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PRIMARY RESEARCH

Maritime safety risk analysis in Alur Pelayaran Barat Surabaya (APBS) during dredging process

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Abstract

The West Surabaya Sailing Route (APBS) is a shipping lane that is an in and out access port of Tanjung Perak Surabaya. The location of the APBS, which is the estuary of several rivers, has resulted in the sediment rate being high, so dredging activities need to be done regularly. In contrast to the dredging activities in other places, the dredging carried out along the APBS must be carried out carefully because it is a mined area. A gas pipeline belongs to Kodeco and PLN's high-voltage undersea cable that runs along the APBS line. As a result of the higher hazard potential of dredging sites elsewhere, more comprehensive risk analysis needs to be carried out to reduce the risk of dredging. From some risk identification found in the APBS, it is known that the major risk with the highest risk value based on qualitative calculations using FGD is the risk of ship collisions. By calculating the cost index (ICAF), the best mitigation to reduce the risk of ship crashing is to install a buoy as a barrier and shipping signs. After obtaining the best mitigation based on costs, then quantitatively performed by numerical simulation to determine how much influence mitigation on the probability of ship accidents. From the simulation calculation obtained the mitigation effectiveness to reduce the risk of ship accidents. The biggest decrease in the probability of a ship accident due to overtaking of 100%, followed by a decrease in the probability of a ship accident due to a head-on collision by 54%. Furthermore, the decrease in the probability of ship accidents due to crossing and the probability of ship accidents due to each stranding decreased by 17% and 12%.

I. INTRODUCTION

APBS is a shipping lane located between Surabaya and Madura Island and an entrance to the port of Tanjung Perak Surabaya. APBS has a length of 19 km with a width of 150 m and a depth of -13 m to become a traffic flow of 41,000 ships per year consisting of passenger ships, commercial vessels and warships with an ideal capacity of up to 30,000 GT [1, 2].

The location of the APBS which became the estuary of several rivers resulted in siltation with the largest sediment rate at spot HI of 1,971,336 m^3 per year and the smallest sediment rate at the EF spot of 34,772 m^3 per year so that dredging efforts were needed with a period of 3-15 years silting spot [3].

As a result of the sedimentation rate in certain locations, it is necessary to periodically dredge activities to maintain the depth of the shipping path to the port. By maintaining the depth of the APBS, the safety of ships going in and out of the harbor will avoid the risk of the ship running aground so that activities in the shipping lane will be maintained. In the dredging activities carried out at the previous APBS, there were a number of problems that occurred. The many remaining World War mines that are still active and scattered are the risk of dredging that is not found in other areas outside the APBS. In 2014, efforts to widen the shipping lane in the APBS were limited to those planned to widen the lane from 100 meters to 200 meters only realized by 150 meters. This is due to the presence of Kodeco's gas pipeline which has crossed and crossed the APBS line twice. Similar to a gas pipeline, there is a submarine cable owned by PLN that crosses from Surabaya to the island of Madura which was broken in 2010 due to being caught in a ship's anchor. The existence of submarine pipes and cables embedded in the seabed that do not have special markers increases the risk

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of dredging to maintain the depth of the shipping lane. In addition to the foregoing, a decrease in the standard value of seawater must also be considered during the process of dredging and disposal of sediment material which causes a decrease in the standard quality value to TSS 30 mg/l, turbidity 19 NTU, and brightness levels 0.55-1.7 m. The decline in sea water quality can threaten the sustainability of marine biota living in the dredging and disposal areas of APBS sediments [4, 5]. Before starting dredging, a study is needed to determine the type of sediment material present in the APBS because the inappropriate dredging method can result in environmental pollution when the dredging process takes place as happened in the Kaohsiung Taiwan sea [6]. Sediments that are raised and dissolved in water can disrupt the sustainability of coral reefs around the dredging area [7]. Therefore, management is needed to regulate how the dredging method is in accordance with the type of material found in dredging sites [8, 9].

In addition to the selection of methods based on the type of sediment, the dredging location in the shipping channel has resulted in many stakeholders needing to be involved. [10] conducted a collaborative method for dredging in the port area of the Seine Bay, France. Collaborative methods are carried out to avoid other parties being harmed as long as dredging activities take place, so that in the presence of collaborative methods decision making is based on shared decisions [11]. The incorporation of suitable dredging methods and environmentally sound with the Decision Support System (DSS) can benefit the dredging project [12].

To maintain safety and avoid environmental pollution due to maritime activities carried out, the United Nations formed an organization that regulates maritime regulations under the name of the International Maritime Organization (IMO). In its efforts to maintain the safety of maritime activities, IMO cooperates with the government and the private sector engaged in the shipping industry by recommending the Formal Safety Assessment (FSA). The FSA is a qualitative method, aimed at improving maritime safety including protection of life, health, the marine environment and property by using risk analysis and cost assessment based on the assessment of experts and stakeholders. To find out the value that must be issued to reduce the risk of accidents that will occur, the ICAF index is assessed, which is a method for measuring the index of decreasing risk for costs to be incurred. After obtaining the best mitigation based on the cost benefit, the calculation is carried out using a quantitative method by conducting a simulation to obtain the mitigation method where the simulation can be divided into two, namely the probability of event simulation and consequence simulation [13].

II. RESEARCH METHODE

A. Formal Safety Assessment (FSA)

FSA is a method compiled and recommended by IMO after the accident of the Piper Alpha rig in 1988 which claimed many lives which subsequently resulted in regulations to build fire retaining walls in an effort to minimize the danger due to explosions in drilling wells. The guidelines for the FSA are approved and recommended by IMO since 2002 and have five steps that are Identification of hazards, Assessment of risk, Risk control option, Cost benefit assessment, Recommendation. In calculating the Cost benefit that will be obtained, the FSA uses a method of calculation in the form of ICAF. ICAF is a method commonly used to calculate the benefit ratio that will be obtained by reducing the level of risk in the maritime world. Calculations to find the ICAF index can be seen in Equation 1 below:

$$\text{ICAF} = \frac{\Delta \text{C}}{\Delta R} \tag{1}$$

with:

ICAF : Implied Cost of Averting a Fatality

ΔC : Risk control cost (gross cost)

ΔR: Risk reduction

The Cost of Averting a Fatality index obtained from the reduction in costs incurred for controlling risk is reduced by how many benefits will be obtained and the results of the reduction are divided by a decrease in the value of risk after mitigation. A low ICAF value implies that mitigation carried out has a high value because the costs incurred have more benefits in reducing the risk value.

B. Risk Matrix

To calculate the risk value, a risk matrix is used whose value is derived from the multiplication of the magnitude of the consequence value multiplied by the probability of occurrence. The consequence assessment and probability of occurrence are obtained from the expert's assessment through the interview process or filling in the questionnaire. There are several types of risk matrices depending on the type of activity to be carried out and for this study used a risk matrix from the Western Basin Dredging and Disposal Project. The table evaluating the magnitude of the consequences of the Western Basin Dredging and Disposal Project can be seen in Table 1 and for the frequency analysis criteria in Table 2 below:

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TABLE 1
CRITERIA FOR THE CONSEQUENCES OF DREDGING AND SEDIMENT REMOVAL

Catagory	Rating	WHE	Environment	Financial	Reputation	Legal	Interuption
Minor	1	Near miss/no injury	On site realease of pollutant contained without external assistance	Losses less than $100,000	Isolated complaint	Court action with small fine – less than $ 10,000	Less than 1 hr
Moderate	2	First aid treatment	On site realease of pollutants contained with external assistance	Losses of $ 100,000 to $ 1 million	Multiple community or customer complaint	Court action with moderate fine– $ 10,000 to $ 75,000	1 hr to 1 shift
Significant	3	Medical treatment	Significant on or off site release and detrimental impacts	Losses of $1 million to 2.5 million	Community action with possible delay to project	Court action with moderate fine– $75,000 to $250,000	1 shift to 1 day
Major	4	Serious injury	Major offsite realease and detrimental impacts	Losses of $2.5 million to 5 million	Community action severely delays project	Court action with major fine – greater than $250,000	1 day to 1 week
Critical	5	Major extensive injury	EPA ordered shutdown of major part of process	Losses of greater than $5 million	Community or customer outrage prevents projects or result in severe damage to corporate image which limits future options	Court action with jail sentence	More than 1 week

TABLE 2
CRITERIA FOR FREQUENCY OF DREDGING RISK AND DISPOSAL

Rare	1	The risk may occure only in exceptional circumstaces (the risk is not likely to occur in next 25 years)
Unlikely	2	The risk could occur at some time (the risk is likely to occur once in the next 5-25 years)
Possible	3	The risk might occur at some time (he risk is likely to occur once in the next 2-5 years)
Likely	4	The risk will probably occur in most circumstateces (he risk is likely to occur once in the next 1-2 years)
Almost Certain	5	The risk is expected to occur in most circumstaces (he risk is likely to occur within the next 12 months)

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Risk level assessment results from multiplying the consequences with frequency using the Gladstone Port Corporation matrix to risk the dredging and disposal of sedimentary material as shown in Table 3 below.

TABLE 3
DREDGING AND DISPOSAL RISK MATRIX

		Minor (1)	Moderate (2)	Significant (3)	Major (4)	Critical (5)
Likelihood	Almost certain (5)	Medium	Medium	High	High	High
	Likely (4)	Low	Medium	Medium	High	High
	Possible (3)	Low	Low	Medium	Medium	High
	Unlikely (2)	Very Low	Low	Low	Medium	Medium
	Rare (1)	Very Low	Very Low	Low	Low	Medium

C. Simulation

Traffic based models are an approach to calculating accident frequency which is adjusted to technical standards, the state of the environment, and past density crossing waters in an area [14]. Through this method can estimated frequency of collision accidents, runoff and also contact with an area specifically. It has earlier been shown that the expected number of ship accidents per unit of time in a specified fairway may be estimated by the following Equation 2.

$$C = \lambda.\mathrm{N} \tag{2}$$

Where: C = Expected number of accidents in seaway per time-unit
λ = Number of accidents per vessel-passage of seaway
N = Number of passages per time unit
A voyage may for computational reasons be defined as the passing of a sequence of fairway sections. As a simplification, it is further assumed that the navigational and topological characteristics are relatively constant within each section of the fairway. The probability of ship collision risk is divided into 2 scenarios, namely probability analysis due to head on collisions calculated using Equation 3 below.

$$N_i = \frac{(B1+B2)}{W} \cdot \frac{(v1+v2)}{vi.v2}.\mathrm{D.N_{m1}} \tag{3}$$

Where:
B1 : Mean beam of meeting ships (m)
V1 : Mean speed of meeting ships (knot)
B2 : Beam of subject ship (m)
V2 : Speed of subject ship (knot)
Nm1: Arrival frequency of meeting ships (ships/unit of time)
D : Relative sailing distance (nm)
and probability analysis of two ship collisions in the stranding and Equation 4 below.

$$\mathrm{Pi} \approx 1 - \frac{2}{\pi} \cdot \frac{W}{D} \tag{4}$$

Where:
Pi : Collision Possibility
D : width of strait (m)
W : Distance of strait (m)
While the analysis for the potential for collisions due to crossing is calculated by considering the density of traffic (ρs) can be seen in Equation 5 and the probability of Pi is seen in Equation 6 below.

$$\rho s = \frac{Nm1.T}{(v1.T).W} = \frac{Nm1}{v1.W} \tag{5}$$

Where:
Ps = Traffic density of meeting ships (ships/nm2)
T = An arbitrary period of time (hours)

$$\mathrm{Pi} = \frac{Nm1}{v} \cdot 2 \cdot (\mathrm{B+L}) = \rho \mathrm{s} \cdot 2 \cdot (\mathrm{B+L}).\mathrm{D} \tag{6}$$

B1 : Mean beam of meeting ships (m)
V1 : Mean speed of meeting ships (knot)
B2 : Beam of subject ship (m)
V2 : Speed of subject ship (knot)
Nm1: Arrival frequency of meeting ships (ships/unit of time)
D : Relative sailing distance (nm)

III. RESULTS AND DISCUSSION

A. Establishing The Context

Before discussing the dredging that will be carried out at the Surabaya Barat Shipping Channel (APBS), it was first discussed about the condition of the shipping channel in normal conditions, where the APBS was passed by ships which were mostly container ships and tankers that had large dimensions (up to 30,000 GT), other medium sized vessels such as roro and warships, as well as small vessels such as fishing boats. Container ships and tankers have the purpose of passing APBS to lean in Gresik port, Surabaya Container Terminal (TPS), and Tanjung Perak port in Surabaya. For roro ships, most of them have a destination

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to the terminals of the Tanjung Perak port, and for warships to aim for the KOARMATIM military base. In normal shipping flow conditions, the biggest risk that exists in APBS is the risk of ship collisions [15]. The risk of ship collisions is divided based on the risk of occurrence, namely the risk of ship collision in head to head, the risk of ship accidents due to overtaking, and the risk of ship accidents due to crossing [14]. Based on the study of ship collision analysis that occurred in the APBS, the risk of ship collisions during overtaking has the highest risk followed by the risk of ship collisions when heading to head, then the risk of ship collisions during crossing [16]. These risks can increase if the shipping volume from and to the APBS also increases due to the limited shipping channel width which increases the risk of accidents. The dredging activity at APBS has 3 stages, namely the dredging stage, the stage of sending sediment material to the exhaust location, and the stage of removal of sediment material. In the first stage, the dredging stage, the dredger where in this study using TSHD type dredgers will standby at the dredge location while carrying out the dredging process through pipes placed on the seabed. At this stage, dredging activities will cover up to half of the shipping channel so that the shipping channel will experience a narrowing of approximately 600 meters. As a result of the closing of half of the shipping lane, the dredging area needs to do traffic engineering in the form of open and close grooves so that the 600-meter track will only be traversed in one direction. In the second stage, the stage of sending dredged material to the dump site. At this stage the risk of overtaking of ship collisions is based on which previous research is the highest risk in the APBS. The risk of overtaking occurs because the speed of TSHD dredgers when carrying sediment material has a lower speed than other vessels that both pass through the APBS so that the vessels will overtake when the dredger is in front of it. The third stage is the stage of disposal of sediment material which has a predetermined location referring to the Government Regulation regarding the location of disposal of dredged material which in this study was determined at the location with coordinates. Based on the location at the coordinates it has a very small risk of ship collisions because it is not a shipping channel and also is not a location for maneuvering or anchoring ships. Although the risk of ship collisions is very small, at this stage there is another risk that is also present in the pumping stage, namely the risk of the spread of sediment material being discharged to other regions so that it can cause environmental pollution. Based on the sediment rate data that occurred at the APBS, it is known that the fastest dredging period is carried out once every 3 years located at the HI spot. While for the type of sediment material in the APBS is clay type material and dredging location which is the shipping channel so that TSHD type dredgers are chosen to obtain dredging efficiency and prevent the risk of environmental damage [1]. The TSHD type dredger as can be seen in Figure 1 is a dredger that uses a suction pipe to extract sediment material and store it in the hull of the ship which then removes the sediment material by transporting it to the dumping area.

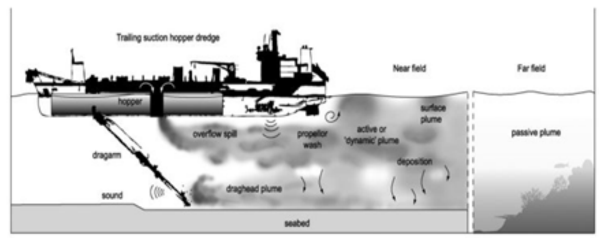

Fig. 1. Illustration of TSHD type dredger operation

The selection of TSHD type dredgers was chosen based on their ability to do dredging activities with clay or clay resistant material, as well as the effectiveness in dredging the waters with high depth. However, the number of TSHD-type vessels operating in Indonesia is quite limited and is only owned by outside contractors such as Jan De Nul and Van Oord, resulting in limited availability of TSHD-type vessels so that the dredging method using TSHD type vessels requires good time management regarding vessel availability.

B. Risk Identification

Previously obtained risk identification obtained from review of previous research and observations based on conditions in the field by researchers. The results of risk identification are then discussed with experts and stakeholders at the time of the FGD to be reviewed whether it is in accordance with the conditions in the field and to bring up all possible risks that have not been identified. Stakeholders and experts asked for opinions in interviews are people who understand the concept of risk, so that it can produce comprehensive risk identification. The FGD participants consist of experts and stakeholders. The results of the FGD to find out what risks are identified in the APBS can be seen in Table 4 below.

Based on Table 4 above, some risk identification is found in the APBS as long as dredging activities take place. At this stage brainstorming is done to get as much as possible the potential risks that may occur as long as dredging activities take place. All these identifications will then be carried out with a risk assessment by asking the expert and stakehold-

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ers to assess the magnitude of the consequences and frequency of occurrence of these risks.

TABLE 4
RISK IDENTIFICATION

No	Risk Identification
1	Dredger ship not available
2	Sediment is scattered
3	Blokade by fisherman
4	Ship Collision
5	Queue in and out of the port
6	Workers fall into the sea
7	Dredger Ship grounding
8	Mine explosion
9	Subsea pipe explosion
10	undersea cable broke up
11	Permit for dredging is not accepted
12	Changes to dredging regulations
13	Sudden stop by the Indonesian Navy
14	Dredgers damaged
15	Theft of project property

C. Risk Assessment

The dredging risk assessment is carried out by experts who have experience and stakeholders who have interests in the APBS. To find out the value of dredging risk obtained from the multiplication of the frequency of events with the value of the consequences of the event. To calculate the magnitude of the frequency value and the magnitude of the consequence value using a table from the Western Basin Dredging and Disposal Project for consequence assessment criteria and for frequency assessment. Consequences and frequency assessments were adjusted for the identification of risks encountered at the dredging sites in the APBS. To that end, risk identification has been carried out based on a review of previous research and journals and identification of risks based on conditions and other potential hazards not found in research elsewhere. Risk identification is the risk that will be faced during the dredging process. The risk assessment carried out is to hold an FGD with experts and stakeholders by first telling about the background of the research to be carried out and explaining structurally and systematically about the risks of dredging. After that, the expert and stakeholders are informed about what is the risk and how to calculate it so that the assessment is given in accordance with the assessment criteria that have been set. The risk value is obtained from the multiplication of the consequence value multiplied by the frequency value. The results of the multiplication are then entered into the risk matrix to determine the level of risk. The value of risk can be seen in Table 5 below.

TABLE 5
MUNICIPAL WATER DEMAND EVALUATION RESULTS SUMMARY

No	Risk Identification	No Risk Identification					Frequency					Risk Value	Risk Catagory
		1	2	3	4	5	1	2	3	4	5		
1	Dredger ship not available					√				√		20	High
2	Sediment is scattered				√					√		16	High
3	Blokade by fisherman			√						√		12	Medium
4	Ship Collision					√					√	25	High
5	Queue in and out of the port				√						√	20	High
6	Workers fall into the sea				√					√		16	High
7	Dredger Ship grounding				√				√			12	Medium
8	Mine explosion			√					√			9	Medium
9	Subsea pipe explosion					√		√				10	Medium
10	Undersea cable broke up					√		√				10	Medium
11	Permit for dredging is not accepted					√		√				10	Medium
12	Changes to dredging regulations					√		√				10	Medium
13	Sudden stop by the Indonesian Navy					√		√				10	Medium
14	Dredgers damaged					√		√				10	Medium
15	Theft of project property			√							√	15	High

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D. Mitigation

To reduce the risk value in the APBS as long as dredging activities take place, mitigation is needed to reduce the value of the consequences or the risk frequency value. Some of the mitigations obtained were obtained from literature studies and also the opinions of experts and dredging stakeholders in the APBS. According to Table 5, the highest risk identification found is ship collision risk and then we choose that risk to decrease the risk value. The residual risk after mitigation can be seen in Table 6 below.

TABLE 6

RESIDUAL RISK FOR SHIP COLLISION AFTER MITIGATION

No	Risk Identification	Mitigation	No Risk Identification					Frequency					Residual Risk
			1	2	3	4	5	1	2	3	4	5	
1	Ship Collision	Insert Buoy for marking dangerous area			√		√						15
		Use patrol ship to manage ship traffict			√		√						15

The ICAF calculation using Equation 1 results in a cost benefit value for both mitigation at the risk of ship accidents where the mitigation is in the form of installing buoys for signs in the shipping channel, and the second mitigation is using patrol boats to monitor and regulate ship traffic. To mitigate the installation of buoys, the costs that need to be spent are buying a buoy that is used as shipping signs. Purchase the amount of buoy based on the size of the buoy selected and the maximum distance between buoys according to the standard of IMO. Whereas for the second mitigation is to use patrol boats as regulators and traffic controllers in the shipping lane by considering the cost of renting the ship and how long the lease will be carried out. For the period of lease the ship follows from the productivity of the dredger where the productivity of dredgers to the amount of sediment to be dredged requires a period of 2 months of work. In addition, the factor of the amount of fuel needed by patrol boats and the price of their fuel is also a calculation of the cost index for mitigation using patrol boats. The results of the calculation can be seen in Table 7 below.

TABLE 7

ICAF CALCULATION FOR EACH MITIGATION

No	Mitigation	Cost (ΔC)	Risk Decrease	ICAF
1	Insert Buoy for marking dangerous area	Rp. 1.156.000.000	10	Rp. 104.000.000
2	Use patrol ship to manage ship traffict	Rp. 3.149.906.250	10	Rp. 209.993.750

Based from the result of Table 7, we choose to insert buoy as a traffic control and marking dangerous area during dredging activities for calculating simulation using traffic based model.

E. Simulation

Simulation of the probability of ship collisions during dredging activities at the APBS was carried out by adding activities from dredgers where in this study Volvox Terranova dredgers were used. The dredger has an overall length of 164 meters with a width of 29 meters and an operating speed of 6 knots starting from the process of dredging sediment material, sending sediment material to the dump site and when dumping sediment material at the dump site with the probability of a ship accident passing the (Pc) APBS. Based on the results of simulation calculations when the shipping channel is in a normal condition with conditions after the dredging activity is obtained, the calculation results show an increase in the probability of a ship collision. The increase in the probability of the risk of a ship collision can be seen in Table 8 below.

TABLE 8

COLLISION PROBABILITY INCREASE DURING DREDGING ACTIVITY

Collision Risk	Normal Condition (accidents per year)	With Dredging Activity (accidents per year)	Probability Change (%)
Stranding	1.38	1.65	+19.5
Head on	10	33	+230
Crossing	0.5	0.8	+60
Overtaking	16	60	+275

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Based on Table 8 above, it is known that there was an increase in the probability of the biggest accident when overtaking increased by 275%, followed by the risk of head on accidents by 230%, accident risk at crossing 60%, and finally stranding risk of 19.5%. To reduce the increase in the probability of accidents due to the dredging activity, mitigation with the most optimal ICAF value was chosen in accordance with the calculation, namely the installation of buoys that function as signs when going through areas of dredging activity. The illustration of buoy installation can be seen in Figure 2 below.

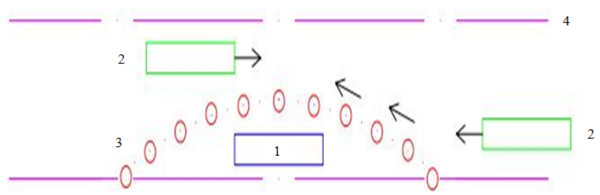

Fig. 2. Illustration of buoy installation and traffic engineering

From the picture above, description number 1 is a dredger, number 2 is a passing boat, number 3 is a buoy, and number 4 is a barrier to the shipping channel. The closure of the shipping channel due to dredging activity closes up to half of the shipping channel width of 75 meters. This reason is because the dredger has a width of 29 meters, which according to the safety rules of IMO requires that the minimum shipping width for the ship is 1.5 times the width of the ship. For buoys that are installed as long as 600 meters where it is also a safety rule set by IMO where the minimum safe distance between ships is 1.5 times the length of the ship so that the ship can maneuver to avoid a collision. Installation of buoys will automatically engineer the flow of ship traffic from previously able to pass directly when passing through the shipping channel to only be able to be passed by one ship in the same direction for ships with a width of 20 meters and above. The trick is to reduce speed or stop if needed if you have seen warning signs while waiting for directions from the martyrdom or flagman who are on duty at the dredging project site. From the calculation of the probability of ship collision accidents in the presence of dredging activities, it is known that the mitigation carried out has succeeded in reducing the probability of stranding and the probability value of collision. The probability of decreasing values for each accident risk can be seen in Table 9 below.

TABLE 9
DECREASING PROBABILITY AFTER MITIGATION

Collision Risk	Probability before mitigation (accidents per year)	Probability after mitigation (accidents per year)	Probability Change (%)
Stranding	1.65	1.98	+20
Head on	33	2	-94
Crossing	0.8	0.008	-90
Overtaking	60	0	-100

Based on Table 9 above, it is known that the biggest decrease is the probability of overtaking of ship collisions as much as 100% followed by the probability of a head on collision by 94%. Furthermore, the decrease in the probability of head-on collision and the probability of stranding down by 90% and increase 20% respectively.

IV. CONCLUSION

The West Surabaya Shipping Line (APBS) is a shipping channel that is a way in and out of three ports, namely Tanjung Perak, Serabaya Container Terminal, and Gresik Port. The location of the shipping channel located in the Madura Strait and also the estuary of several rivers causes the sedimentation rate in the APBS to be high and results in the need for periodic dredging with the fastest dredging period at the HI spot ie for 3 years. Dredging itself is useful to maintain the security of the shipping channel from ship risk to run aground and to increase the volume capacity of vessels going to the port so that it can increase revenue and port competitiveness. The present study focuses on the risk analysis of dredging at the APBS as long as dredging activities take place by identifying any risks present in the APBS both in conditions before dredging and when dredging is carried out based on the results of interviews with experts and stakeholders. The dredging that will be carried out at the APBS has internal risks and external risks whose risks are divided based on the stages of dredging activity, namely the risk when dredging is carried out, the risks when sending sediment material to the discharge location, and the risk of removing sediment material. Another risk in dredging activities in the APBS that is not found in other dredging activities is the presence of submarine pipes and cables and mines scattered around the dredging area. However, based

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on the location map of the objects with potential risk, they are outside the dredging area and for submarine pipes and cables that cross with the shipping channel at a depth that is relatively safe from dredging activities. This is also supported by the assessment of experts and stakeholders who stated that the risk of damage to submarine cables and pipes and the risk of mine explosions have a medium risk value.
For the highest risk in the APBS as long as dredging activities take place the results of interviews with experts and stakeholders are the risk of ship collisions. This is supported by research from [15] which states that the biggest risk that exists in the APBS on shipping lines with normal conditions is the risk of ship collisions with the highest risk value and followed by the risk of workplace accidents in the second position. While the research by [17] mentions the risk of tanker accidents by taking samples on MT tankers. Krasak concluded that tankers have an accident risk with a medium risk value when passing through the APBS. And research by [3] states that the highest risk of accidents found in the APBS is the risk of accidents when the ship manages overtaking to overtake the ship in front of it due to the narrow shipping lane. Based on previous studies which mention the highest risk in the APBS when normal flow conditions are the risk of ship collisions, it can be ascertained that the presence of additional activities in the form of dredging activities in the shipping lanes will increase the risk of ship collisions which have already become the highest risk.
From the results of the analysis conducted, it was found that the risk of ship collisions due to overtaking is a risk with the highest probability value when dredging activities are carried out followed by collisions due to head on, stranding, and crossing occupying the last position. However, after mitigation, collision risk due to overtaking has decreased by 100% to have a probability of occurrence of 0, and the highest collision risk is a collision risk caused by head on collisions, followed by stranding collision risk, and risk of crossing collisions being the smallest risk. By decreasing the probability value, it is evident that mitigation is carried out effectively to reduce the value of the risk of ship collisions that occur during the dredging process. However, to reduce the risk of such collisions, mitigation can create other potential risks, namely vessel traffic flow that will either lead to or leave the port will be hampered, which will reduce the potential of port revenues during dredging activities. In addition, mitigation carried out is only effective in reducing the probability of ship accidents in locations where dredging activities are carried out and the value of the probability of the accident will return to value when the shipping channel is normal when the ship has passed the dredging area. Therefore, for future research it can be investigated how the effect of shipping channel closure due to dredging activities so as not to disrupt port productivity and how mitigation carried out to reduce the probability of ship accidents can apply to along the shipping channel.

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