The Economic Importance of the Straits of Malacca and Singapore: An Extreme Scenario Analysis

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ABSTRACT

This paper proposes a decision tree model to estimate the loss to global economy on the hypothesis of an extreme scenario of blockade of the Straits of Malacca and Singapore. The insurance surcharges, inventory costs and the time values of cargoes, and time charter equivalent rate are used to estimate the psychological loss, the loss to industries, and the loss to carriers, respectively. Interestingly, there is a pseudo-paradoxical phenomenon with respect to the loss to carriers. An illustrative example is also provided to explain the "Malacca Paradox".

Key words: Blockade; the Straits of Malacca and Singapore; discrete choice model; impact analysis; Malacca Paradox

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1. INTRODUCTION

The Straits of Malacca and Singapore is one of the most important shipping waterways in the world from both an economic and a strategic perspective. It is the shortest shipping channel between the Indian Ocean and the Pacific Ocean, linking major economies such as Middle East, China, Japan, South Korea, etc. There are more than 200 vessels passing through the Straits on a daily basis and this gives an annual throughput of approximately 70,000 ships, carrying 80% of the oil transported to Northeast Asia as well as one third of the world's traded goods including Chinese manufactures, Indonesian coffee, etc. (Gilmartin, 2008). The Straits is not deep enough to accommodate some of the largest ships (mostly oil tankers). At Phillips Channel, the Straits narrows to 2.8 km wide, with 2.1 km in the shipping waterways, creating one of the world's traffic chokepoints.

Quite a number of researchers and authorities have paid their attention to the Straits. For example, Wang and Meng (2011) investigated impact of the landbridge on the Port of Singapore and Straits of Malacca and Singapore; and Qu and Meng (2011) proposed a simulation model for ship movement in the Straits based on discrete event models. In order to enhance the navigational safety in the Straits, in 1981, Traffic Separation Scheme (TSS) was brought into force and the opposing streams of traffic have been separated by the establishments of traffic lanes; in 1998, the Straits of Malacca and Singapore was segmented into 9 Sectors as shown in Figure 1 by the mandatory ship reporting system.

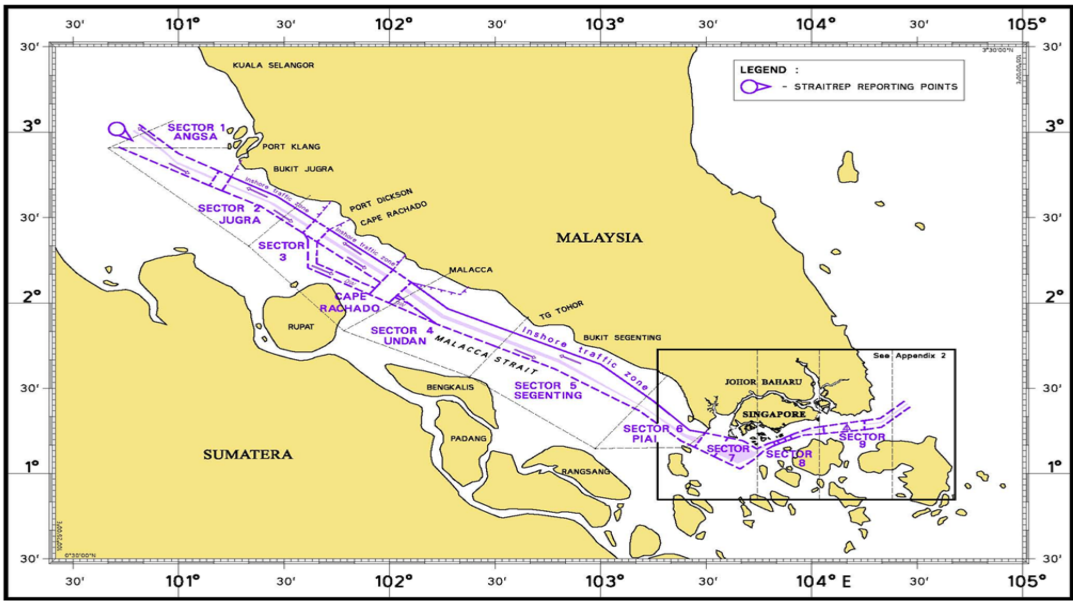

FIGURE 1 Shipping lanes of the Straits of Malacca and Singapore.

Major and minor disasters in the Straits have posed severe consequences, which may be caused by incidents due to the shallowness and narrowness of the Straits with high traffic volumes. If the incidents are involved in an oil tanker, as happened near to Port Dickson on 19 Aug 2009 and Changi terminal on 30 May 2010, the Straits may have to be closed or partially closed for clearance. Recently, impact analysis is widely applied to quantify the impact of foldable containers (Shintani et al., 2010), demand amplification on freight transport (Potter and Lalwani, 2008), etc. Imagine an hypothesis extreme incident, either intentional or accidental, took place in the Straits and blocked the vessels passing through the Straits, the impact would no doubt have a quick global reach on many levels: political, security, psychological, economic and, last but not least environmental level. About 400 shipping lines linking 700 ports worldwide regularly utilize the Straits for transit and/or transhipment (Ho, 2007). All corners of the globe would be affected once the Straits is blocked for several days. The blockade of the Straits is so-called low probability – high consequence event, which is widely addressed in various industries (e.g. nuclear power plant explosion (U.S. Regulatory Commission, 1975); tunnel fire (PIARC, 2008; Meng et al., 2010), and etc.). As for this type of rare-event risk assessment, consequence analysis and frequency analysis are considered as the two most important components (Farmer, 1967; Jonkman et al., 2003). Accordingly, it is essential for the maritime authorities like Maritime and Port Authority of Singapore to quantify the consequences of various levels that conveys messages about the economic importance of the Straits to carriers, shippers, littoral countries, user states, etc.

Although many researchers predicted dire consequences for global shipping and trade, seldom of them goes further to provide the estimation of what the actual costs might be. In November 2008, Gilmartin published a report to illustrate the cooperative efforts in the Straits of Malacca and Singapore by Europe, the U.S., and China (Gilmartin, 2008). The importance of the Straits to global shipping and trade are quantified by using Time Charter Equivalent (TCE) as estimators. In 2010, Shibasaki and Watanabe developed a simulation tool to perform a risk assessment study for blockade of the Straits of Malacca and Singapore. However, the above-mentioned papers address only partial levels of damages. Psychological loss and the loss to industries or shippers are not taken into consideration in the above-mentioned studies. Psychological loss refers to reputational loss that the Straits may be borne if the Straits was blocked. In 2005, the Joint War Committee (JWC) of Lloyd’s Market

Association (LMA) added the Straits of Malacca and Singapore to the list of high risk areas, which was subsequently listed out in the following year. The insurance company immediately placed an additional premium to all the vessels transiting through the Straits in 2005 and 2006. This reflected that the confidence of JWC and insurance company to the safety of the Straits. The loss to carriers means the economic loss that the carriers might be borne for not being able to make money by providing their services due to the blockade of the Straits. The loss to shippers or industries refers to the economic loss that shippers might be borne caused by the delay of their cargoes. Based on the analysis above, this paper proposes an impact analysis approach to quantify the consequences of the blockade of the Straits including psychological loss to Straits authorities in littoral countries and the loss to shippers and carriers.

The contributions of this paper to the literature are summarized as follows. First, this paper proposes an impact analysis method to estimate the loss caused by extreme events. Second, the decision tree model is incorporated with discrete choice model to simulate the route choices of ships. Third, the insurance surcharges, inventory costs and the time values of cargoes, and time charter equivalent rate are used to estimate the psychological loss, the loss to industries, and the loss to carriers, respectively. Last but not the least, an interesting pseudo-paradoxical phenomenon with respect to the loss to carriers is proposed and further analyzed in this study.

The remainder of the paper is organized as follows. In Section 2, a decision tree model is built to simulate the route choices of various vessels with different categories on condition that the Straits is blocked. This is followed by the loss quantification with different levels. The results and discussions are presented in Section 4 and Section 5 concludes this study.

2. DECISION TREE ANALYSIS

2.1 Decision Tree

If the Straits was blocked, nearly half of the world's fleet would be required to reroute around the Indonesian archipelago through the Sunda Strait or the Lombok Strait based on the expert judgment from practitioners (officers from maritime authorities and ship captains from carriers). As shown in Figure 2, the Sunda Strait is located between Java and Sumatra, connecting the Java Sea to the Indian Ocean. It is very shallow (<20m) in parts of the eastern end and most containerships could not pass through the shallow and dangerous Straits. It would require 1.5 days delay compared with transiting through the Straits of Malacca and Singapore based on the statistics. The Lombok Strait is a strait connecting Java Sea and the Indian Ocean, located between the islands of Bali and Lombok in Indonesia. It would require approximately 3.5 days to steam the additional distance through the Strait, assuming an average speed of 15 knots. Other than the two alternatives mentioned above, the vessels may wait beside the Straits of Malacca and Singapore till it is recovered.

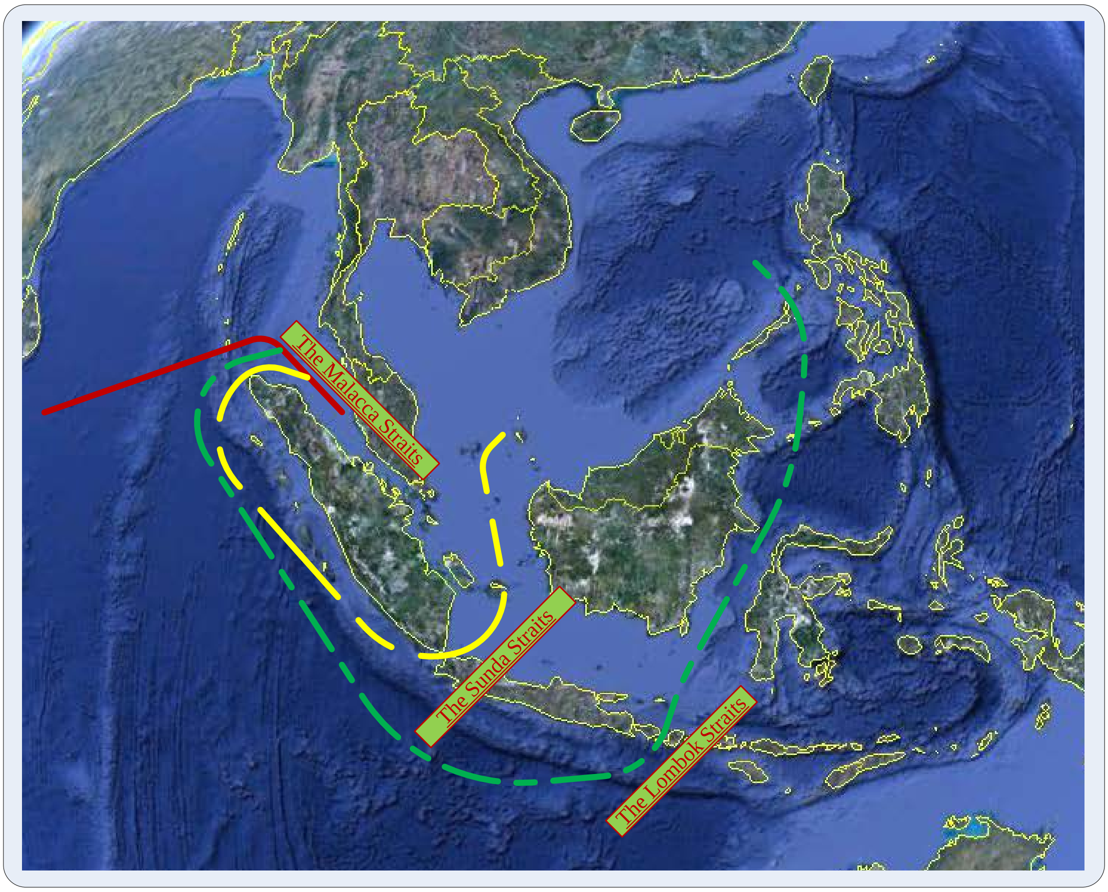

FIGURE 2 Alternatives of the Strait of Malacca and Singapore.

A decision tree is depicted in Figure 3. Firstly, the ships are classified into transhipment ships, which will be transhipped or terminated in one of the downstream ports in the Straits, and transit ships, which refer to all the other ships which will not call at the downstream ports. We assume that all the transhipment ships are container ships, which must wait beside the Straits of Malacca and Singapore in order to tranship in the ports downstream. As for the transit ships, we assume that Very Large Crude Carriers (VLCCs) and container ships could only choose to wait or to transit through the Lombok Strait in view of their needs of deep draft. The Liquefied Natural

Gas (LNG) / Liquefied Petroleum Gas (LPG) carriers and other small ships are with draft < 12 meters and have an additional choice – transiting from the Sunda Strait. *N* in Figure 3 is the predicted time of blockade of the Straits of Malacca and Singapore reflecting the severity of blockade.

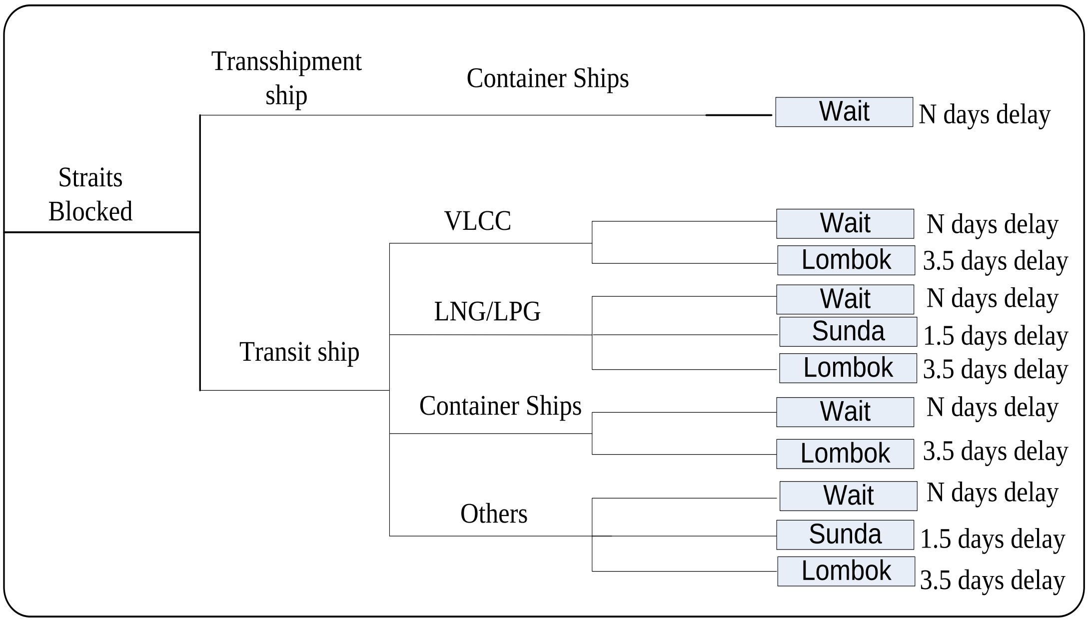

FIGURE 3 Decision tree model.

2.2 Discrete Choice Model

For each particular scenario (a leaf node in Figure 3), the expected delay time is known. Therefore, we should estimate the possibility of each scenario, namely, the proportion of one category of ships choosing a particular alternative. A discrete choice model is used to simulate the decisions of the transit ships, that is, to calculate the possibilities or proportions of ships choosing to wait, to transit through the Lombok Strait, and to transit through the Sunda Strait.

The actual delay times for transiting from the two alternatives of the Straits (the Lombok Strait, and the Sunda Strait) will vary with the sailing velocities, the weather condition, and the course selected, which are not suited to be represented by a crisp delay time. Similarly, the actual blockade time of the Straits is also not appropriate to be considered as a crisp value in view of the following two considerations. Firstly, the predicted recovery time provided by the maritime authorities may not be accurate due to the complexity of the clearance. Secondly, even on condition that the recovery time is 100% accurate, the perceived recovery time for decision makers with different risk attitude may not be the same based on their confidence to the prediction. For example, if the Straits is blocked and the authority accurately estimates the recovery time as 4 days and informs the estimation to various carriers, some risk-loving carriers may regard the actual recovery time as 3.5 days when they choose their routes, while the risk-averse carriers may conservatively estimate the actual recovery time as 4.5 days when they make their route-choice decisions. From the literature, random variables are widely used to formulate such type of situation with parameter uncertainty (Ferson and Ginzburg, 1996; Baraldi and Zio, 2008; Meng and Qu, 2011). Accordingly, discrete choice models are capable of formulating the route choice problem based on the maximum utility principle. Accordingly, we assume the delay time to be the sum of an approximate delay time and an error term. The mathematical expressions of the actual delay times are

$$T_{im}^{d} = T_{im}^{a} + \varepsilon_{im} \tag{1}$$

$$T_{il}^{d} = T_{il}^{a} + \varepsilon_{il} \tag{2}$$

$$T_{is}^{d} = T_{is}^{a} + \varepsilon_{is} \tag{3}$$

where T_{im}^{d}, T_{il}^{d}, and T_{is}^{d} denote the actual delay time of ships with category *i* for the alternatives *wait, the Lombok Strait,* and *the Sunda Strait,* respectively; T_{im}^{a}, T_{il}^{a}, and T_{is}^{a} are the predicted delay time for ships with category *i* for alternatives *wait, the Lombok Strait,* and *the Sunda Strait*, respectively (e.g., 3.5 days for VLCC transiting through the Lombok Strait); ε_{im}, ε_{il}, and ε_{is} are the error terms.

Discrete choice models have been used to examine situations in which the potential outcomes are discrete, such that the optimum is not characterized by standard first-order conditions, e.g., the choice of which car to buy (Train and Winston, 2007), which customer should be chosen (Goett et al., 2002), which travel mode and route should be selected (Sheffi, 1985), etc. The output of the discrete choice model is the proportion or probability that each alternative is chosen in decision making procedure (Ben-Akiva and Lerman, 1985). The logit model is the most widely used discrete choice model that the error terms are assumed to follow a typical Gumbel distribution. Accordingly, logit models can be developed to perform the route-splitting for the transit ships. The disutility of each alternative is assumed to be the summation of its predicted delay time and corresponding error term. Hence, we obtain the probabilities of a ship choosing the three alternatives as follows.

$$P_{im} = \frac{e^{-T_{im}^a}}{e^{-T_{im}^a} + e^{-T_{is}^a} + e^{-T_{il}^a}} \quad (4)$$

$$P_{is} = \frac{e^{-T_{is}^a}}{e^{-T_{im}^a} + e^{-T_{is}^a} + e^{-T_{il}^a}} \quad (5)$$

$$P_{il} = \frac{e^{-T_{il}^a}}{e^{-T_{im}^a} + e^{-T_{is}^a} + e^{-T_{il}^a}} \quad (6)$$

where P_{im} , P_{is} , and P_{is} denote the probabilities of a ship with type *i* choosing to wait, to transit through the Sunda Strait, and to transit through the Lombok Strait, respectively. T_{im}^a, T_{il}^a, and T_{is}^a are the disutilities of the alternatives *wait*, *the Sunda Strait*, and *the Lombok Strait* expressed by the delay times, namely, *N*, 1.5 days, and 3.5 days, respectively.

3. QUANTIFICATION OF THE CONSEQUENCES

3.1 Psychological Loss

Psychological loss refers to reputational loss that the Straits may be borne if the Straits was blocked. In 2005, the Straits of Malacca and Singapore was considered as a risky waterway and the market placed a surcharge per trip equal to 0.01% of the estimated value of the loaded ships (Gilmartin, 2008). Assume the average passage time through the Straits is 3 days. The daily surcharge rate is 0.0033% of the estimated value of cargo. Evidently, the blockade of the Straits may result in much more worse impression to carriers, shippers, and other stakeholders. It is safe to assume that the psychological loss (reputational loss) of the Straits is not less than the increased surcharge. Accordingly, the daily psychological loss of the Straits blockade can be estimated as

$$L_p = V \times 0.0033\% \quad (7)$$

where L_p is the daily psychological loss, *V* is the estimated value of daily transported cargoes through the Straits.

3.2 Loss to Industries (Shippers)

The loss to shippers or industries refers to the economic loss that shippers might be borne caused by the delay of their cargoes. The delay of the ships will trouble the vulnerable economy entities. Although most countries in Northeast Asia have strategic reserves including oil reserve, some industries of those countries may suffer significantly from the delay of the ships, especially for those importing nations. The loss to those industries is difficult to predict. The fact why industries do not want long term reserves results from two aspects: the inventory cost and the time value of money. In this study, we use the summation of inventory cost and the time value of money resulted from the delay time as an estimator of the loss to industries, namely,

$$L_i = \sum_{k=1}^{K}\sum_{j=1}^{J}\left(I_k \times T_{kj} \times N_{kj}\right) + MARR \times \sum_{k=1}^{K}\sum_{j=1}^{J}\left(V_{kj} \times T_{kj}\right) \tag{8}$$

where L_i denotes the loss to industries, I_k is the daily inventory cost in terms of volume for cargo with type k, K is number of types of cargo, J is the number of scenarios in the decision tree (leaf nodes in Figure 3), T_{kj} is the delay time of cargo with type k in scenario j, N_{kj} is the amount of cargo with type k in scenario j which is derived from the discrete choice models, V_{kj} is the estimated monetary value of cargo with type k in scenario j, *MARR* is the Minimum Attractive Rate of Return. Note that the T_{kj} is known for one particular scenario (N, 1.5 days, and 3.5 days).

3.3 Loss to Carriers

The loss to carriers means the economic loss that the carriers may be borne for not being able to make money by providing their services due to the blockade of the Straits. Most cargo vessels on global routes are contracted at a daily charter rate, commonly reported as Time Charter Equivalent (TCE), which is considered as the predominate components out of loss to carriers. Accordingly, the average shipping charter rates for various categories of vessels can be considered as a good measure to quantify the loss to carriers. In 2007, the average rate for VLCC is around 200,000 USD per day (Ho, 2007). According to Malaysia's Marine Department Klang Vessel Traffic Services (VTS), 3,753 VLCCs in the Malacca Straits were reported in 2007, namely around 10 vessels per day (Malaysia Marine Department, 2007). Similarly, we can obtain the traffic volume and the charter rate to calculate the daily loss to the shipping industry. The traffic volume and the charter rate with respect to various ship categories are summarized in Table 1.

TABLE 1 Summary of Daily Traffic Volume and Charter Rate for Various Ship Types

Ship Category	Daily Traffic Volume (2007)	Daily Charter Rate
VLCC	10 vessels	200, 000 USD

LNG/ LPG	7 vessels	60, 000 USD
Container Ship	62 vessels	30, 000 USD
Others	100 vessels	30, 000 USD

The loss to carriers can be estimated as

$$L_c = \sum_{i=1}^{I} \left(R_i \times \sum_{j=1}^{J} \left(T_{ij} \times N_{ij} \right) \right) \tag{9}$$

where L_c denotes the loss to carriers; R_i is the daily charter rate of ship category i; T_{ij} is the delay time with ship category i in scenario j in the decision tree; N_{ij} is the number of ship with category i in Scenario j which is determined by discrete choice models.

4. RESULTS AND DISCUSSIONS

According to the approach mentioned above, we can estimate the impact on the psychological and economics level. In this study, we assume 1/2 out of all containerships will be transshipped in the downstream ports in the Straits. We assume the yearly *MARR* is 10%. In 2007, around 1 trillion USD in goods and services passed through the Straits of Malacca and Singapore. The daily goods transported through the Straits values (*V* in eqn. (7)) around 2,739,726,017 USD.

4.1 The Results of the Discrete Choice Model

Based on eqns. (4) to (6), the probabilities of route choices of vessels are summarized as follows.

TABLE 2 Route Choices for Various Types of Transit Ships (Disutilities *N*, 1.5 days, and 3.5 days)

Delay time (day)	Route Choices for Large Vessels		Route Choices for Small Vessels		
	Malacca	Lombok	Malacca	Sunda	Lombok
1	0.924	0.076	0.592	0.359	0.049
1.5	0.881	0.119	0.468	0.468	0.064
2	0.818	0.182	0.348	0.574	0.078
2.5	0.731	0.269	0.245	0.665	0.090
3	0.622	0.378	0.164	0.736	0.010
3.5	0.500	0.500	0.107	0.787	0.106
4	0.378	0.622	0.067	0.822	0.111
4.5	0.269	0.731	0.042	0.844	0.114
5	0.182	0.818	0.026	0.858	0.116
5.5	0.119	0.881	0.016	0.867	0.117
6	0.076	0.924	0.010	0.872	0.118

4.2 The Consequences

Based on eqns. (7) to (9), the psychological loss, the loss to industries, and the loss to carriers are estimated, which are shown in Table 3 and Figure 4.

TABLE 3 The loss of the Straits blockade for blockade time from 1 day to 6 days

Delay time (day)	Psychological loss (USD)	Loss to industries (USD)	Loss to carriers (USD)
1.0	547,945	1,430,137	7,935,495
1.5	821,917	2,145,205	10,657,047
2.0	1,095,890	2,860,274	12,918,637
2.5	1,369,863	3,575,342	14,695,779
3.0	1,643,836	4,290,411	15,997,144
3.5	1,917,808	5,005,479	16,842,016
4.0	2,191,781	5,720,548	17,274,957
4.5	2,465,753	6,435,616	17,385,114
5.0	2,739,726	7,150,685	17,291,125
5.5	3,013,699	7,865,753	17,103,109
6.0	3,287,671	8,580,822	16,897,237

Figure 4 presents the psychological loss, the loss to industries, the loss to carriers, and the total loss with blockade time from 1 day to 6 days.

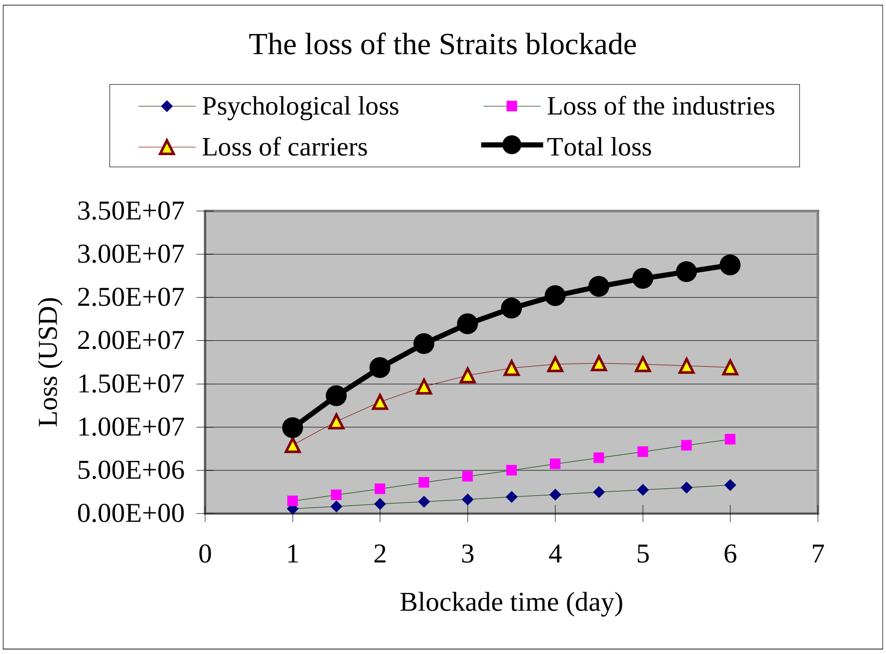

FIGURE 4 The loss of the Straits blockade.

As can be seen from Table 3 and Figure 4, the daily loss of the Straits blockade is around 10 million USD and the loss to carriers contributed most of them. The important point to note here is that the loss is 17,385,114 USD for 4.5 days blockade as compared to 16,897,237 USD for 6 days blockade. The additional blockade time seems to have made the situation better. This counter-intuitive result is called "Malacca Paradox" in this study. This "paradox" results from the discrete choice of the shipping routes. A comparative scenario analysis is shown in Table 4. Firstly, let us consider a scenario that the Straits will close for approximately 4.5 days. Based on the discrete choice, 26.9% out of all large transit carriers may have the hope of the Straits being able to be recovered soon and may not want to reroute through the Lombok Straits for saving fuel expenses. Accordingly, those carriers will suffer 4.5 days delay and the rerouted ships suffer 3.5 days. However, if the Straits is blocked for approximately 6 days, only 7.6% out of all large transit ships will choose to wait beside the Straits of Malacca and Singapore, that is, more ships will make "wiser" decisions with less delay time. Under this scenario, 7.6% of ships will suffer 6 days delay and 92.4% of them will suffer 3.5 days. The increase of the proportion of the wiser choice causes the decrease of the total loss, which is shown in Table 4 by an example.

TABLE 4 A Comparative Scenario Analysis of "Malacca Paradox"

Scenario	Blockade time	Route choice (*wait*)	Route choice (*Lombok*)	Average delay time
1	4.5 days	26.9% (4.5 days delay)	73.1% (3.5 days delay)	3.769 days
2	6 days	7.6% (6 days delay)	92.4% (3.5 days delay)	3.690 days

It should be pointed out that the loss estimated in this study can only be considered as a lower bound of the total loss because the consequences with other levels, such as political level, environmental level, etc., are not taken into account due to the difficulties of quantification.

5. CONCLUSIONS

This paper proposes an approach to estimate the psychological loss, the loss to industries, and the loss to carriers with different severities of the blockade. A decision tree model combining discrete choices is applied to simulate the route choices of the ships when the Straits is blocked. The insurance surcharges, inventory costs and the time values of cargoes, and time charter equivalent rate are used to estimate the psychological loss, the loss to industries, and the loss to carriers, respectively. The result shows that the loss to carriers contributes the most out of the total loss. A pseudo-paradoxical phenomenon is discovered that the loss to carriers decreases as the increase of blockade time when the blockade time is greater than 4.5 days. This is caused by the increased proportion of the wiser choice, namely, the long time blockade of the Straits may force ships to skip the Straits of Malacca and Singapore round the Sunda Strait or Lombok Strait in Indonesia. Accordingly, the maritime authorities should devote to implementing solutions to control the possibility of the Straits blockade. Additionally, the quantification of the potential loss may help maritime authorities to evaluate the cost-effectiveness of risk reduction solutions.

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