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Applications of AIS Data Analysis in the bunkering industry and its related factors

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Abstract

In the ocean fuel transportation industry, the optimization of bunkering operations depends on price, position, delays from the expected route, and the cost of delays caused by the bunker operations themselves. Despite their potential importance, detailed bunker activity statistics at each port of call (e.g: waiting time, barge capacity, berth, or berth) are not available. A greater hid deviation from the usual method is that the provider, therefore, arrives past due for a bunker mission. The purchaser commonly has a time slot wherein it anchors as much as acquire bunker. If the bunker barge arrives past due, the purchaser can be beneath neath time strain because of closing dates for shipment, which may also reason the purchaser to interrupt the bunker operation earlier than the agreed quantity of bunker is supplied. This is obtainable confined interest from transport businesses and charterers because the fraudulent quantity is thought to be negligible. However, studies have recommended that the aggregated quantity of misplaced bunker is of big value. To screen such conduct we intend to make use of Automatic Identification System (AIS) statistics from bunker barges and numerous vessels they supply.

Introduction

AIS turned into advanced as a useful resource for vessel tracking and collision avoidance. It has ended up a multipurpose tool, applied with inside the calculation of emission profiles and in gaining perception into technical and operational power

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performance in transport. AIS has an extensive ability of packages and has consequently ended up with an increasing number of prevalent. To hit upon cheating, we want to become aware of what everyday operation conduct is. With the opportunity of tracking vessels and storing massive quantities of statistics, we will hint at the barge and vessel`s ancient movements. By investigating the conduct of the bunker barge and the vessel for the duration of bunker operations, we can be capable of becoming aware of everyday conduct and thereby anomalies.

Communication is important for ship operators, ports, and suppliers. Train operators can benefit from the knowledge of service and refuelling wait times to make informed operating decisions. Examples of such decisions are: deviating from tunnels or tunnels during cargo operations, route planning, travel speed selection, and quantity decisions hold to load. Bunker suppliers can use the age and capacity of their bunker barge fleet and capacity, service time, and fuel prices to assess the location. they put themselves in the center/inter-port competition. This is useful in decisions regarding service pricing, fleet renewal, fleet location, or fleet Maintenance. Port operators can track and compare bunker service times and gauge how this affects their core business (cargo/passenger) and port competitiveness and, if service does not yet exist, bunker integration as part of their service team. Take the port of Antwerp as an example.

The bunkering statistics presented in this paper are derived from Automatic Identification System (AIS) data from ships. AIS has expanded from its primary use as an aid to navigation and collision avoidance1 to several other uses including being a tool for vessel trading pattern recognition. AIS data has been used extensively as part of both commercial activities and research, with more suppliers of data entering the market and benefiting from an ever-increasing network of low-earth orbit satellites and coastal receivers. Higher observational frequency also creates an escalating challenge in terms of algorithm effectiveness for large databases, as is the case for the empirical study in this paper.

Literature Review

The literature review for this project was done to get an initial understanding of how AIS data has been of use in research. AIS data have been utilized in a wide spectre of research fields, but none specifically explore the use of AIS data for monitoring bunkering or similar vessel-to-vessel operations. In cooperation with four other students working AIS data-related project thesis, I have studied 16 articles. Based on these articles, we try to categorize and give an overview of the AIS data literature. Further on, we assess studies assumed to have relevance for this project thesis. However, only a few of these studies are of interest to the thesis, and these are presented and discussed.

Sr no.	**Title**	**Author of source**	**Citation**	**Research Gap**
1	How big data enriches maritime research – A critical review of the Automatic Identification System (AIS) data applications	Dong Yang, Lingxiao Wu, Shuaian Wang.	Yang, D., Wu, L., Wang, S., Jia, H., & Li, K. X. (2019). How big data enriches maritime research–a critical review of Automatic Identification System (AIS) data applications. Transport Reviews, 39(6), 755-773.	The only chasm I have found in this research work is it's based on the pros of AIS. so I think it's required to mention some necessary cons and safety issues related to the AIS and its dependency.
2	Generating bunkering statistics from AIS data: A machine learning approach	Gabriel Fuentes	Fuentes, G. (2021). Generating bunkering statistics from AIS data: A machine learning approach. Transportation Research Part E: Logistics and Transportation Review, 155, 102495.	Operations from individual ports which do not exist in the paper.
3	Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions	Ziaul Haque Munim, Mariia Dushenko, Veronica Jaramillo Jimenez, Mohammad Hassan	Munim, Z. H., Dushenko, M., Jimenez, V. J., Shakil, M. H., & Imset, M. (2020). Big data and artificial intelligence in the maritime industry: a bibliometric review and future research	The only chasm I have found in this research work has not exactly determined the future issues of the technology in the maritime business.

		Shakil & Marius Imset	directions. *Maritime Policy & Management*, *47*(5), 577-597.	
4	Sustainable Development of Maritime Operations in Ports	John Dinwoodie,1 * Sarah Tuck,1 Harriet Knowles,1 James Benhin1 and Mark Sansom	Dinwoodie, J., Tuck, S., Knowles, H., Benhin, J., & Sansom, M. (2012). Sustainable development of maritime operations in ports. Business Strategy and the Environment, 21(2), 111-126.	The only chasm I have found in this research work is that it is accordingly an old research work that does not contain the newly generated problems in maritime operations.
5	Data analytics for fuel consumption management in maritime transportation: Status and perspectives	Ran Yan a , Shuaian Wang a, Harilaos N. Psaraftis	Yan, R., Wang, S., & Psaraftis, H. N. (2021). Data analytics for fuel consumption management in maritime transportation: Status and perspectives. Transportation Research Part E: Logistics and Transportation Review, 155, 102489.	The only chasm I have found in this research work is related to the comparison of other methods with AIS as it is also a progressive helping tool for the maritime Industry.
6	Estimation of Vessel Emissions Inventory in Qingdao Port-Based on Big data Analysis	Xing Sun 1,2, Zhe Tian 1 , Reza Malekian 3 and	Sun, X., Tian, Z., Malekian, R., & Li, Z. (2018). Estimation of vessel emissions inventory in Qingdao port based on big data	The only chasm I have found in this research work is it revolves around vessel emission control by using data analytics and AIS. But its ethical

		Zhixiong Li	analysis. Symmetry, 10(10), 452.	ways to use for certain environmental aspects are insufficient.
7	A Feasibility Study of Assessing Bunkering Operations Through AIS Data	Marion Marines	Aarsnes, M. (2018). A Feasibility Study of Assessing Bunkering Operations Through AIS Data (Master's thesis, NTNU).	The only chasm I have found in this research work is it defines the AIS data readings and their applications by statistical data rather than all other needs of usage in bunkering operations.
8	An Introduction to Assessing Bunkering Operations Through AIS Data.	D Wu, M Aarsnes	Wu, D., & Aarsnes, M. (2017). An Introduction to Assessing Bunkering Operations Through AIS Data. Project Report, NTNU.	The only chasm I have found in this research work is that it is a basic understanding related to AIS but no safety & security factors related to the AIS are mentioned in its applications or uses.
9	Exploiting AIS Data for Intelligent Maritime Navigation	E. Tu, G. Zhang, L. Rachmaw ati, E. Rajabally and G. -B. Huang	E. Tu, G. Zhang, L. Rachmawati, E. Rajabally and G. -B. Huang, "Exploiting AIS Data for Intelligent Maritime Navigation: A Comprehensive Survey From Data to Methodology," in IEEE Transactions	The only chasm I found in this research work is it's based on the technological aspect of AIS, not its physical characterizations.

			on Intelligent Transportation Systems, vol. 19, no. 5, pp. 1559-1582, May 2018	
10	How big data enriches maritime research – a critical review of Automatic Identification System (AIS) data applications	Yang, D., Wu, L., Wang, S., Jia, H., & Li,	Yang, D., Wu, L., Wang, S., Jia, H., & Li, K. X. (2019). How big data enriches maritime research–a critical review of automatic identification system (AIS) data applications. *Transport Reviews*, *39*(6), 755-773.	
11	Towards Smart Port: An Application of AIS Data	A. Rajabi, A. Khodadad Saryazdi, A. Belfkih and C. Duvallet	A. Rajabi, A. Khodadad Saryazdi, A. Belfkih and C. Duvallet, "Towards Smart Port: An Application of AIS Data," 2018 IEEE 20th International Conference on High-Performance Computing and Communications; IEEE 16th International Conference on Smart City; IEEE 4th International Conference on Data Science and Systems (HPCC/SmartCity/DSS), 2018, pp. 1414-	The only chasm I found in this research work is it talks about port logistical activities of AIS.

			1421, doi: 10.1109/HPCC/SmartCity/DSS.2018.00234.	
12	An AIS data Visualization Model for Assessing Maritime Traffic Situation and its Applications	Jiacai, P., Qingshan, J., Jinxing, H., & Zheping, S.	Jiacai, P., Qingshan, J., Jinxing, H., & Zheping, S. (2012). An AIS data visualization model for assessing maritime traffic situations and its applications. Procedia Engineering, 29, 365-369.	The chasm I found in this research work is nothing but the applications mentioned are from a long way back.
13	Traffic knowledge discovery from AIS data	G. Pallotta, M. Vespe and K. Bryan,	G. Pallotta, M. Vespe and K. Bryan, "Traffic knowledge discovery from AIS data," Proceedings of the 16th International Conference on Information Fusion, 2013, pp. 1996-2003.	The only chasm I found in this research work is it discusses all the statistical activities in nature which is difficult to understand and judge for any not logistical background person.
14	Development and analysis of AIS applications as an efficient tool for vessel traffic service.	S. J. Chang	S. J. Chang, "Development and analysis of AIS applications as an efficient tool for vessel traffic service," *Oceans '04 MTS/IEEE Techno-Ocean '04 (IEEE Cat. No.04CH37600)*, 2004, pp. 2249-2253	The only chasm I found in this research work is nothing it's the detailed prospectus of AIS data and its applications using physical and technical aspects as well.

			Vol.4, doi: 10.1109/OCEANS.2004.1406499.	
15	Statistical analysis of motion patterns in AIS Data: Anomaly detection and motion prediction	B. Ristic, B. La Scala, M. Morelande, and N. Gordon	B. Ristic, B. La Scala, M. Morelande and N. Gordon, "Statistical analysis of motion patterns in AIS Data: Anomaly detection and motion prediction," 2008 11th International Conference on Information Fusion, 2008, pp. 1-7.	The only chasm I found in this research work is it's based on a prediction basis which is hard to understand hence this should be explained using simple examples or case analyses.
16	Comprehensive Assessment of Automatic Identification System (AIS) Data Application to Anti-collision Manoeuvring	Felski, A., Jaskólski, K., & Banyś, P.	Felski, A., Jaskólski, K., & Banyś, P. (2015). Comprehensive Assessment of Automatic Identification System (AIS) Data Application to Anti-collision Manoeuvring. Journal of Navigation, 68(4), 697-717. doi:10.1017/S0373463314000897	The only chasm I found in this research work is this focuses on limited applications of AIS data system and its quite older data applications as compared to other research papers available hence the conclusive factors are difficult in the research work.

OBJECTIVE:

The main objectives of this research are to:

1. To obtain variable usage criteria based on AIS data to trace bunkering operations.
2. To obtain operational parameters from bunkering AIS data which measure the quality of operations.
3. To analyse the bugs in the system and recommend some appropriate solutions related to it and also understand the ongoing improvements in the AIS system.

BUSINESS PROBLEM:

This research accesses the problems that will help to analyze how bunkering operations can be identified through AIS data by taking examples that can give any insight on the quality of bunker operations and how it can help to make operations without delay and interruptions in different bunkering operations with variable types of data.

Approach:

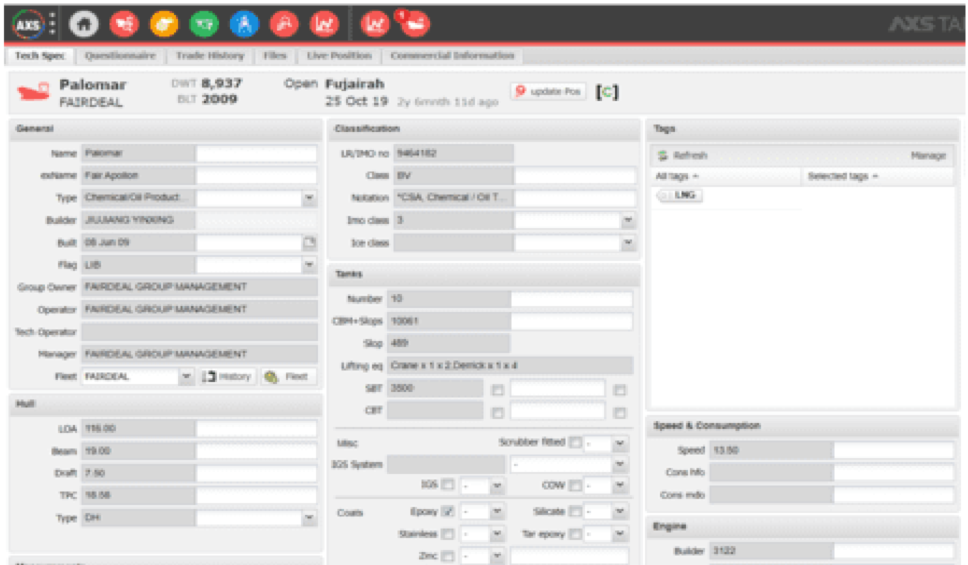
AIS data for a bunker barge is chosen as a basis and plotted with the data visualization tool, Tableau. The plot trace for the bunker barge will be inspected, and potential bunkering operations will be identified by patterns in the plot formed as circles or ellipsoids using sea secondary data study. AIS data from vessels registered close to these circles within the same time interval was plotted for comparison. By visual identification, we were able to detect possible bunkering operations with its applications and by taking one vessel AIS data in particular I will stimulate the overall study and its usage in the whole conducted operations. The bunker barge and the vessel sample AIS data at different rates, so missing data will be found by interpolation to generate lists with equal time stamps. In this study, the Haversine formula will be used to calculate the distance between the coordinates of the vessel and barge to show the usage of AIS and its data analysis. The resulting plots will be used to suggest parameters that can be utilized to identify bunker operations and their applications in the bunkering industry.

AIS Theory and Applications including its related factors

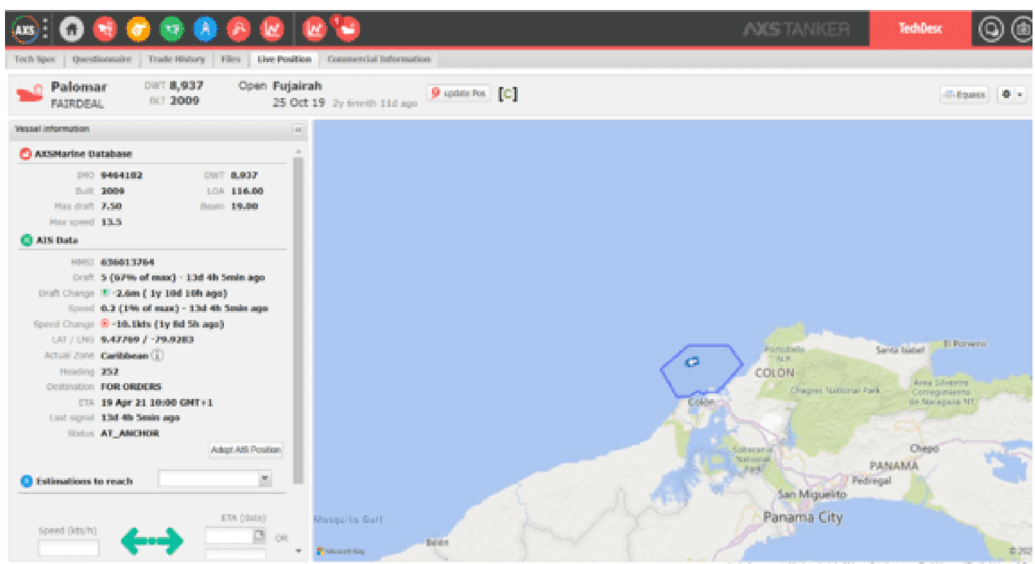
AIS Basics

An automatic Identification System (AIS) is a communication system that utilizes a Very High-Frequency System to transmit Ship movement and technical data are transmitted at specified intervals. AIS data can be recorded from the port and land ground stations, ground AIS data, or specially equipped satellites, satellite AIS (SAIS) data.

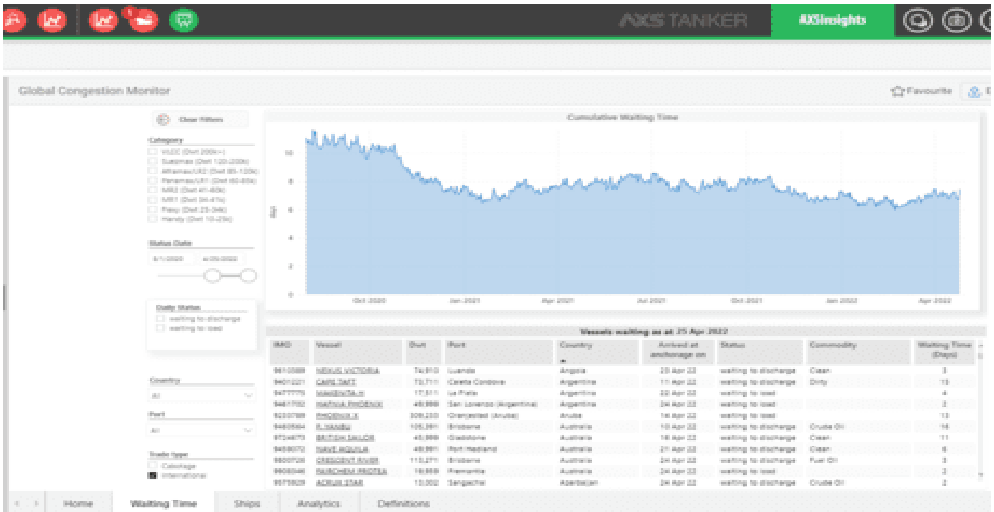
The communication system protocol specifies the technical equipment to use and the type of information to send. The data is divided into static data including navigation details such as ship name and destination, and



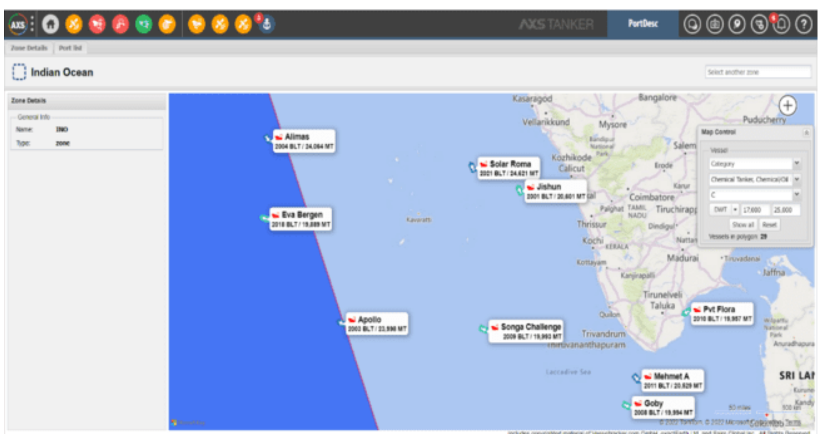
Vessel technical details in AXS MARINE



Live Vessel tracking using AIS coordinates and its updated predicted positions with time.



Port updated waiting time using AXS MARINE



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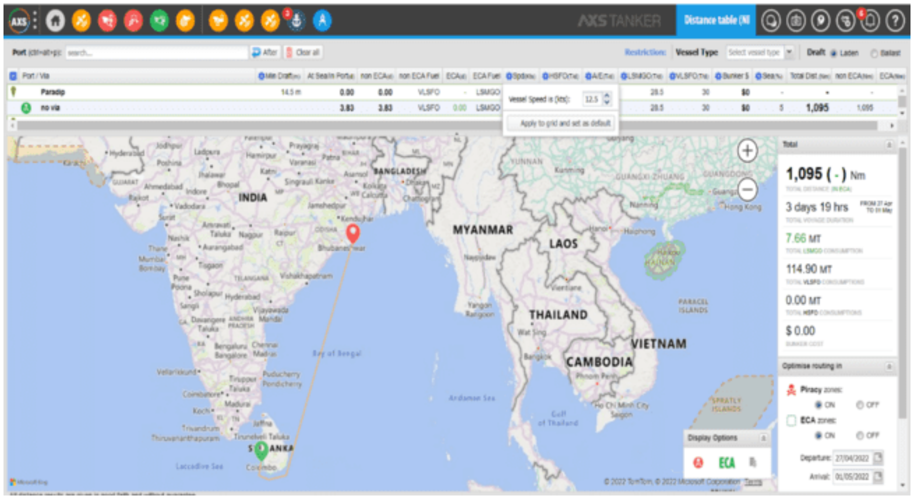
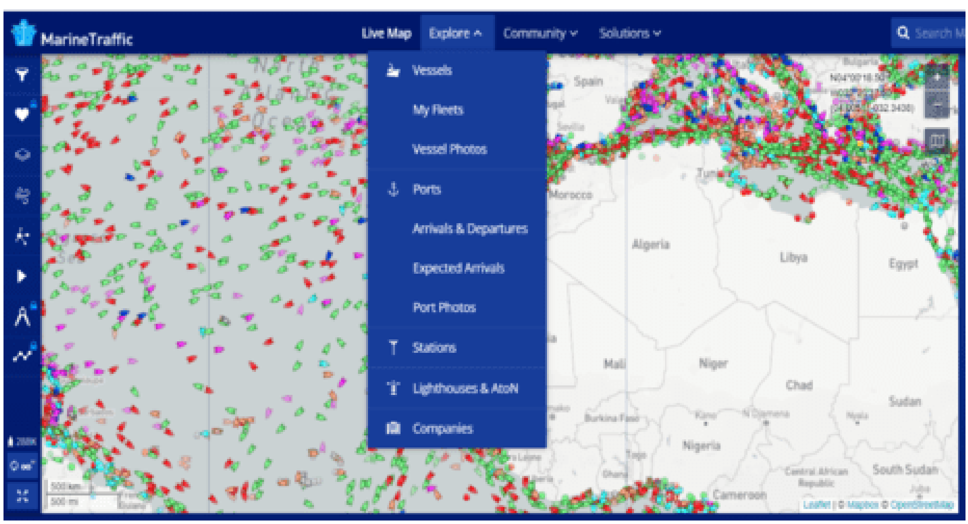
Chemical Vessels with selected Deadweight in the Indian Ocean region.



The distance & time calculations between the two ports from Paradip to Colombo for any vessel.



MarineTrafic vessel data fetching and display dashboard

AIS Data Content

The AIS data used in this project is provided by VesselTracker. The data is sampled from raw AIS data with a time interval of ten minutes, meaning that each AIS sample is chosen as the one with a time difference closest to ten minutes from the last AIS data sample.

The raw AIS data is sampled with varying time intervals depending on the navigation status. For example, when the vessel is anchored or at berth the raw data sampling rate can be four minutes while it can be ten seconds when the vessel is underway. The raw data is retrieved from both base stations and satellites. As mentioned previously this project thesis aims to investigate bunkering operations that require data on a high-resolution level. Terrestrial is therefore used and sampled to a rate sufficient for the project (10-mins intervals).

The main components used for this project work are IMO numbers, SOGs, latitudes, and longitudes. These are described in detail below.

Methods of usage & Calculations

This paper presents various methods which aimed either to improve the quality of the data which will be utilized further in the below-presented case study. And made us understand all the used methods for improving the AIS data visualizations and their related calculations.

Distance between vessels:

The accuracy of the reported data is +/- 10 meters, so tracking at high-resolution levels can result in greater uncertainty. The recorded distance between the two vessels also depends on the location of the AIS transceiver. Depending on the bow orientation of the ships, the measured distances range from the distance of the normal lines between the transceivers when the ships are lined up to a specific distance depending on the length of the ship when the bow orientations of each ship are opposite to each other.

It is subject to change with this in mind, the minimum and maximum distances between the two vessels should be set to the minimum and maximum possible distances between the AIS transponders, respectively. Based on Figure 5.1, if the AIS transponders on both ships are in the same position, the minimum normal distance is C + C and the maximum distance is D + D. In addition, the bow orientation of the ship needs to be considered.

Distance between geographic coordinates is calculated by using various formulas mentioned below:

The geographic location of the ship and bunker barge is indicated in coordinates and due to the curvature of the earth, the distance between the given coordinates must be calculated using appropriate means. Several methods have been proposed for calculating geographic distances by specifying latitude and longitude compared to two known methods. Both algorithms refer to a particular shape or representation of the Earth. However, the Earth is not a perfect geometry, it is close to an oblate spheroid. There is a bulge around the equatorial bulge, which is shaped like a sphere along the polar axis, resembling the shape of an egg or pear. Therefore, the accuracy of both of the following expressions will be reduced.

Haversine Formula: as an assumption approach to calculate the observatory distance on a spherical shape:

The Haversine formula is used to calculate the distance on the sphere. Usually used for great circle distances from two sets of coordinates. This equation is based on the assumption that the shape of the earth is spherical, and the general haversine equation is given in Equation 5.2.

<u>Case Analysis & Discussions</u>

This case study evaluates how to identify a bunker operation from AIS data and parameters derived from an AIS bunker operation message that can explain the quality of a particular bunker operation. The case study focuses on barges operating in Singapore. Singapore's port has been selected as one of the busiest bunker ports in the world (the gateway to east-west trade by sea). As a popular bunker port, it was a scene of a large number of documented bunker scams. In addition, the Singapore Strait limits the flow of traffic to concentrated areas, which can narrow the geographic scope of case studies. To conduct a case study, we will conduct a survey based on AIS data from a particular bunker vessel operating at a bunker supplier company that owns a fleet of bunker vessels.

Tableau was used as a data visualization tool (data plot) technique used to interpret the data.

Identify AIS messages related to the bunker:

First, formulate some properties of the AIS message sent during the bunker operation. Bunkering usually occurs when the ship is moored at sea, but it can also occur when the ship is moored. Given this, AIS messages sent during bunkering should report slow or zero speed when pinned with the receiving vessel.

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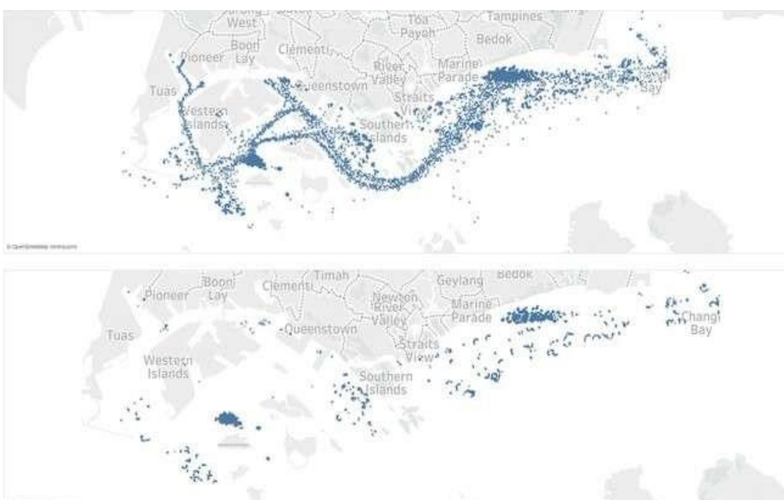
Characteristic SOG and AIS patterns;

The AIS data for the bunker vessel is visualized in Figure 6.2. The figure above shows a trace of unfiltered data. By filtering this data at a specific speed limit, you get a second number that represents the location of a potential bunker. The 0.5 knots SOG initially turned out to be a sufficient filter limit, as there were enough points left to indicate where the ship had stopped for a long time.

Satellite image of AIS messages from sample bunker barge, (upper) is unfiltered and (lower) is filtered.

<u>Explanation of the above figure</u>: Observe some areas where AIS messages are dense by evaluating the data visualized in the figure below in Figure 6.2. The figure shows the case of such a concentration.



<u>Conclusions and Recommendations</u>

The main goals of this study were set out by the introductory department as follows:

1. Definition of criteria for identifying bunker operations

2. Obtain operational parameters from the bunkered AIS data and measure operational quality.

3. To study detailed applications of AIS data as well as their reliability.

The first goal of our case study, we suggested a way to identify the operation of the bunker. The need for tools to handle large amounts of data automatically became apparent. However, we were able to formulate possible script concepts and key input parameters to identify bunker operations. The case study specifies a set of parameters that need to be filtered to receive AIS messages sent during the "idle time". Idle time is a situation where bunkering may have taken place. No effort was made to evaluate the validity of the parameter range, as the values selected provided satisfactory data for further work. Finding a potentially bunkered ship (a bunker candidate) was easy, so the determined idle time can be considered satisfactory. We used Vesseltracker, a function of the external AIS database, to get candidate AIS data for a range of idle times. We have proposed a method (script) to calculate the distance between a candidate and a barge to determine if bunkering is taking place and in which bunkering is taking place. This method has been shown to provide results for specific cases by checking the trajectory of candidates before and after bunkering. The validity of this method has not been properly evaluated because the procedure is tedious. Therefore, this method was not executed on a larger dataset to evaluate its effectiveness.

Second purpose:

In addition, it was suggested how the bunker time frame functions as an operational parameter to explain the quality of the bunker operation. This is the ratio of the time the ship has to wait for the barge to the time the ship is moored after the bunkering is complete. This has been proposed as an operational parameter related to the quality of the bunker. The parameter may indicate whether a particular barge arrives consistently late. Due to time constraints, there was no definition of how these parameters would be calculated automatically for bunker replacement. Whether this operating parameter correlates with intentional delay was not evaluated due to a lack of parallel data. For example, A barge dataset is known to arrive intentionally late.

Recommendations for Further Work:

The ultimate goal of the project is to define indicators of quality performance for bunker vessels based on a set of operational parameters. This work was done by suggesting operating parameters without evaluating their effectiveness. Therefore, it is clear to evaluate how the parameters correlate with different barges with known bunker performance qualities.

You also need to automate the calculation of time slot parameters. One way to evaluate the time slot parameters is to split the bunkering operation based on the type of ship being bunkered. This allows you to leverage your knowledge of the mode of operation of each type of vessel. For example, if you know that certain ship types tend to be in close timing, you can compare the time frame parameters for those ships with the average for all ship types. In this example, we assume that the tighter the schedule, the higher the penalty for ship delays, and the more attractive it is for fraudulent barges to arrive intentionally later than the order.

The important role that AIS data can play is in monitoring ship performance to:

1] Check and react to show data testified in the noon report (heading, location, speed distance).

2] Recognize steady-state/unstable state situations in an active division.

3] Presents a summary of key fleet functioning info for fleet managers.

4] Using a wealth of information available through AIS data, ABS expands its services to provide the best possible advice to customers.

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