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Safety of Navigation at the Straits of Malacca

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Abstract
The amount of maritime traffic in Malaysia's port waterways continues to increase, and the growth of regional economies, maritime trade and shipping traffic will continue in the future. As the population of shipping traffic grows, so accidents and environmental catastrophes will increase. When an accident occurs, it is essential to understand the root cause to take adequate preventive measures. Malacca strait, one of the world busiest waterways, makes Malaysia water more likely to be a marine incident. Although safety is essential, no extensive study has been conducted on the maritime incident in Straits Malacca. This prevents a clear view of the condition of the marine incident in Straits Malacca. This study aims to determine the pattern of marine incident cases, the frequency-number of marine incident deaths occurring, and establish a frequency-number chart at Straits Malacca. The method used to collect primary data for the research will be interview sessions with the authorities, questionnaires distributed to the people in charge at the respective site, and benchmarking. These data were analyzed using linear regression on the number of cases, type of marine incident, type of ship and fatal marine incident to analyze their growth pattern and compare with the previous study to evaluate the value of Malaysia's social risk curve. It is expected that the number of cases shows a decreasing pattern over the year. The type of ship and type of incident will show the different patterns for each additional category.

Keywords: Straits Malacca, maritime traffic, marine cases, incident, pattern

1. Introduction

Global container trade has increased every year since unitization was introduced to deep-sea routes in the late 1960s. Since 1980, global container port handling has grown at an average annual rate of 9.5%, a growth rate that has continually exceeded underlying trade growth by several percentage points (Global port congestion, 2006). The shipping industry does around 90% of world trading as it is considered a safe, economical, and environmentally benign form of commercial transport (Chauvin, 2013). Maritime traffic volumes in the Malaysian port waterways continue to increase. Given trends with regional economies and seaborne trade, shipping traffic growth will continue (Osnin, 2011).

Inevitably, as the population of shipping traffic grows, so will the likelihood of accidents and environmental catastrophe (Osnin, 2011). When an accident occurs, it is essential to understand the root cause to take adequate preventive measures (Wang, 2012). The power of knowledge is necessary as it can be used to improve existing solutions (Psarros, 2009), which states that improvement can be achieved through considering accident scenarios. For example, improved bridge design management facilitates reducing the probability of collision and grounding events. Also, addressing human interaction with navigation systems or when fire scenarios are developed, crew actions related to detection, firefighting and assisting evacuation are modelled to predict their effects. By introducing risk analysis and cost-benefit assessment into the traditional decision-making process and incorporating operational aspects, the capability for cost-effective safety solutions is increased (Psarros, 2009). This shows the importance of having a clear view of a situation and in the case of this study, is the Malaysia Maritime Incident situation.

Malaysia is a maritime country surrounded by water. With more than 800 total islands, sea transportation is indeed prominent. Malaysia is also home to the Malacca strait, which is one

of the world busiest straits, making Malaysia water more prone to marine incidents. Although safety is essential, no extensive study has been conducted on the marine incident in Straits Malacca, thus preventing a clear view of the maritime incident in Straits Malacca. Without a clear picture of the marine incident in Straits Malacca, a better analysis in finding a better solution couldn't be conducted as stated by (M. Hassel 2011) that it is a problem not only for authorities trying to improve maritime safety through legislation but also to risk management companies and other entities using maritime casualty statistics in risk and accident analysis.

2. Literature Review

2.1 Straits of Malacca

The Malacca Strait is a vital strategic region for seaborne trade. The Malacca Strait is the longest in the world, used for international navigation. From the economic and international trade perspective, the Strait of Malacca is one of the world's most essential and busiest maritime waterways. The Strait is a vital shipping channel linking European Union the with the central Asian countries (Thanh et al., 2015). The Malacca Strait is located between the east coast of Indonesia's Sumatra Island and the west coast of Peninsular Malaysia and links with the Strait of Singapore at its southeast end. The Malacca Strait extends from its northwest extremity at Ujung Baka, Sumatra (5°40'N, 95°26'E) by a line to its southern extremity at Laem Phra Chao, Koh Phuket Island, Thailand (7°45'N, 98°18'E). The Strait extends across its southeastern portion by a line between Tahan (Mount) Datok (1°20'E, 104°20'N) and Tanjung Pergam (1°10'E, 104°20'N) (Zaman et al., 2015).

Three more minor straits are found within this waterway: Bengkali Strait, located between Bengkali and Sumatra; Rupat Strait, between Rupat and Sumatra; and the Johore Strait, between the southern tip of Peninsular Malaysia and the north coast of Singapore. Together, these straits form an important international shipping route linking the Indian Ocean to the South China Sea and the Pacific Ocean, as shown in Figure 1 (Thia- Eng et al., 2000). However, the Straits of Malacca is categorized as a high-risk area for maritime transportation. Based on some researchers, more than 80% of ship's captains or any ship's crew responded that they are worried whenever they need to pass the Strait (Zaman, 2016). The Malacca Straits are bordered by four littoral States, namely Thailand, Indonesia, Malaysia and Singapore. However, the navigational channel passes through Indonesia, Malaysia and Singapore (Thia-Eng et al., 2000). Their length is around 600 nautical miles (nm), with the most comprehensive section of 220 nm near the northwest entrance, narrowing gradually to approximately 8 nm at the southeast entrance near the Riau Archipelago with the depth of the water is irregular, from 17 to 55 m (Thia-Eng et al., 2000).

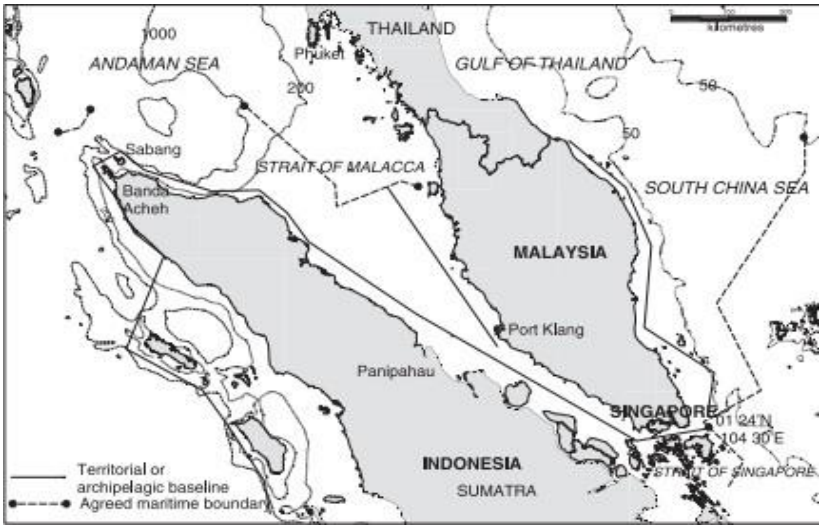

Fig. 1 Map of Straits Malacca. Source: (Thia-Eng et al., 2000)

2.1.1 Topography

The West Coast of Peninsular Malaysia is dominated by coastal plains and basins formed by alluvial deposits, and sandy beaches are found in a few areas. The eastern islands of Sumatra, mainly the Riau Archipelago, are generally made of granitic and old sedimentary materials that are rich sources of tin and bauxite. The broad alluvial coastal plain of central Sumatra consists largely of thick deposits of sediments where Indonesia primary deposits of oil and gas are located. Offshore, there is a mix of 241 islands, coral reefs, estuaries, deltas and lagoons. Some 14 rivers in Sumatra drain into the Straits of Malacca, another 12 significant rivers enter from Malaysia, including the Perak River, which is the second largest (Thia-Eng et al., 2000).

2.1.2 Climatology and oceanography

The Malacca Straits have a tropical climate. They are strongly influenced by the north-east Monsoon, which brings rain from December to February and the dry Southwest Monsoon from June to August. In the two inter-monsoon periods, the weather becomes unpredictable, and the direction of the wind varies with the monsoon seasons. Moreover, there is abundant rainfall, and torrential rains of short duration occur at any time of the year. Visibility in the Straits is clear for 10 km or more about 95% frequency and less than 1 km below 0.5% frequency, except during heavy rain and when haze occurs. Currents follow the topographic configuration of the sea bottom. The surface current flow is more vital during the north-east Monsoon when the dominant direction of the surface current is from the South China Sea to the Andaman Sea.

Surface current also enters from the Andaman Sea but turns northwest to Pulau Penang and the Perak coast. An undercurrent is flowing from the Andaman Sea towards the Straits during monsoon periods which causes a light upwelling near the One Fathom Bank. Wave strength is most vital during the north-east Monsoon while the surface water temperature is warmer during the Southwest Monsoon, ranging from 28°C to 30°C, but drops 1±2°C during the north-east Monsoon. Additionally, primary productivity is constant throughout the whole year but varies geographically. There appear to be higher phytoplankton counts in the south, where water is shallower and vertical mixing and increased nutrient input from rivers from Sumatra. The northern, deeper and more open areas have lower chlorophyll than the shallower and narrower southern areas. On the other hand, Zooplankton varies with the monsoon seasons (Thia-Eng et al., 2000).

2.2 Economic importance of Straits Malacca

The coastal economy of these areas was mainly agricultural; however, in recent years, there has been a shift in employment patterns towards non-agricultural production and services. The farm labour force was 49.9% of the total, while the industrial and service sector was 50.1%, while in Singapore, only 0.2% are now employed in the agricultural and fisheries sectors (Thia-Eng et al., 2000). A lot of Very Large Crude Carriers (VLCCs) trading between the Middle East and Northeast Asia, transiting the Straits of Malacca rather than the Lombok Strait results in a saving of about 1,000 miles or about 3 days steaming (Noraini 2016). Traversing the Straits of Malacca rather than the Sunda Strait from the Cape of South Africa saves 200 miles.

Preference is given to an area that is better surveyed, provided with reliable navigational aids, a readily available emergency response system and the availability of good support facilities such as ship supports, repairs, crew change and cheaper bunkers (Upadhyaya, 2010). Because of the Strait economic importance on a global scale, the continuous and uninterrupted flow of energy supplies and other commodities is essential for the entire international community (Zulkifli et al., 2020). Straits of Malacca provides the shortest East-West Sea route compared to Indonesia's Lombok and Makassar Strait (Noraini, 2016). Due to its strategic advantage becomes the main route for merchant traffic between the Indian Ocean and the Pacific. Straits of Malacca also provides a shortcut for ships from the Middle East to the East Asian countries. As a nation relying on international trade and having 98% of its total trade carried over the sea, the Straits of Malacca have become a significant lifeline of Malaysian trade (Evers and Gerke, 2010).

2.3 Safety of navigation

Safety of navigation is a significant issue on the maritime side. Implementation of AIS to enhance safety is recommended by IMO regulation. AIS obtained the real-time condition in the traffic area. Management traffic has been conducted using AIS data (Zaman, 2019). Several ship's accidents are due to human error. To reduce it and enhance the safety of navigation in the marine traffic area, it is necessary to increase understanding of human factors aspects of the maritime operation. Moreover, the equipment of navigation and other factors should operate properly (Zaman, 2016).

There are over 200 straits and canals throughout the world, and only a few are considered strategic chokepoints for the movement of raw and finished goods. Thus, the importance of the Straits of Malacca to the world maritime community cannot be denied (Zulkifli et al., 2020). The global significance of this waterway is such that its closure, or even restriction, would severely impact world economies. When the topic of the Straits of Malacca was raised, piracy would always come to the fore. This is due to its physical attribute that the confined waters of the Strait make the ships that transit it vulnerable to piracy and sea robbery. However, the issues of the Straits of Malacca should be viewed from a broader perspective. The maritime safety challenges to the Straits of Malacca encompass the traditional non-threat to security (Simon, 2011).

2.3.1 Marine traffic in the Strait of Malacca

Marine traffic in the Strait of Malacca consists of two main types of traffic: transit traffic and cross-strait traffic. The first one is vessels passing through the Strait with or without call one or some ports along the Strait (Thanh et al., 2015). The second one is vessels operating on the routes between Malaysian ports of Port Dickson, Melaka, Muar and Kukup with various Indonesian ports on the opposite shore, including Pelabuhan Belawan, Tanjung Balai, Dumai and Bengkalis in Sumatra (Mohd Hazmi, 2012). Because the Strait of Malacca is long and wide, most vessels passing through the Strait are international voyage vessels equipped with AIS (Zaman, 2019). Figure 2 shows traffic density in the research area. According to this figure, East and Westbound vessels sail on the two almost separated routes. The East-bound ships with a deep draft sail on notable routes when passing sector 3 of the Straitrep.

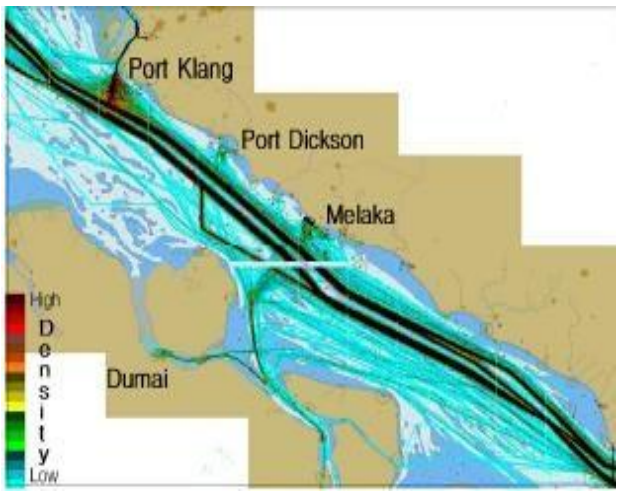

Fig. 2 Traffic density in Straits Malacca. Source: (Thanh et al., 2019)

Based on the updated ship movement records, the Strait's vessel speeds are relatively low, except only 3.18% records reflecting speeds over 25 knots. The probable explanation could be that the speed limit in most legs of the Strait is 12 knots. Therefore, absolute speed may not be qualified as a reliable risk index in contrast to speed dispersion. Based on the consultations and discussions with several experienced ship captains, we concluded that it was reasonable that more significant differences in speed among vessels are related to higher collision risk.

2.3.2 Marine cases and the incident at Straits Malacca

As shown in Table 7, it showed that the highest level of risk was overtaking and crossing situations in the Malacca Strait. Collision risk in the fairway area connecting the Strait of Malacca with the Port Kelang area is the highest in the Malacca waterway area. It is caused by the increased possibility of head-on condition in this fairway, together with the highest number of arriving or depart vessels compared with other ports located along the Strait of Malacca. The second area of high-risk traffic is the Strait of Malacca area from P.Udan light to Port Dickson. The collision risk mainly causes by overtakes condition (Thanh et al., 2019).

A version of Passage Planning Guide: Malacca & Singapore Straits, including the Straits background and passage notes, guides shipmasters and navigating officers transiting the Straits (SIGTTO, 2008). These rules were set based on the surveys from the shipmasters who were experienced and knowledgeable shore-based personnel from various marine organizations by SIGTTO (Rusli, 2020).

3. Methodology

3.1 Introduction

This research chapter shows the methodologies used, techniques and ways to collect the data, including research framework, area of study, data collection and data analysis.

Table 1: Collision occurred by the different conditions at Straits Malacca.

Condition	No. of collision incidents	Unit
Overtaking	5.342	Years between Incidents
Head-on	158.000	Years between Incidents
Crossing	17.020	Years between Incidents
Merging	48.630	Years between Incidents
Bend	65.740	Years between Incidents
Total Collisions	3.471	Years between Incidents

Several managerial and navigational solutions have been implemented in the Straits of Malacca over the past years to enhance navigational safety in the Strait, such as the Traffic Separation Scheme (TSS). According to TSS, the opposing traffic streams have been separated by the establishment of traffic lanes. The International Maritime Organization (IMO) enforced the Straits' mandatory Strait ship reporting system (STRAITREP). Furthermore, in 1998, the Society of International Gas Tanker and Terminal Operators Ltd (SIGTTO) published the 1st

Basically, in answering the objectives, data collection such as observation thorough site survey and conducting the interview from the expert.

3.2 Research design

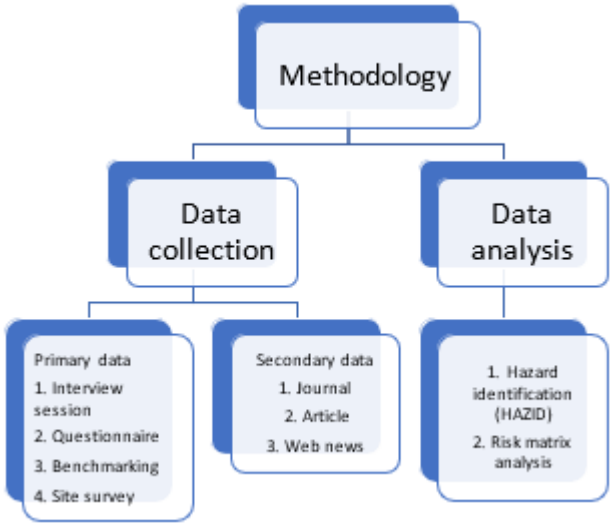

Fig. 5: Research methodology design.

3.3 Research framework

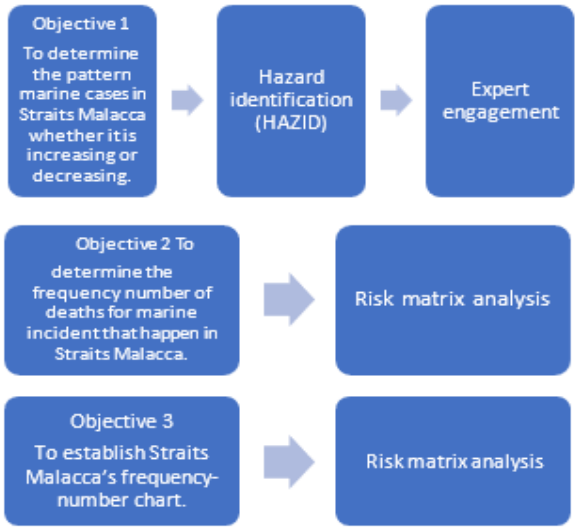

Fig. 6: Research framework of methodology.

3.4 Data Collection

Data was primarily collected through a questionnaire distribute online for Straits Malacca officers. During this site survey, observations have been made towards all available means that can potentially create hazards to Straits Malacca areas. The dangers of these areas have been observed and later brought to the responsible organization. The expert engagement was made during this step by verifying every hazard observed from the site survey.

Secondary data was obtained in the early stages before the primary data was collected. This was done by doing an extensive literature review to understand the problem with the cases at Straits Malacca. Furthermore, a literature review was done to determine the best method to identify the hazards by following other researchers. References to the literature review include books, online databases, articles, journals, and news.

3.4.1 Literature Review

This method can be used to identify the problem statement and objective of the research through the thesis, report,

journal and article published about the respective research. They are building this research with the only existing knowledge, as there were so many limitations inside and out. Hence, this research was conducted based on available literature reviews or case studies that already happened. To be more precise in data collection, literature reviews are only taken within ten years which 2010 onwards. The needs of literature are crucial in doing this research as literature is a simple guideline to be followed in which research findings. In addition, a literature review is an excellent way of synthesizing research findings to show evidence on a meta-level and to uncover areas in which more research is needed, which is a critical component of creating theoretical frameworks and building conceptual models.

3.4.2 Expert Engagements

Moreover, this research probably cannot be done without the help of expert engagements. In this term, expert engagements refer to Straits Malacca officers. Data collected Will be assisted by these expert engagements to avoid misleading of the data. Furthermore, data collected should be tally with the cases that occurred at Straits Malacca.

3.5 Data Analysis

Analysis of data is based on the expert engagement and literature reviews. The information to determine the best method to identify hazards has been collected from the observations and expert attention. Thus, Hazard Identification (HAZID) method has been implemented to list all identified threats. The result of the identified hazards was then being analyzed using risk matrix analysis.

3.5.1 Hazard Identification (HAZID)

Hazard identification is used in this research to identify and observe the Straits Malacca area by using all available means. This method involved interviews with experts and determining the frequent hazards related to the accident within the research area.

3.5.2 Risk Matrix

In this research, all identified hazards from hazard identification (HAZID) have been further analyzed using the risk matrix method. This method was used to outline the level of risk by considering the class of likelihood against the type of consequence severity with a straightforward mechanism to extend the visibility of risk assist management decisions. The following risk matrix has been used to provide a risk score that combines the seriousness of a particular consequence and the probability of the result occurring.

Table 2 Risk index, frequency index and severity index table for risk matrix analysis.

Risk Index					
F.I	Frequency	Severity Index			
		1	2	3	4
		Minor	Significant	Severe	Catastrophic
7	Frequent	8	9	10	11
6		7	8	9	10
5	Reasonably probable	6	7	8	9
4		5	6	7	8
3	Remote	4	5	6	7
2		3	4	5	6
1	Extremely remote	2	3	4	5

4. Results and Discussion

4.1. Introduction

The Automatic Identification System (AIS) was developed in the 1990s, but before 2000, vessels began to equip AIS transceivers on board as a new IMO requirement. Before this time, traffic survey work was mainly performed by manual inspection, making it impossible to find the distribution of traffic. Thus, at that time, the traffic distribution was primarily determined based on the formula created by statistical analysis. The Malacca Straits is one of the main routes for warships engaging in trade between the Far East, the Middle East's oil-rich countries, and Europe other than the Singapore Straits. The Malacca Straits has more than 50,000 shipping movements each year. Once ferry and other local traffic are included, the cumulative number of movements of vessels reaches 250 a day. Many ships sailing through these straits means more danger, mainly when they are clustered at shock points. In addition,

traffic in the Straits is expected to double over the next ten years, rendering the Straits the most congested in the country.

4.1.1 Hazard identification of marine cases at Straits Malacca

Marine cases have been usual cases to any port in Malaysia as well as Straits Malacca. As mentioned above, the hazards identification process has been implemented through various approaches, including questionnaires and observation methods. Table 1 shows the risk index for the Straits of Malacca.

Table 3 Risk index for Straits of Malacca.

Risk Index					
F.I	Frequency	Severity Index			
		1	2	3	4
		Minor	Significant	Severe	Catastrophic
7	Frequent	8	9	10	11
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4		5	6	7	8
3	Remote	4	5	6	7
2		3	4	5	6
1	Extremely remote	2	3	4	5

Table 4 The frequency index (F.I.), severity index (S.I.) and risk index (R.I.) of each fault event and contributing / causal factor pair.

No	Fault event	Factors	FI	SI	RI
1	Collision with passing commercial vessels (container ships, tankers & barges)	Miscommunication between the self-propelled barge and commercial vessel	5	4	9
		Equipment failure on commercial vessel	1		5
		Equipment failure on self-propelled barge	2		6
		Error in navigation	1		5
		Adverse weather	1		5
2	Collision with small boats	Equipment failure on commercial vessel	5	2	7
		Equipment failure on self-propelled barge	2		4
		Error in navigation	2		4
		Adverse weather	1		3

The result has been analyzed and identified by way of possible hazards associated with the proposed transit of the self-propelled barges, including its causal/contributing factors:

Table 5 Types of hazards and their contributing factors.

No	Hazard	Factors
1.	Collision with passing commercial vessels (container ships, tankers & barges)	• Miscommunication between the self-propelled barge and commercial vessel • Equipment failure on a commercial vessel • Equipment failure on a self-propelled barge • Error in navigation • Adverse weather
2.	Collision with small boats	• Equipment failure on a commercial vessel • Equipment failure on a self-propelled barge • Error in navigation • Adverse weather

3.	Grounding of self-propelled barge	• Equipment failure on a self-propelled barge • Error in navigation • Adverse weather

4.2 Evaluation of leading causes on marine cases at Straits Malacca

Accidents in the Straits include accidents, collision, foundry, stranding, explosion, engine trouble, bilge, and leakage. An overview of the kinds of vessels involved in a maritime crash shows that the possibility of an accident will affect almost any type of vessel in the Malacca Straits. The condition is serious, given the scale of the losses, many of which result in loss of life, contamination and loss of earnings for those whose livelihood relies on the Straits, as well as large waste disposal schemes. Fire, fires and emissions have also resulted from collisions between small and large ships. Based on the questionnaire conducted, the leading causes of marine cases in Straits Malacca are:

1. Human error and poor judgment: Following the events resulting, for example, in oil leaks, an investigation into the cause of the crashes concluded that human negligence and lousy judgement were the primary cause of the crashes, as a lack of situational knowledge of the bridge staff was noticed.
2. Navigational hazards: Protection of navigation is one of the critical problems facing the Malacca Straits. Protection in navigation is primarily affected by navigational risks, collisions and minor safety threats. Despite the construction of warships with advanced navigation aids and the assistance of Vessel Traffic Information Systems, the Straits is still considered an accident-prone waterway. Apart from the immediate risk to lives and property, accidents can threaten the Straits eco-system, mainly cargo and oil spills close to significant fishing grounds and tourist beaches.
3. Mechanical problems: Ships that are either poorly managed or underway when undergoing mechanical issues add to collisions. Power or steering loss in busy or rough waters will quickly turn into a problematic situation.
4. Traffic: The most difficult waters of the Straits lay between the Horsburgh Lighthouse and the One Fathom Bank Lighthouse, about 217 miles away. The remaining 500 miles have a more accessible maritime climate. Since Masters are free to plot their course within the rules and the TSS, the natural temptation is to take the shortest path. This, in essence, would result in many ships following the same five courses that will force them to meet as they overtake within the tight limits of the fairway.
5. Non-observance of rules: The most significant aspect is the human element. Compliance with international safety regulations and procedures has not been satisfactory and has resulted in a condition that can best be characterized as a "waiting accident." The consequence of this is that not all users of the rivers will be cautious as anticipated when negotiating straits.
6. Inadequate use of collision prevention aids: In its investigation, the MPA has found that devices such as the Automatic Identification System (AIS), Automatic Radar Plotting Assist (ARPA) and the Electronic Map Display and Information System (ECDIS) are not being used efficiently or adequately by bridge teams to deter collisions.

4.2.1 Conclusion

As the traffic volume grows, it is anticipated that accidents and pollution will rise too. Thus, implementing a portion of international law requiring user states to cooperate in implementing maritime safety in the Straits is the concern of all shipping communities. We must be looking at ways of reducing accidents, not as a vague aspiration but as a legitimate and logical ambition. The coastal states have invested a great deal of time and effort in promoting, maintaining navigational safety and controlling pollution in the Straits; it is an ongoing challenge for Malaysia, Indonesia and Singapore.

4.3 Type of Ship Involve in Marine Incident at Straits Malacca

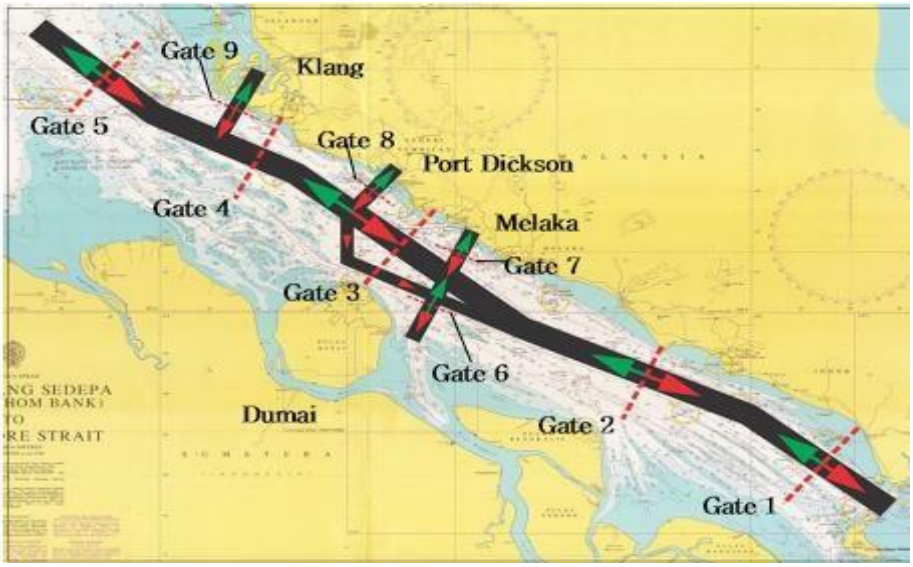

Fig.7: Gates position at Straits Malacca.

As the analysis results, the number of vessels passing the gate. No.1 is 6,484, which is about 216 vessels per day and

77,800 vessels per year. The type of passing vessels is displayed in figure 4.3.2. The statistics show that general cargo vessels such as container vessels, available cargo vessels, bulk carrier and tanker vessels (include oil tankers, chemical tankers and GAS carriers) accounted for about 95 % of all passages, and most of the vessels have a length of over 175 meters (average length of vessels is about 210 meters).

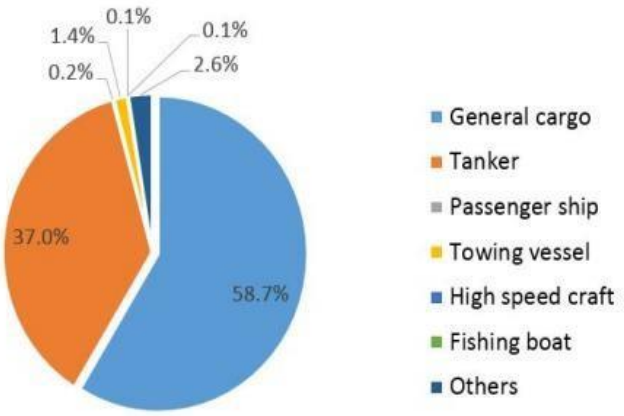

Fig. 8: Types of vessels passing through Malacca Straits.

Containerships or general cargo remained the most significant segment to transit the Malacca Straits with a 58.7% traffic share. The trend towards enormous and ultra-large containership tonnage has dampened the overall growth in transits. The container carrying capacity of newer ships has dramatically increased in recent times. As a result, container ports in the Straits handled higher cargo tonnage on fewer ships calling in recent years. Tanker became the next largest segment on vessels passing through Malacca Straits with 37%, followed by towing vessels, high-speed craft and others. Although small boats like fishing boats have low cases involved at the Straits of Malacca, it can threaten the bigger ship, such as cargo or containership. The collision between these types of a ship can cause many Injuries, or to worst, can cause fatal and other environmental pollution such as oil spills.

5.Conclusion

In this study, the risk reduction solutions should be prioritized being implemented in the cases mentioned above. It should be pointed out that several cargo vessels sail with speed beyond the speed limit, which results in higher potentials for vessel collision and incidents. Impact analysis indicates that the safety level would be significantly enhanced if all the vessels followed the passage guidelines. The speed limit with passage notes is just a recommended rule for vessels passing through the Strait.

However, according to the review of maritime transport 2008 published by the United Nations Conference on Trade and Development, global maritime trade is predicted to increase by 44% in 2020 and double by 2031 (UNCTAD, 2008). This would result in an increase in the marine traffic volume through the Malacca Strait accordingly. By then, the necessary risk reduction solutions such as compulsory speed limit should be implemented to assure safe navigation in the Malacca Strait.

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