Marine Trajectory Using Automatic Identification System (AIS) Data of Port Klang Waterway

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Abstract. Port Klang Malaysia is a key maritime gateway and essential logistical hub for the country. Its central role in Malaysia's economy necessitates ensuring safe marine navigation within its bounds. This research uses the AIS dataset to analyze marine traffic density and patterns in Port Klang. Data from 72 hours over three months, averaging 24 hours monthly, was scrutinized. Vessel positions, marked by latitude and longitude, were mapped, producing density maps categorized by vessel type. This provided detailed insights into traffic flows. The study highlights the value of AIS data in enhancing navigational safety and logistics in vital maritime areas.

Keywords: Automation Identification (AIS), Malacca Strait, Marine Traffics, Trajectory.

1.0 Introduction

Malaysia, a significant player in the Asian economy with a strong presence in global trade, boasts a thriving coastline that plays a vital role in its intricate logistics network, primarily relying on water transportation. Port Klang, a key component in meeting the logistical demands of the economically advanced Klang Valley and Kuala Lumpur, emphasizes the importance of maritime trade. This synergy has led to a rapid growth in maritime traffic, increased cargo volumes, and larger vessels serving Port Klang. Over the last decade, Port Klang witnessed an impressive 40% rise in the number of vessels utilizing its services, surging from 259,094 vessels in 2006 to an astounding 441,580 vessels in 2015 [1]. These statistics highlight Port Klang's indispensable role in Malaysia's maritime landscape and broader economic activities.

The Strait of Malacca holds immense global importance in the 21st century, serving as a critical maritime passage connecting the Indian and Pacific Oceans. In 2011, it

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witnessed the transit of over 60,000 vessels, transporting about 25% of the world's traded goods, including vital resources like oil, Chinese manufactured products, and Indonesian coffee. Notably, around 35% of globally shipped oil containers pass through this strait, linking the Middle East to China, Japan, South Korea, and the Pacific Rim. This narrow 890- kilometer passage between Peninsular Malaysia and Sumatra poses significant navigational challenges. Analyzing vessel traffic patterns is vital for safe navigation, and it carries substantial economic implications [2].

2.0 Literature Review

Numerous studies have explored the analysis of maritime traffic trajectories and densities by harnessing the power of Automatic Identification System (AIS) data. These investigations exhibit a broad spectrum in terms of their research focus, geographical settings, environmental conditions, and temporal scopes. The AIS, a system designed to autonomously transmit both dynamic (kinematic) and static (identity) information, plays a pivotal role in the realm of maritime communication, facilitating the seamless exchange of navigational data between AIS-equipped terminals.

In December 2004, the International Maritime Organization (IMO) issued a mandate stipulating that all vessels exceeding 299 Gross Tonnage (GT) engaged in international voyages must be equipped with a Class A AIS transponder for AIS data exchange, while smaller vessels had the option to utilize a Class B AIS transponder [3]. This directive originated from the 2002 Safety of Life at Sea (SOLAS) agreement, which required the transmission of essential vessel information, including name, registration, ship type, destination, as well as real-time position, speed, and heading [4].

The widespread adoption of AIS technology has ushered in a revolution in the analysis and mapping of maritime traffic density within the confines of Port Klang. AIS now facilitates the provision of information that was once the exclusive purview of contemporary Vessel Traffic Service (VTS) centers, endowing mariners with more precise and clearer data for vessel identification and communication within VHF range [5]. Remarkably, AIS boasts the capability to handle well over 4,500 reports per minute, with updates occurring as frequently as every two seconds. To effectively manage this high broadcast rate and ensure reliable ship-to-ship communication, AIS employs 'Self-Organized Time Division Multiple Access' (SOTDMA) technology [6].

AIS data stands as a linchpin for maritime voyage safety, enabling the detection of anomalous ship routes and providing warnings to nearby vessels. A ship path anomaly detection model integrates historical data with real-time capabilities, effectively combining batch and stream computing [7]. This model leverages stream computing for trajectory data and real-time annotations, while batch computing handles F-DBSCAN outlier detection, model training, and detection services. By incorporating a memory database, this system adeptly identifies abnormal ship paths in real-time AIS data, as empirically demonstrated [8].

AIS serves myriad purposes in maritime planning, with its primary function being the delineation of sea area usage, often expressed as vessel density per unit area. This succinctly summarizes the utilization of sea regions within a scaled grid. It is crucial to consider the time duration represented by AIS density grid outputs, which may span from hourly to annual statistics. Additionally, the scale of the grid holds significance, with smaller areas necessitating finer grids to ensure appropriate data resolution [9].

3.0 Method

3.1 AIS Data Collection

The data collection process commences with an antenna receiving VHF signals emitted by vessels, as depicted in Fig. 1. Positioned at an elevated point approximately 130 meters above sea level, the antenna is strategically oriented towards the Malacca Strait and the port to optimize data coverage. Data is collected continuously within specific timeframes as outlined in the study [10]. Subsequently, an AIS receiver undertakes the task of converting the received VHF radio signals into a decoded digital format, specifically the NMEA signal. This digitalized data is tailored for direct interfacing with a PC or Chart Plotter device [11].

In the subsequent phase, the AIS Decoder plays a pivotal role in processing AIS data. It accepts AIS data from multiple sources, including an AIS Receiver, the Internet, or a Local Network connection. This device performs the intricate task of decoding the received data and presents it in a format conducive to display and analysis. The data can be seamlessly integrated into mapping programs or subjected to in-depth analysis using software such as Excel or database tools.

To visualize and interpret the AIS data in a user-friendly manner, a PC or, potentially, a chart plotter comes into play. Typically, this data is presented visually on a chart or map, facilitating easier comprehension and analysis of vessel movements. Notably, for the purposes of this particular study, a web-based application has been developed to streamline the data analysis process and enhance accessibility for researchers and stakeholders involved in the project.

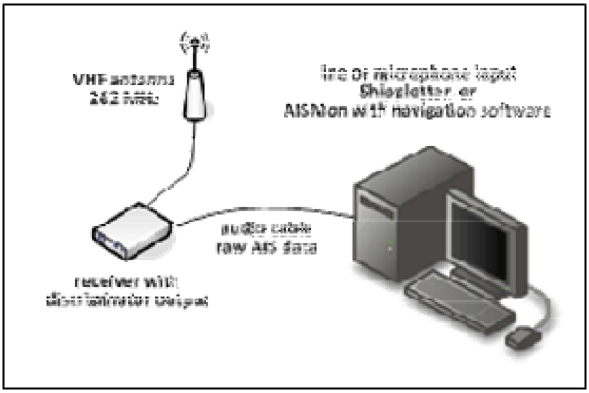

Fig. 1. NMEA Input [12].

3.2 Data Processing

The processing stages, illustrated in Fig. 2, are intricately designed to handle raw AIS files as discrete data 'packages.' These AIS transmissions are received as ASCII data packets, following NMEA 0184 or NMEA 2000 standards (Fig. 1), containing vessel details like MMSI, navigation status, turn rate, speed, heading, and timestamp. This meticulously decoded data is stored in CSV format for analysis. The CSV file is then imported into an SQL database, ensuring data integrity and facilitating structured analysis [13].

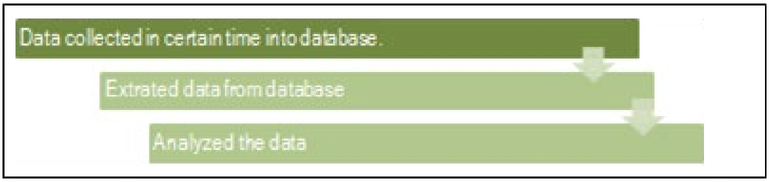

Fig. 2. Data processing flow.

An advanced web-based analytical tool has been thoughtfully crafted to aid in the examination of enriched AIS data. It stands as a robust resource for researchers and stakeholders, providing a user-friendly interface to navigate and interpret maritime data [14]. This empowers users to glean valuable insights, facilitating comprehensive studies and informed decision-making. The incorporation of this web-based analytical solution amplifies research capabilities and dataset accessibility, fostering a deeper comprehension of vessel movements and maritime operations in the study region.

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!AIVDM,1,1,,B,13P<0D3P@oww8H4NdCcQT@Jh2D1E,0*58,26/10/2010 13:24:22
!AIVDM,1,1,,A,13P;LWh02@0wTmvNcO>Kc98h0H=n,0*45,26/10/2010 13:24:22
!AIVDM,1,1,,B,33`ufb0sQT0v:>V0:8GdU9vd00sh,0*12,26/10/2010 13:24:22
!AIVDM,1,1,,A,Dh2=aAA>IN?`00N01>9N000,2*13,26/10/2010 13:24:25
!AIVDM,1,1,,A,13`ufb0uiT0v:J0:8WdU9vj0@?0,0*17,26/10/2010 13:24:25
!AIVDM,1,1,,B,14Q:DFhP1qOw$HL0:A`dt<j0D05,0*56,26/10/2010 13:24:25
!AIVDM,1,1,,A,33kui@021iOwW440>juJq``n00u0,0*5A,26/10/2010 13:24:26
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Fig. 3. NMEA Input.

533131046	FORTUNE QUEEN	3° 4.577' N	101° 20.55	0	55.4	30/08/2022 16:05:	Malaysia
533131055	STRAITS ENERGY	3° 0.377' N	101° 20.70	3.7	204	30/08/2022 16:05:	Malaysia
701						30/08/2022 16:05:	Not defined
533131046	FORTUNE QUEEN	3° 4.577' N	101° 20.55	0	55.4	30/08/2022 16:05:	Malaysia
995331036	NO.19A PORT KLANG	2° 59.664' N	101° 21.756' E			30/08/2022 16:05:	Malaysia
701						30/08/2022 16:05:	Not defined
533131046	FORTUNE QUEEN	3° 4.576' N	101° 20.55	0	55.4	30/08/2022 16:05:	Malaysia
995331036	NO.19A PORT KLANG	2° 59.664' N	101° 21.756' E			30/08/2022 16:06:	Malaysia
533131046	FORTUNE QUEEN	3° 4.576' N	101° 20.55	0	55.4	30/08/2022 16:06:	Malaysia
995330938	NO. 20A PORT KLANG	2° 59.738' N	101° 21.721' E			30/08/2022 16:06:	Malaysia
352980851	EVER CWN	3° 0.967' N	101° 21.36	1.2	257.6	30/08/2022 16:06:	Panama (Republic of)
533131046	FORTUNE QUEEN	3° 4.576' N	101° 20.55	0	55.4	30/08/2022 16:06:	Malaysia
352980851	EVER CWN	3° 0.967' N	101° 21.36	1.2	257.6	30/08/2022 16:06:	Panama (Republic of)

Fig. 4. Decoded data.

4.0 Results and Discussion

The research drew upon an examination of 21,600 hours of AIS data recorded in July, October, and September 2017. To construct a comprehensive traffic pattern for Port Klang, approximately 72 hours were extracted, yielding an average of 24 random hours per month. This dataset represented 540 distinct vessels, each associated with varying MMSI (Maritime Mobile Service Identity) numbers, signifying diverse vessel types and routes. In total, the study yielded 89,542 data points, reflecting AIS transmissions from these vessels. This method entailed the deliberate selection of specific monthly hours to ensure a representative sample of vessel traffic, thereby offering a comprehensive overview of Port Klang's maritime activities during that period. The variety in MMSI numbers underscores the complexity and diversity of maritime traffic in the region. These 89,542 data points are an invaluable resource for future analyses and decision-making pertaining to Port Klang's maritime operations.

4.1 Traffic Density

Figure 5 provides a visual representation of traffic density in the Malacca Straits, with prominent red areas indicating the highest concentration of vessels. Notably, the section spanning from point 1 to point 2 emerges as a focal point of intense vessel traffic.

This heightened activity is primarily due to its role as a vital conduit for international maritime transit through the Strait of Malacca. The prevalence of high-density traffic extends throughout the entire Malacca Straits, a phenomenon driven by substantial maritime operations in the area. It is crucial to recognize that the Strait of Malacca holds immense importance as a critical maritime route, with Port Klang, located at its northern endpoint, ranking as Malaysia's busiest port [15].

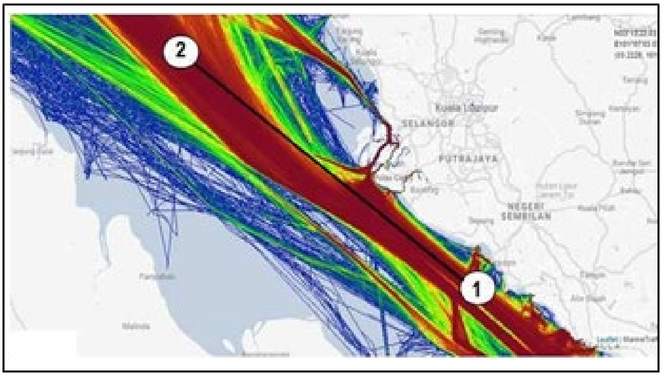

Fig. 5. Traffic density of Malacca Straits [16].

In contrast, Figure 6 offers an in-depth perspective on traffic density exclusively within Port Klang. Notably, a significant hotspot emerges at a crucial entry and exit point for maritime traffic in Port Klang, Malaysia. Point 4 also shows substantial vessel density, as it serves as a vital route for maritime traffic from the Malacca Straits and northern Malaysia. These concentrated high-density zones underscore Port Klang's pivotal role in the broader maritime logistics network [17].

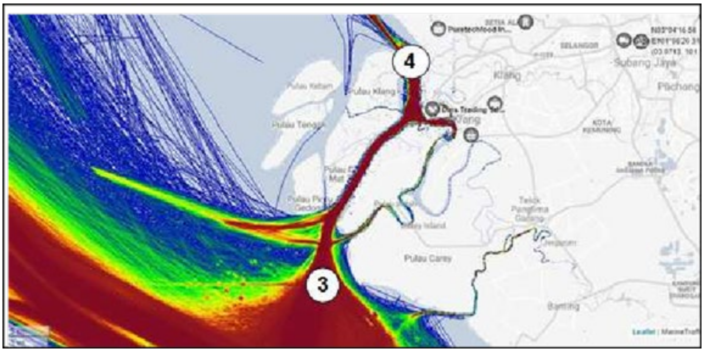

Fig. 6. Traffic density of Port Klang Waterway [16].

Analyzing traffic density patterns in the Malacca Straits and Port Klang has profound implications for maritime traffic management, safety, and route optimization. Comprehensive comprehension of vessel dynamics in these vital zones is crucial for effective navigation and well-informed decisions in maritime transportation [18].

4.2 Traffic Trajectory

In our analytical procedure, we proceeded to create traffic trajectory plots to identify patterns within vessel traffic dynamics. It's important to emphasize that these plotted trajectories represent individual ship movements, but our primary emphasis was on revealing broader traffic patterns rather than diving into specific vessel movements. Figure 7 displays the outcomes of these traffic path plots.

After conducting a thorough examination of the traffic path plots, a distinct pattern emerges, highlighting two significant maritime traffic routes at Port Klang, Malaysia. The first, labeled as Path A, signifies the primary route used by vessels entering and departing Port Klang itself. In contrast, Path B corresponds to the route predominantly utilized by international traffic transiting through the Strait of Malacca. These pathways offer essential insights into the traffic dynamics within this maritime area.

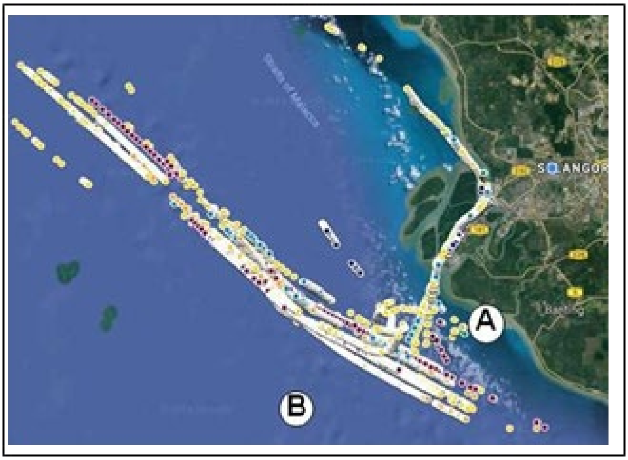

Fig. 7. Traffic pattern of Malacca Straits [16].

Additionally, the traffic path plots offer a compelling depiction of the congestion in the waters surrounding Port Klang, Malaysia. The data analysis and visual representation of vessel routes emphasize the substantial traffic density in two specific zones: the Strait of Malacca and the proximity of Port Klang. The Strait of Malacca, a narrow 805-kilometer waterway between Peninsular Malaysia and Sumatra, Indonesia, holds utmost importance as the principal maritime route connecting the Indian Ocean to the Pacific Ocean [19]. It plays a pivotal role in facilitating trade between major Asian economies, including India, China, Japan, and South Korea.

This insightful examination of traffic trajectories not only furnishes crucial information about traffic patterns within Port Klang, Malaysia but also underscores the critical role of the Strait of Malacca as a vital maritime artery connecting significant global economic centers. Understanding these traffic dynamics remains indispensable for effective maritime management, ensuring safe navigation, and optimizing shipping routes [20] in this strategically pivotal region.

The analysis of traffic trajectories, as depicted in Fig. 8, within Port Klang offers valuable insights into the prevailing maritime routes and patterns within this vital Malaysian port. The trajectory data illuminates the presence of two prominent pathways, referred to as Path A and Path C, serving as essential channels for maritime traffic entering and exiting Port Klang.

Path A and Path C are vital water routes in the Malacca Straits, serving vessels from different regions of Malaysia. Path A is essential for maritime traffic coming from the southern areas of Malaysia, playing a pivotal role in connecting vessels to Port Klang, enhancing the port's maritime connectivity significantly. On the other hand, Path C is crucial for vessels arriving from northern Malaysia and navigating through the Malacca Straits. Similar to Path A, Path C is instrumental in ensuring the smooth flow of maritime commerce and activities within Port Klang, making it an essential component of the port's operations.

Fig. 8. Traffic pattern of Port Klang Waterway [16].

These two distinct traffic pathways, Path A and Path C, underscore the strategic significance of Port Klang as a pivotal maritime gateway in the region. The precise delineation of these traffic routes aids in enhancing navigation efficiency, safety, and traffic management strategies, ultimately contributing to the optimization of Port Klang's maritime operations. This analysis serves as a valuable resource for maritime stakeholders, enabling them to make informed decisions and further streamline the traffic dynamics within this vital.

4.3 Trajectory of Traffic by AIS Type

Figures 9 and 10 clearly illustrate that container vessels and tankers significantly contribute to the heightened vessel density observed in both the Straits of Malacca and the vicinity of Port Klang. Notably, container vessels, in particular, constitute the predominant vessel type engaged in maritime activities at Port Klang. These findings underscore the crucial role played by container shipping in the region's maritime logistics network. Container vessels are instrumental in facilitating the movement of goods, and their prevalence reflects the port's significance as a major trade gateway.

Furthermore, figure 11 provides insights into the spatial distribution of tugboats, revealing their predominant presence in the Northport and Westport areas of Port Klang.

Tugboats are integral to the safe maneuvering of vessels within port waters, and their concentrated presence in these specific zones highlights the strategic importance of these areas for vessel operations and harbor assistance.

Examining the pattern of Bulk Carriers in figure 12, it becomes evident that this vessel type primarily utilizes the waterways within the Malacca Straits. Bulk Carriers are typically associated with the transportation of large quantities of unpackaged cargo, such as raw materials or commodities. The preference for the Malacca Straits as their predominant route underscores the suitability of this corridor for the efficient movement of bulk cargo.

These findings pertaining to vessel types and their distribution have implications for maritime traffic management, port operations, and the optimization of shipping routes within the region. Understanding the vessel type preferences and their spatial distribution enhances our ability to make informed decisions in the realm of maritime transportation and infrastructure planning.

Fig. 9. Trajectory of container [16]

Fig. 10. Trajectory of tanker [16].

Fig. 11. Trajectory of tug [16].

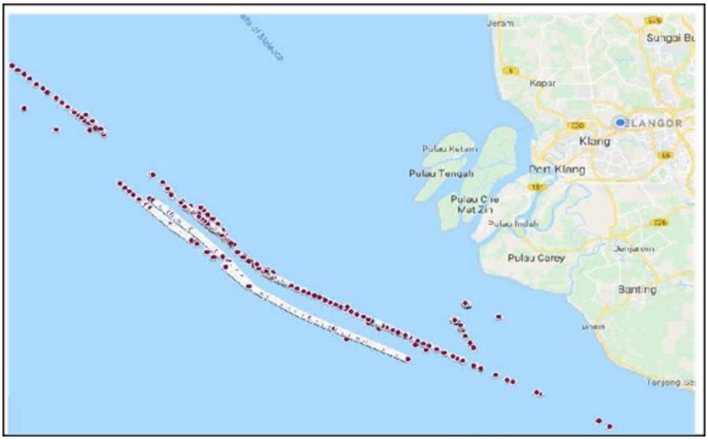

Fig. 12. Trajectory of bulk carrier [16].

5.0 Results and Discussion

This study effectively explores the traffic patterns and congestion levels within the Port Klang waterways while underscoring the invaluable utility of Automatic Identification System (AIS) data in comprehending the dynamics of high-density vessel traffic in bustling waterways. The research involves the collection and examination of AIS data from both Port Klang and the Strait of Malacca, enabling the visualization of traffic density patterns. The precision and real-time nature of AIS data confer significant advantages for traffic research and statistical analyses in heavily trafficked waterways. Looking ahead, this research framework can be expanded to encompass other Malaysian ports like Johor, Kuantan, Penang, and those in East Malaysia, given the country's numerous ports, each with its unique capabilities and infrastructure for extensive cargo transportation. Furthermore, AIS systems continually transmit concise messages containing vital information, such as vessel position, course over ground (COG), speed over ground (SOG), gyro course (heading), and additional data. Consequently, analyzing other AIS-transmitted data can provide further insights into marine transportation dynamics, especially as Malaysia's industrial sector continues to grow, solidifying its role as a pivotal player in global trade. Finally, the findings from this study offer promise for future research endeavors, particularly in the fields of vessel collision risk assessment and the estimation of vessel exhaust emissions.

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