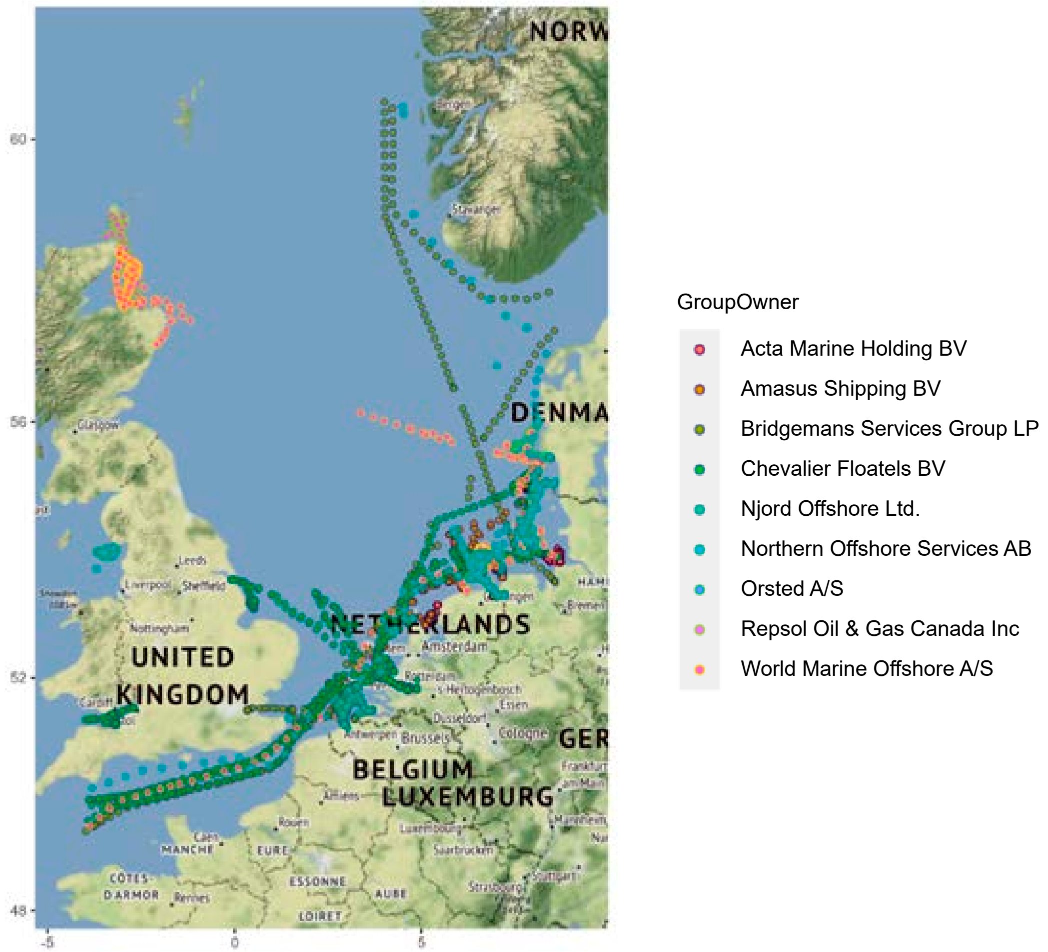

Figure 4. Passenger ship routes with their owners marked in color. Here, the top 9 groups by total time are given

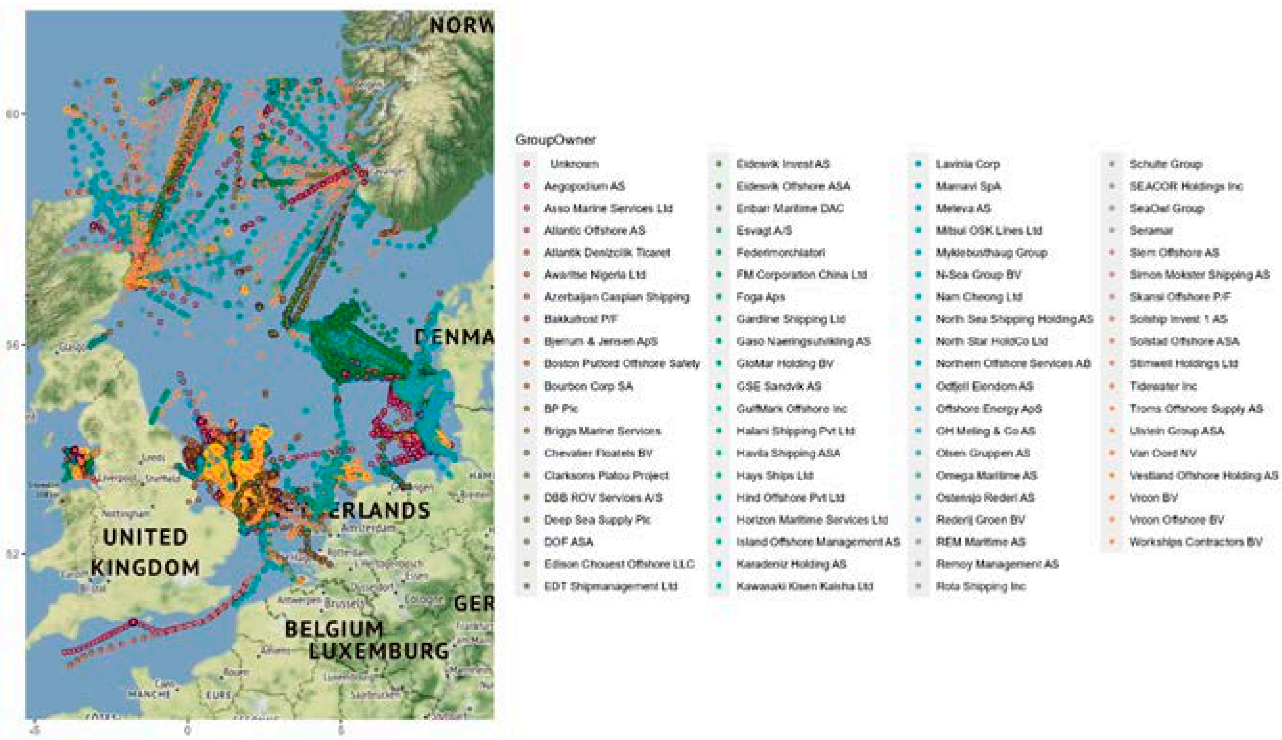

Figure 5. Cargo ship routes with their shipowner marked in color

are only covered by one group owner (for example, Bridgemans Services Group LP or World Marine Offshore A/S).

Moreover, according to the group owners, we compare the passenger ship routes with the cargo ship routes. The transport of cargo was analyzed by filtering the data with ship type equal to "Cargo" and the destination name of the gas, oil, or wind platform. This provides the total number of records equal to 416,009, and the ship routes are shown in Figure 5.

The most frequent ship movement can be observed for the case of Boston Putford Offshore Safety (163,934 hours), Havila Shipping ASA (52,114 hours), Odfjell Eiendom AS (25,815 hours), Mitsui OSK Lines Ltd (23,439 hours), and Vroon BV (11,718 hours).

It is noticeable that the pathways of the passenger-carrying ships are correlated with the paths obtained from the cargo ship data. However, the owner of the ship groups for which vessels travel most frequently differs in both cases.

Additionally, the difference between the draught when the passenger ship is moored and is underway using its engine is calculated according to:

$$\Delta\text{draught} = \text{draught moored} - \text{draught moving} \quad (1)$$

and is shown in column name "Difference" in Table 2. Some ships have a higher draught when they move (for example, IMO 9538531), while this occurs for other ships when they are moored (for example, IMO 9365104).

Table 2. Average values of speed and draught, and difference in draught, for the chosen moored and moving passenger ships

IMO	Status	Average speed	Average draught	Difference
9295103	Moored	0.00	3.11	0.000
9295103	Underway using engine	0.95	3.11	
9295490	Moored	0.00	3.20	0.006
9295490	Underway using engine	1.79	3.19	
9538531	Moored	0.00	5.50	–0.400
9538531	Underway using engine	2.24	5.90	
9668996	Moored	0.00	1.50	0.013
9668996	Underway using engine	3.16	1.49	
9365104	Moored	0.00	4.52	0.130
9365104	Underway using engine	4.08	4.39	

Table 3. Draught statistics for different Ddraught of passenger ships

	No.	Percent	Avg (m)	Min (m)	Max (m)
Ships	139	100.00%			
Ship's delta draught < 0	45	32.37%	–0.71	–0.004	–3.000
Ship's delta draught = 0	61	43.88%			
Ship's delta draught > 0	33	23.74%	0.79	0.001	6.000

The summary of draught differences for three different delta draughts is presented in Table 3. There is a total number of cargo ships equal to 139 in the filtered database. It can be seen that about 32.4% of ships have a difference in draught smaller than 0 (i.e., the draught when they are moving is higher

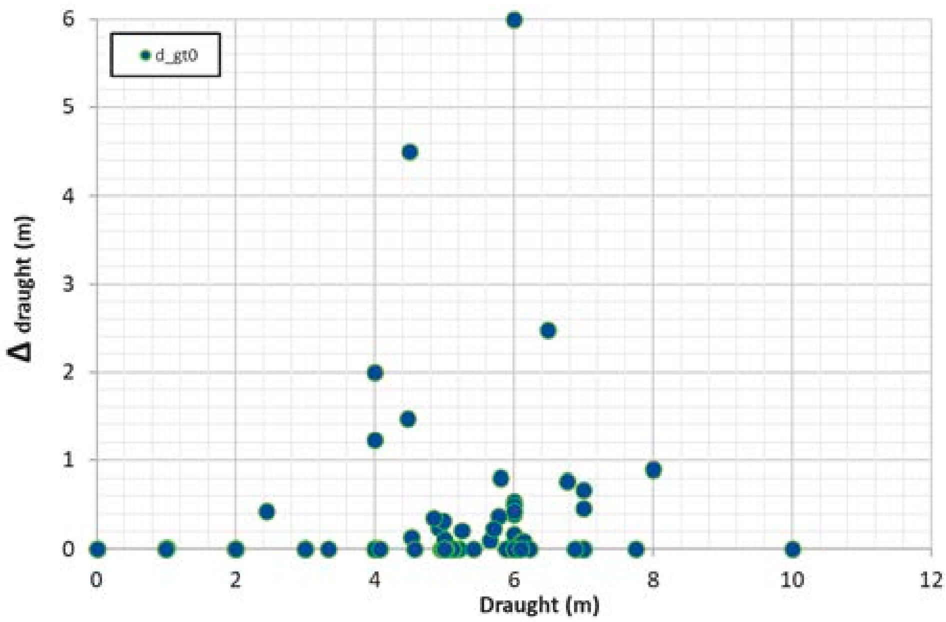

Figure 6. Distribution of the draught and Δdraught for Δdraught > 0

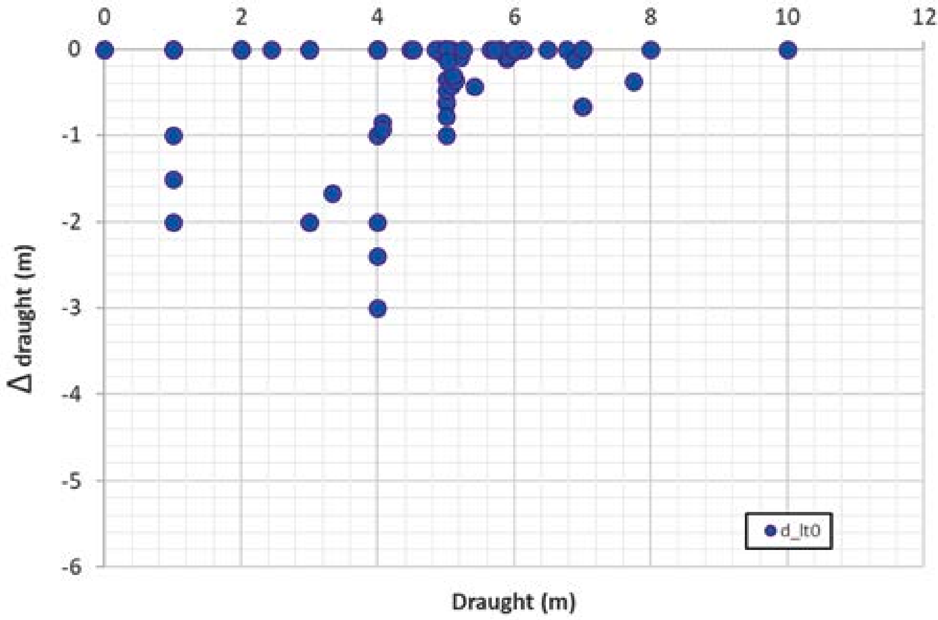

Figure 7. Distribution of the draught and Δdraught for Δdraught < 0

than when they are moored), while 43.88% have no difference in draught, and 23.74% have higher draught when they are moored. The average differences of draught are similar and equal to 71 and 79 cm. The maximum draught differences are equal to 3 and 6 meters. Minimum differences are less than 1 cm, which can be treated as measuring errors.

The distribution of drought and drought difference (i.e., Δdraught) is shown in Figures 6 and 7. It is noticeable that some points can be treated as anomalies; for example, Figure 6 shows a point in which the Δdraught value equals 6 m for a draught equating to 6 meters. The other points are gathered within reasonably similar areas.

There are many errors in the processed database, for example, the lack of information on the ship's speed or missing information on the ship's status. In this case, the data was filtered to obtain the complete records.

Conclusions

Tracking the movement of seagoing vessels can have a positive impact on economic efficiency, especially for shipping. Access to information on the location and course of seagoing vessels makes it possible to optimize shipping routes, saving time and costs. For example, the shortest, fastest, and cheapest routes can be selected based on live information on vessel movements. Tracking the movement of seagoing vessels enables accurate planning of deliveries. By having access to live information on the location and arrival time of ships, they can more accurately plan the delivery of goods to ports and warehouses. Maritime vessel tracking also allows them to control the quality of service. They can, for example, monitor the transit time of goods and compare it with customer expectations, thus improving quality and increasing customer confidence. Better control of safety at sea is also achieved. By having the ability to monitor vessel movements in real time, it is possible to react quickly in the event of hazards, such as ship collisions or accidents. It could be said that maritime tracking tools can help improve economic efficiency by optimizing shipping routes, planning deliveries, controlling service quality, and ensuring safety at sea.

However, currently, several data gaps are experienced and incorrect data delivery may occur, which makes the above-mentioned activities less accurate and reliable. In correlation with the vast scale of the all-day tracked ship movement records, there is a clear need for further research and technology development towards data accuracy improvement and, simultaneously, elaboration of the methods for data gap substitutability with the highest possible precision factor.

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Cite as: Czerwiński, D., Kiersztyn, A., Przyłucki, S., Oniszczuk-Jastrząbek, A., Czermański, E. (2023) Analysis of passenger ships activity in the oil and gas offshore shipping sector in the North Sea. *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 75 (147), 68–78.