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Risk Assessment Of Fishing Trawl Activities To Subsea Pipelines Of Sabah And Labuan Waters

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ABSTRACT

Trawling is a method of catching fish in a large volume where fish nets are pulled through water using one or two boats. Bottom trawling is where the nets are pulled over on the seabed. The gear of the bottom trawling would impact the exposed subsea pipeline, on the seabed. Subsea pipelines transport crude oil and gas from the offshore platform to shore facility. This study assesses the risk of fish trawling activities to the subsea pipelines at Sabah and Labuan offshore. The specification of trawl equipment used by local trawlers in Sabah was determined by onsite survey. The frequency of fish trawler crossing over the pipelines was calculated based interview on operation and site survey. The calculation of pull-over load of otter board was calculated using the DNVGL algorithm. The severity and frequency index of the risk matrix was developed based on literature review. Results showed that the pull-over load of otter board would not damage the pipelines. The risk posed by fish trawler activity to the pipelines is low and moderate.

1. Introduction

Sabah is known for its fresh sea catches. Seas of Sulu, Sulawesi and South China which surround Sabah, contribute to 41.8% in marine fish catches in Malaysia. Sabah fisheries and aquaculture industries produce nearly 200,000 metric tons of fish annually and contribute to the Sabah's annual Gross Domestic Product by 2.8%. Marine capture fishery is the major contributor, which accounts for about 80% of the statistics. This is a catalyst by various fishing gear methods used by the fisherman in Sabah. The main fishing method that contributes to the total catches is the trawl net. Trawling is a method of fishing where fish nets are pulled through water using one or two boats. Trawl can be split into bottom trawling and mid-water trawling (Seafish, 2015). Apart from fisheries and aquaculture industries, Sabah has an oil and gas industries with a reservoir that consist of West Sabah Basin, Northwest Sabah Basin, and Northeast Sabah deep-water area. Most oil and gas come from the west basin, namely Erb West, Tembungo and Kababangan oil field as shown in Figure 1.

However, the existing subsea pipelines connecting oil field to shore are affected by fishing activities especially the bottom-trawling. The interaction may cause damage to the subsea pipelines, which eventually leak and cause marine pollution. This interaction is considered as third-party impact due to human activity at sea. The third-party impact is the impact caused by

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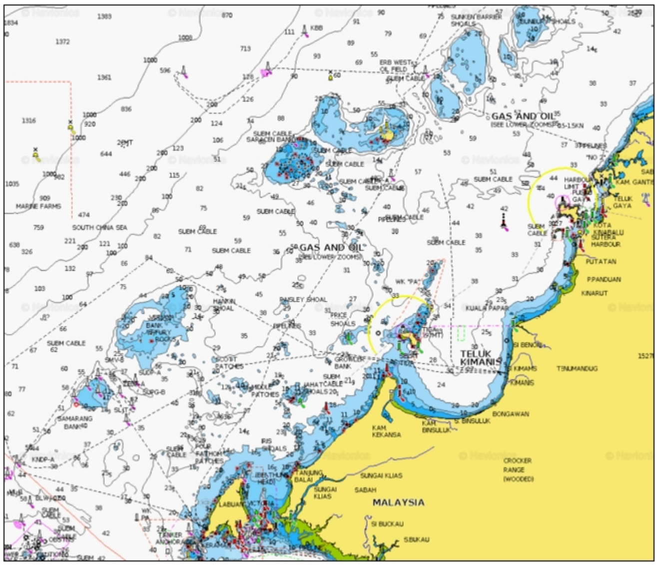
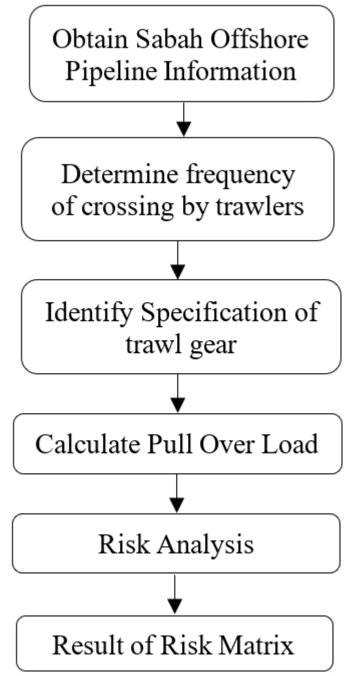
Figure 1: Oil fields and subsea pipelines at Sabah west basin.



Source: Navionics, 2018.

Figure 2: Overall research activities.



Source: Authors.

external activities such as trawling, anchoring, and dropped objects (Pratiwi et al., 2018). Hitherto, no study has been conducted on the fish trawlers activities to subsea pipelines at Sabah offshore. Therefore, the objective of this research is to determine the impact of pull-over load of trawlers to the subsea pipelines at from Sabah and Labuan offshore to shore gas and crude terminal.

2. Methodology.

In this research, several methods were used to achieve the main objective. The overall research activities are shown in Figure 3. The explanation of each method is given in the following paragraphs.

The first step of the research is to obtain information on oil and gas pipelines from offshore fields to shore facilities at Sabah and Labuan. The information was obtained from the relevant MAL charts series, which produced by the Malaysia National Hydrographic Centre. The electronic navigation chart series are available from C-Map and Navionics. The pipelines data was also obtained from the oil and gas company that owns the pipelines.

The second step is to determine the frequency of crossing by trawlers on the pipelines. According to the Sabah Fisheries Department, less than 30% of fishing vessels in Sabah is fitted with the Automatic Identification System (AIS). Thus, the AIS data for trawlers was not available. To determine the number of crossings on pipelines, an alternative way was developed. The first method of the second step was to determine the typical operation of trawlers in Sabah. The information was gathered by conducting a survey to the three operator fish trawlers at Kota Kinabalu fish jetty. The information was the location of fishing ground, speed, and duration to the fishing ground, trawling speed and duration, the number of trawling per day, duration of fishing, speed and duration return to fish landing jetty, duration of transfer cargo to jetty and replenishment before going back to fishing. The second method of the second step is to do a site verification survey by boating along the route of the pipelines. The course, speed, name, and type of fishing vessels detected on site were recorded. The third method of the second step is to determine the density of fishing trawler per area of fishing ground. This step was started by identifying fishing grounds in Sabah waters. The area for each fishing ground was marked and measured by using the Google Earth application.

The third step was to identify the specification of trawl gear and otter board used by the trawlers. The site survey was conducted to fishing trawlers at the Kota Kinabalu fishing port and shipyard at Sepanggar Bay. During the survey, the dimension of the otter board was measured and the thickness of the warp line was measured.

The fourth step was to calculate the force of the pull-over load by using Equation 1, Equation 2, Equation 3 and Equation 4 developed by DNV (DNV GL, 2017a). The Pull-over load is the horizontal and vertical forces from the trawl boards acting towards the subsea pipeline. It shall be applied as single point load to the pipeline under consideration (Yohannes, 2012).

The equation for Pull-Over Load of an otter board or trawl door as below (DNV GL, 2017a):

$$F_P = C_F \, .V(m_t k_w)^{1/2} \tag{1}$$

Where:

F_P is Pull-Over Load of an Otter board / Trawl Door
k_w is warp line stiffness
V is trawling velocity

m_t is steel mass of board/beam with shoes
C_F is an empirical coefficient
C_F is determined by:

$$C_F = 8.0 \bullet (1 - e^{-0.8\overline{\mathrm{H}}}) \tag{2}$$

Where $\overline{H}$ is a dimensionless height

$$\overline{H} = \frac{H_{sp} + OD/2 + 0.2}{B} \tag{3}$$

Where:
H_{sp} is the span height (negatively for the partly buried trenched pipeline)
OD is the pipeline outer diameter including coating
B is half of the trawl board height
The warp stiffness, k_w is assumed as:

$$k_w = \frac{3.5 \,.\, 10^7}{L_W} \tag{4}$$

Where L_W is the length of warp line in meter

The fifth step was to conduct risk analysis, which consists of the frequency index, severity index, and the risk matrix. The frequency index and severity will be developed based on DNV GL and ISO publications.

The Frequency Index developed in this study is shown in Table 1. The table is a 9-point scale ranging from 0 to 8,100 frequency with an increment of 900 between categories. The table is developed based on DNV GL (2017b) report on Recommended Failure Rates for Pipelines by adapting Table Criteria for score assessment, threats related to shipping loss, emergency anchoring and dragged anchors from anchored ships. The table has 3 scores as follows: 0, 1, and 2 for number of crossing less than 90,000 between 90,000 to 180,000, and above 180,000 respectively. The adaptation was by taking 1% of scores of each category from DNV GL table and developed the scores in 9 scales. This adaptation would increase the impact probability to 100 percent, which is due to the impact of trawl gear on pipeline on each crossing.

Table 1: Frequency Index of Fishing Vessel Crossing.

Index	Meaning	Range
0	Extremely low	0 – 900
1	Very low	901 - 1800
2	Low	1801 - 2700
3	Slight low	2701 - 3600
4	Moderate	3601 - 4500
5	Slight high	4501-5400
6	High	5401-6300
7	Very high	6301-7200
8	Extremely high	7201-8100

Source: Authors.

Severity Index in Table 2 was developed base on research conducted by Kristoffersen, Børvik, Westermann, Langseth, & Hopperstad (2013). However, no results of the calculated force shown in the table of this section. The test conducted in the research is in accordance with DNV-RP-F111: interference between trawl gear and pipelines (DNV GL, 2010). Results from the research were used to determine the magnitude of the force that resulted in the extent of damage to the pipeline, which also subjects to the thickness of the pipeline. A pipeline's load resistance against external interference primarily depends on the pipeline diameter and wall thickness. Tests have shown that the most commonly used excavators and construction equipment do not exercise enough load to cause leaks or rupture to pipelines with a wall thickness larger than 11-12 mm (DNV GL, 2017b). The index number and meaning of Index of severity in Table 2 is developed based on ISO 17776 Risk Matrix with index number starting from 0 to 4 (DNV, 2001).

Table 2: Severity Index of Pull-Over Force/Load.

Index	Meaning	Calculated Force (Fp)
0	No Damage	No data
1	Slight Damage	No data
2	Minor Damage	No data
3	Local Damage	No data
4	Major Damage	No data

Source: Authors.

Table 3 is the Risk Matrix Table for Fishing Activities on Pipeline, which is used to determine the result for the risk index. Table 3 combined the severity index and frequency index in one table and was used to calculate the summation between frequency and severity index for a particular pipeline. Result of the summation and the corresponding level of risk is shown in Table 4. There are five levels of risk matrix shown in Table 4 from very low to very high risk.

3. Results And Discussion.

There were four pipelines were identified in the study. Pipeline ID85 and ID80 from Erb West Oil Field to Sabah Gas Terminal Kota Kinabalu (SBGAST) and Labuan Gas Terminal (LGAST) respectively. Pipeline ID107 and 144A from Semarang Oil Field to LGAST is shown in Figure 3.

3.1. The Density of Fishing Trawler in Sabah Waters.

According to Jakobsen, Hartstein, Frachisse, & Golingi (2007), the are four main fishing grounds of Sabah as shown in Figure 3. Fishing ground A is located between Erb West oil field and Kota Kinabalu mainland. Fishing ground B is located at Teluk Kimanis. Fishing ground C is located between Mantani Island

Table 3: Risk Matrix Table for Fishing Activities on Pipeline.

	Severity	0	1	2	3	4
Frequency		No Damage	Slight Damage	Minor Damage	Local Damage	Major Damage
0	Extremely Low	0	1	2	3	4
1	Very Low	1	2	3	4	5
2	Low	2	3	4	5	6
3	Slight Low	3	4	5	6	7
4	Moderate	4	5	6	7	8
5	Slight High	5	6	7	8	9
6	High	6	7	8	9	10
7	Very high	7	8	9	10	11
8	Extremely High	8	9	10	11	12

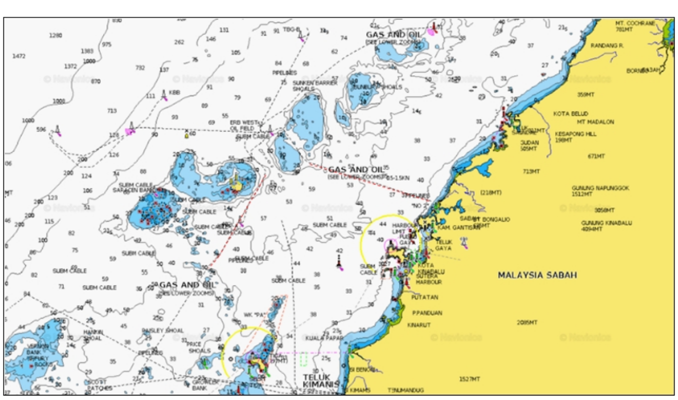
Source: Authors.

Table 4: Risk Matrix Table of Fishing Activities Impact on Pipeline.

Meaning	Risk Matrix	Colour
Very Low Risk (VL)	0-3	
Low Risk (L)	4-5	
Moderate (M)	6-7	
High Risk (H)	8-10	
Very High Risk (VH)	11-12	

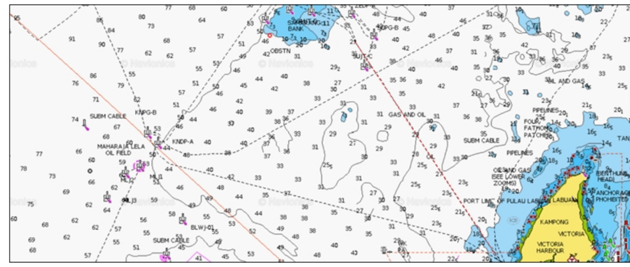
Source: Authors.

Figure 3: Pipeline ID 85 Erb West to SBGAST (Red dotted line right) and ID80 Erb West to LGAST (Red dotted line left).



Source: Authors.

Figure 4: Pipeline ID107 and ID144A Route Semarang to Labuan Gas Terminal (LGAST) (Red line).



Source: Authors.

Table 5: Pipelines Information.

Pipeline Name	Pipe Length (km)	Pipe Diameter (inch/cm)	Design Code	WT (mm)	Yield Strength KN/m^2
ID85 Erb West to SBGST	60.4	16/ 40.6	API 5L X60	15.9	4.2 x 10^5 @ 60 ksi
ID80 Erb West to LGAST	140.4	14/ 35.5	API 5L X42	9.53	2.9 x 10^5 @ 42ksi
ID107 Semarang to LGAST	46	14/ 35.5	API 5L X52	9.53	3.55 x 10^5 @ 52 ksi
ID144A Semarang to LGAST	47.71	20/50.8	API 5L X65	11.1	4.5 x 10^5 @ 65 ksi

Source: Authors.

and the mainland, and fishing ground D is located between Semarang oil field and Labuan mainland.

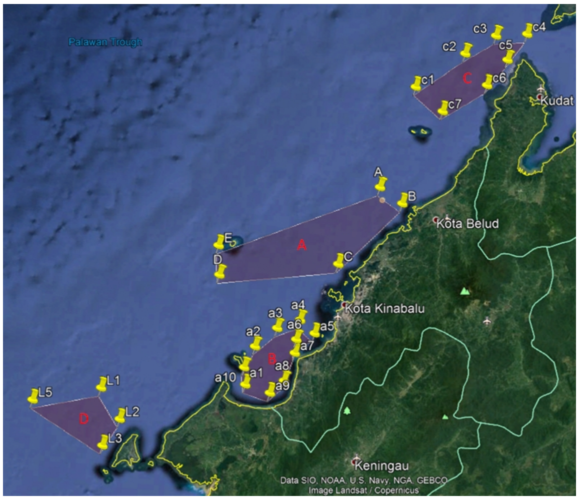
The area of fishing ground A is 488 nm2. Results of site survey at ground A shows that twelve trawlers were found as shown in Figure 4 (the positions depicted by camera icon). The density of fishing trawler in an area was obtained by dividing the area measured with the number of fishing trawlers found, thus the density of fishing trawler in area A is 40.7nm2 per trawl. Fishing ground A is used as the benchmark for density of trawler because it has the highest number of fishing trawlers registered at its coast (Kota Kinabalu) compared to other fishing ground and it is also the biggest fishing ground in Sabah. By using the result from ground A, the density of trawler for fishing ground B, C, and D is calculated. The area for ground B, C, and D are 157 nm2, 213 nm2, and 156 nm2 respectively. The density of trawler for ground B, C, and D are 4, 5 and 4 respectively.

3.2. *Typical Operation of Fishing Trawlers in Sabah Waters and Frequency of Crossing.*

An interview with three skippers of fishing trawler had identified the typical operation of fishing trawlers in Sabah waters. The information of the operation is applied to fishing ground A, an area between Erb West oil field and the coast of Kota Kinabalu to Karambunai Sabah (Figure 4). The result for fishing ground A is as follows:

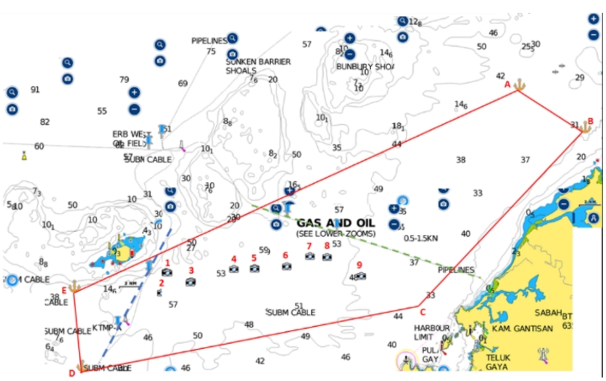
i. The duration of one cycle of fishing trawl operation is 10 days, which consists of 0.5 days going to a fishing ground,

Figure 5: Fishing ground in west coast Sabah and Labuan.



Source: Authors.

Figure 6: Trawling area that involves Erb West to Labuan Gas Terminal pipeline (blue dotted line) and Erb West to Sabah Gas Terminal pipeline (green dotted line). The camera icon depicts the position of 10 trawlers.



Source: Authors.

7 days of trawling, 0.5 days return to fish landing jetty, and 2 days for discharge cargo and replenishment.

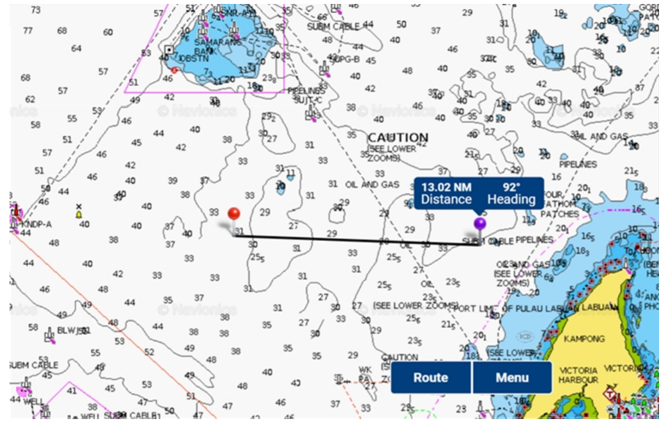
ii. The trawling operation is conducted 5 times per day, where the duration for each trawling operation is 4 hours, namely 1 hour to deploy and retrieve net, and 3 hours to tow net).

iii. The trawl distance per day is 45 nm resulted from 5 times trawl per day multiply 3 hours duration per trawl and multiply speed 3 knots.

iv. The distance of the fishing area is 28nm, which is measured from pipeline Erb West – Labuan Gas Terminal to pipeline Erb West – Sabah Gas Terminal in Figure 2. For a trawler that makes a U-turn after 28nm trawling to make a new trawl leg, with a trawling distance of 45 nm, a vessel would cross 1 pipeline twice and 1 pipeline once. However, by taking into consideration of slight increase of speed, lesser time in deployment and retrieval of trawl gear, it is assumed that a trawler may cross these two pipelines 2 times per day.

v. Monthly crossing: For 3 fishing trips @ 7 days actual

Figure 7: The width distance of Area D (Labuan) fishing ground.



Source: Authors.

trawling operation, the trawling days is 21 days. Each trawler would cross 42 times on each pipeline (21 days trawling per month x 2 times crossing per day).

vi. Annual crossing: Assuming 11-months annual operation (one month reserved for maintenance and repair), each trawler would cross one pipeline 462 times (42 times cross/month x 11 months)

vii. The density of fishing trawler for the area is 12. Therefore, the number of annual crossing is estimated at about 5544 crossings (i.e. 12 trawlers x 462 crossed per vessel) for each pipeline in Area A.

The result of fishing ground D is as follows:

i. 10 days per cycle of operation (0.5 days to fishing grounds, 7 days trawling, 0.5 back to port, and 2 days to land fish and replenish fuel and supply).

ii. Trawler density: 40.7 nm2 area density per trawler at area A is applied to other areas in Sabah and Labuan. Therefore, for area D with 156 nm2, the density of trawlers for the area at one time is 4 trawlers (156 nm2/ 40.7 nm2).

iii. Trawling distance of a trawler per day is 45nm (5 times trawl per day x 3-hour trawl x 3 knots).

iv. Length of fishing area = 13nm (From Semarang – Labuan LGAST ID:107 & ID:144) (Figure 4 and Figure 5).

v. A trawler would make a U-turn after a distance of 13nm for new trawl leg.

vi. With a distance of 45 nm trawl distance, a vessel would cross 2 pipelines (ID:107 & ID:144) 4 times crossing per day (Figure 5).

vii. Monthly crossings: 84 crossings/ trawler / pipeline (@ Three 7-day fishing trips/ month) i.e. 7 days x 3 trips x 4 times crossing per day).

viii. Annual Crossing: 924 crossings/ trawler / year (Assuming 11-months operation, less 1 month for maintenance and repair). i.e. 84 crossings x 11 months.

ix. Based on the density of fishing trawler for the area which is 4 (see above assumption) the total number of annual crossing = 3,696 (4 trawlers x 924 crossing).

The frequency index table for the number of crossing on a

Figure 8: Steel vee door (left) and common flat wooden door (right) used by trawlers in Sabah.

Source: Authors.

Table 6: Type of Fish Trawl Otter-board used in Sabah and Labuan.

Trawler categories	Types of otter-boards	Dimensions in cm (L x W x T)	Material used	Weight (kg) of one otter board
350 HP and above	Steel Vee Door	190 x 106 x 6.5	Steel	300 kg
350 HP and above	Common Flat Wooden Door	230 x 115 x 5	Steel Frame and Wood	250 kg
350 HP and above	Steel Vee Door	165 x 110 x 5	Steel	210 kg

Source: Authors.

pipeline by trawlers in a year is developed based on the assumed frequency of trawlers passing the pipeline.

3.3. Specification of Trawl Gearg.

The type of trawl gear used in Sabah is the typical otter trawl gear, which is using the polyvalent or rectangular board. This type of trawl gear consists of a pair of otter boards, warp line, and net. There are two types of otter board used by trawlers in Sabah, namely the steel otter board and the steel-reinforced wooden otter board as shown in Figure 8.

The types and dimension of the otter-board are shown in Table 1. The category of fish trawler that are using these otter-boards must have sufficient power to tow the heavy fishing gear at 3 knots. Therefore, the engine horsepower is 350 HP and above. The majority of engine used in the fishing trawlers have horsepower between 350 hp to 500 hp. The diameter of the warp line used is 2.5cm.

3.4. Calculation of Pull Over Load.

Both severity index for pipeline Erb west to Labuan Gas Terminal and Erb west to Sabah Gas Terminal is zero because the impact force from the otter board resulted in no damage to the pipelines. The risk matrix results for both pipelines depends on the frequency of crossing as shown in Table 8.

3.5. Calculation of Frequency Index, Severity Index and Risk Matrix for Fishing Activities.

Both severity index for pipeline Erb west to Labuan Gas Terminal and Erb west to Sabah Gas Terminal is zero because the impact force from the otter board resulted in no damage to

Table 7: Subsea Pipeline Erb West Oil Field to Labuan Data.

Pipeline Name	Pipe Length (km)	Pipe Dia meter (inch/ cm)	Design Code	WT mm	Yield Strength (kN/m²)	Pull-Over Load (kN)
ID80 Erb West to LGAST	140.4	14/ 35.5	API 5L X42	9.53	2.9×10^5 @ 42ksi	23.122
ID85 Erb West to SBGST	60.4	16/ 40.6	API 5L X60	15.9	4.2×10^5 @ 60 ksi	24.855
ID107 Semarang to LGAST	46	14/ 35.5	API 5L X52	9.53	3.55×10^5 @ 52 ksi	28.19
ID144A Semarang to LGAST	47.71	20/50.8	API 5L X65	11.1	4.5×10^5 @ 65 ksi	38.183

Source: Authors.

the pipelines. The risk matrix results for both pipelines depends on the frequency of crossing as shown in Table 8.

Table 8: Level of Damage according to Force of Impact.

Pipeline Name	Thickness mm	Extent of Damage	Force kN	Yield Strength (kN/m²)	Pull over load F_P (kN)
ID80 Erb West / LGAST	9.53	Major	172.011	2.9 x 105 @ 42ksi	23.122
		Local	127.067		
		Minor	72.946		
		Slight	47.062		
ID85 Erb West/ SBGST	15.9	Major	286.985	4.2 x 105 @ 60 ksi	24.855
		Local	212.000		
		Minor	121.704		
		Slight	78.519		
ID107 Semarang/ LGAST	9.53	Major	172.011	3.55 x 105 @ 52 ksi	28.19
		Local	127.067		
		Minor	72.946		
		Slight	47.062		
ID144A Semarang/ LGAST	11.1	Major	200.348	4.5 x 105 @ 65 ksi	38.183
		Local	148.000		
		Minor	84.963		
		Slight	54.815		

Source: Authors.

The trawling method used in Sabah waters is the bottom otter trawl. This type of trawling would cause contact between the trawl boards with subsea pipelines. Based on the specification of the trawl board and the subsea pipeline of the study area, the impact force of the trawl board?s pull-over load is lower the force that would cause slight damage to the pipelines. The interaction between the otter boards and subsea pipelines in West Sabah area and Labuan waters would not damage the subsea pipelines. However, the frequency of the crossing in Labuan and Sabah (Kota Kinabalu) waters are moderate and high respectively. Based on the severity and frequency index, the risk of fishing activities Labuan and Sabah (Kota Kinabalu) waters are Low Risk and Moderate Risk respectively.

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Conclusions.

Multiple observers have suggested major changes are necessary for OTI's to remain viable in future years (Johnson, 2016; Gueard and Martinez-Simon, 2012). Increased consolidation and further disintermediation of the industry to facilitate cloud based booking systems that can be done simply and easily may well occur in the near future. At this writing though, the role of ocean freight forwarders and NVOCCs is still an invaluable necessity for expediting the movement of goods from sellers to buyers. OTIs still handle a major portion of the cargo flow of international trade, hence the need for regulations and procedures to govern their activities. The need for OTIs to offer differentiated, unique, difficult to replicate services and avoid commodity type activities will be necessary to their continued growth.

What will change for OTIs is the removal of manual tracking of shipments, most phone calls and many customer interactions due to the advent of apps offering storied learning, chatbots, and decision algorithms. Block chain technology will make the documentation process far more transparent than it has been and cargo flows across the supply chain that is connected will flow more seamlessly than the sequential handoffs that are performed at present. Datasets can be easily created with the Internet of Things that will show when and where loads are that will most likely negate the need to work with individual carrier websites. New data sources with combined information, predictive data, devices and sensors will provide far more visibility to products than ever before. Tracking systems will be put in place to offer door to door pickup across the global spectrum.

One of the major challenges regarding the information revolution is security and privacy. To participate in the benefits of enhanced information exchange, firms need to modify their views and policies on information collaboration. Increased cooperative access to information may perhaps erode some minor competitive advantage of a firm; but the larger 'pie' created by increased simplification of maritime trade will far outweigh the minor losses due to revelation of some minute trade specifics. Especially in a time when prices and terms are highly competitive, we know that with sophisticated buyers, knowledge of price becomes less important, since they are all competitive; terms and service capability become the differentiators. Thus specifics of transactions and transits, revealed through access by query to large databases, will be more valuable shared than closely held.

The above technologies will transform the nature of the OTI but not replace them. Their role as the conduit of international trade from ship to rail to truck to warehouse will still require their presence and perhaps preeminence as the key channel member within the international logistics realm. The important coordination function they fill means that they cannot locate away from port areas. There will continue to be a need for OTIs to locate in clusters near ports of entry and exit, due to 'soft' factors regarding salesmanship and negotiation regarding localized services, even though the information may be available from anywhere to anywhere. Size and scale are important but an understanding of customers and coordination relationships, and a diversity of key services offered will be essential to OTIs? continued ability to survive and thrive in the 21st century. We therefore believe centers like Chicago and major sea and air port geographies will continue to be sources of innovation in the Ocean Freight Forwarding field, resulting in both new entrants and their subsequent consolidation into larger firms.

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