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Probability of Ship Collision Using Minimum Distance to Collision (MDTC); A Case Study of Surabaya West Access Channel (SWAC)

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Abstract – By 2013, it was recorded that the density of ship traffic in the Madura Strait reached 43.000 ship calls. This number is considered exceeding the existing capacity of Madura Strait which is only 27.000 ships per year (Kabar Bisnis, 2014). With the plan of port development around the area, the existence and future oil and gas platform installation, subsea gas pipeline and cables around the shipping channel, it is estimated that the density of Madura Strait is even more congested. It is important, therefore, to assess the probability of maritime accidents due to the high potential hazard in the area, and one of which is the ship collision. The existing shipping line condition in Madura Strait is limited (narrow) and not proportionate to the number of ships passing, and this could lead to ship collision. The loss caused by ship collision can be in many ways, such as loss of life, loss of environmental impact caused when oil spills, physical damage and economic loss as a result of the damage to the cargo. This research utilizes the Minimum Distance method to Collision (MDTC) to get an estimate value of the probability of ships collision (Montewka, 2011) and found the probabilities of ship collision as follows: in the inner channel at 19,000 to 30,000 spots in head-on collision 2,138 accidents/year and the lowest probabilities of ship collision is overtaking in the outer channel 0.086 at 13,000-19,000 spots accidents/year. While the Traffic Based Model (Kristiansen, 2005) found that the highest probability of ship collision in the inner channel at 19,000-30,000 spots in head-on 1,151 accidents / year and the lowest probabilities of ship collision is overtaking in the outer channel at 38,000-43,000 spots 0.130 accidents/year.

Keywords — : probability, minimum distance to collision, ship collision, Surabaya West Access Channel (SWAC), traffic based model.

1. INTRODUCTION

Surabaya West Access Channel (SWAC) is the entrance to the Tanjung Perak Port and some surrounding port. The SWAC recent condition is width 100 meters with a depth -9 m LWS, supported with only one lane trajectory and 8.5 meters maximum ships draft. A lot ship accident reported in the Madura Strait, especially around the Surabaya West Access Channel (SWAC). **Fig.1** represent in detail the ship accident in SWAC.

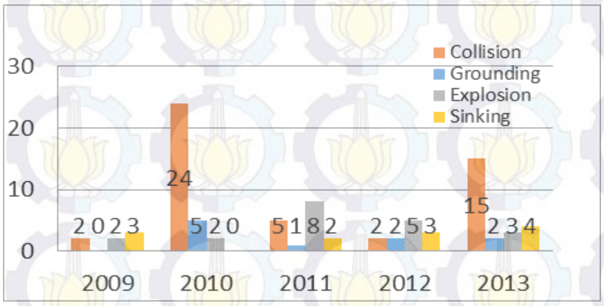


Fig. 1. Number of Ship Accidents in SWAC

Limited width and depth of Shipping lanes conditions is one of the high potential causes of accidents .The restrictions on the allowable draft of ships into the Madura Strait due to the shallow waters, also result in delays in the rate of the economy in eastern Indonesia. To solve the problems above, the following plan to revitalize in shipping lanes:

Table 1.1. Shipping Channel Revitalization Plan

No.	Description	Existing Condition	Revitalization
1.	-Lenght -Width -Depth	25 Nautical Mile 100 meter -9.5 LWS	25 Nautical Mile 200 meter -12 LWS
2.	Dredging Volume	700.000 m^3/3 year	2,3 million m^3/year
3.	Accidents	Often	Minim Accidents
4.	Service	One Way	Two Way
5.	Traffic Capacity	27.000 ship calls	59.000 ship calls

(source : Majalah Dermana Edisi 173, April 2013)

Infrastructure development plan by the government through MP3I program is expected to reduce the traffic density in Madura Strait. The establishment of the Terminal Multipurpose Teluk Lamong (TMTL), the addition of 10 units of the ferry and some infrastructures, regional Shipping lanes in the Madura Strait will be more crowded. Ship traffic grow affect the level of safety around shipping lanes. As described in the following equation:

$$N_a = P_a \times N_m \quad (1.1)$$

From the equation above can be defined that the number of accident (Na) is the result of multiplying the chances of a collision events (Pa) by the number of ships that traverse an area at a particular time (Nm). In other words, the higher number of vessels crossing the SWAC, the greater number of accidents that may occur. The probability of ships collision is likely to occur with the current visit ships growth higher. SWAC divided into two channels :

1. *Outer Channel* :
   - Spot 0 – 6500
   - Spot 6500 – 13.000
   - Spot 13.000 – 19.0000
2. Inner Channel :
   - Spot 19.000 – 30.000
   - Spot 30.000 – 38.000
   - Spot 38.000 – 43.000

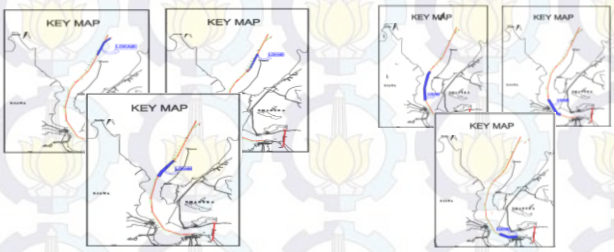


Fig. 2. Outer Channel & Inner Channel SWAC

2. METHODS

2.1 Minimum Distance To Collision

Minimum Distance to Collision method (MDTC), introduced by Montewka in 2010 to assess the risk of tankers that will go through the area of Gulf of Finland with a fairly dense branching flow between Helsinki to Tallinn. Two ships will collide if the distance between the ships of the other vessels to each other to less than a specific value, called Minimum Distance to Collision (MDTC). Modeling Three variations of collision scenarios, and various types of existing vessels in the shipping lanes is analyzed. Ships collision scenarios:

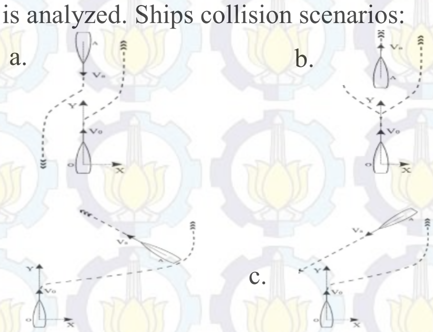


Fig.3. Ship Collision (a) Head-on (b) Overtaking (c) Crossing (L.P.Perera et al, 2009)

2.1.1 Head On Collision

Candidate head-on collision can be determined by the equation :

$$N_{head\ on} = T_0 P_0 \quad (2.1)$$

$$T_0 = \frac{N^2}{2L} E[V_{ij}] \quad (2.2)$$

$$E[V_{ij}] = \sqrt{(V_i^2 + V_j^2 - 2V_i V_j \cos\theta} \quad (2.3)$$

$$P_0 = P(x \le \frac{B_1 + B_2}{2}) \quad (2.4)$$

T_0 is the overtaking rate (the number of vessels which will overtake another while on parallel courses, irrespective of the passing distance), P_0 is the spatial probability of the vessels coming close to each other. N is the expected number of vessels in the waterway on parallel courses and L is the length of the waterway. Dist is the distance between two ships while overtaking and B is the breadth of a vessel.The distribution of relative velocity (V_{ij}) between two ships of the given types i and j was obtained by means of Monte-Carlo simulation, following the formula:

$$V_{ij} = \sqrt{\left(V_i^{(1)}\right)^2 + \left(V_j^{(2)}\right)^2 - 2\,V_i^{(1)} V_j^{(2)} \cos\theta} \qquad (2.5)$$

V_i, is the velocity of a vessel in a group i, picked up randomly from an appropriate distribution.

2.1.2 Overtaking Collision

Candidate overtaking collision can be determined by the equation :

$$N_{overtaking} = T_0 P_0 \qquad (2.6)$$

$$T_0 = \frac{N^2}{2L} E[V_{ij}] \qquad (2.7)$$

$$E[Vij] = \sqrt{(V_i^2 + V_j^2 - 2V_i V_j \cos\theta} \qquad (2.8)$$

$$P_0 = P, x \leq \frac{B_1 + B_2}{2} \qquad (2.9)$$

T_0 is the overtaking rate (the number of vessels which will overtake another while on parallel courses, irrespective of the passing distance), P_0 is the spatial probability of the vessels coming close to each other. N is the expected number of vessels in the waterway on parallel courses and L is the length of the waterway. Dist is the distance between two ships while overtaking and B is the breadth of a vessel.

2.1.3 Crossing Collision

Candidate crossing collision can be determined by the equation :

$$N_{crossing} = \Sigma_{ij} \frac{E[V_{ij}]\lambda_i \lambda_j}{V_i V_j sin\alpha} \qquad (2.10)$$

where $E[V_{ij}]$ denotes the expected relative velocity of all pairs of vessels of types i and j, λ is the intensity of the vessels of the given type entering the given waterway, V stands for the velocity of the vessels according to type, and a means the angle of intersection between the courses of two vessels. MDTC method will be compared with Traffic Based Models.

2.2 Traffic Based Model

Models Based Traffic accident frequency calculation is an approach adapted to technical standards, environmental conditions and vessel traffic density in a specific waters (Kristansen, 2005). Applied in SWAC, the ships meet a collision scenario with three models of collision, i.e.: head-on, crossing and overtaking.

2.2.1 Head On Collision

Head-on collision occurs when two ships oncoming, the position facing each other in the opposite direction. Potential collision occurred on the bow of ships, as shown in the **fig.4** :

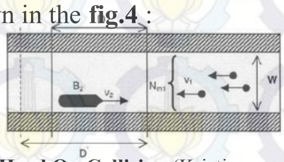


Fig.4. Head On Collision (Kristiansen, 2005)

the probabilities of head on collision, use the following equation :

$$\rho = \frac{Nm}{V_1 * W} \qquad (2.11)$$

$$N_i = \frac{(B_1 + B_2)}{W} * \frac{(V_1 + V_2)}{V_1 * V_2} * D * N_{ml} \qquad (2.12)$$

$$Pa = Ni * Pc \qquad (2.13)$$

$$Na = Pa * Nm \qquad (2.14)$$

ρ : traffic density of meeting ships (ship/m^2), Nm : arrival frequency of meeting ships (ship/unit of time), V_1: mean speed of subject ships (knots), V_2 : speed of head on ships (knots), W : width of waterway (m), Pi : impact probability, Pa : probability of head on collision (accidents/passage), B_1 : mean beam of subject ships (m), B_2 : beam of head on ships (m).

2.2.2 Overtaking Collision

Overtaking collision when two ships moving toward a point in the same direction but different speeds, so the probability to collide. Overtaking can be demonstrated through the following **fig.5** :

Fig.5. Overtaking Collision (http://fw.ky.gov/FishBoatGuide/Pages/Boating.aspx, 2014)

2.2.3 Crossing Collision

Crossing collisions occur when two or more ships moving toward an intersection at the same time, so it has a chance to collide.

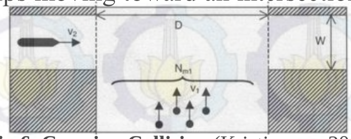


Fig.6. Crossing Collision (Kristiansen, 2005)

the probabilities of crossing collision, use the following equation :

$$\rho = \frac{Nm}{V_1 * W} \quad (2.15)$$

$$P_i = \frac{Nm}{V_1 * V_2} * [(B_1 + L_2) * V_1 + (L_1 + B_2) * V_2 \quad (2.16)$$

$$Pa = Pi * Pc \quad (2.17)$$

$$Na = Pa * Nm \quad (2.18)$$

ρ : traffic density of meeting ships (ship/m^2), Nm : arrival frequency of meeting ships (ship/unit of time), V_1: mean speed of subject ships (knots), V_2 : speed of crossing ships (knots), W: width of waterway (m), Pi : impact probability, Pa : probability of crossing collision (accidents/passage), B_1 : mean beam of subject ships (m), B_2 : beam of crossing ships (m).

3. RESULTS AND DISCUSSION

Based on two methods that used to calculate the frequency of ship collision, head on collision is an incident with the highest frequency of ship collision than crossing and overtaking. And the highest area of ship collision is inner channel on spot 19000-30000.

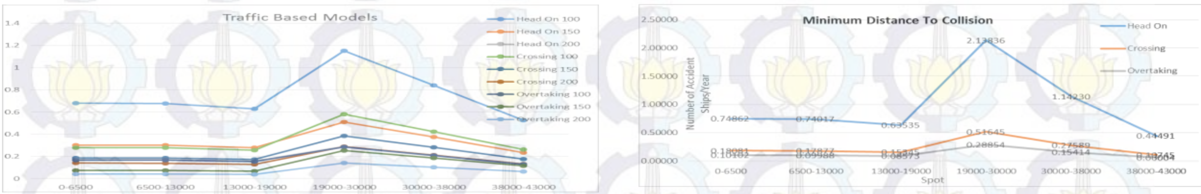
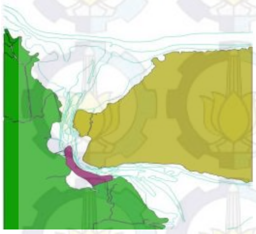


Fig.7. Frequency of Ship Collision

3.1 Plotting Area with The Highest Frequency of Ship Collision on GIS

Geographic Information Systems (Geographic Information System / GIS) is a component that consists of hardware, software, geographic data and human resources to work together effectively to input, store, repair, update, manage, manipulate, integrate, analyze and display data in a geographic-based information. GIS has the ability to connect a wide range of data at a given point on earth, combine, analyze and eventually charted the results.



From the calculation, the frequency of ship collision obtained, plot the area with the highest frequency of ship collision on the GIS. Red area on **fig. 8** shows that inner channel has the highest frequency of ship collision.

Fig.8. Frequency of Ship Collision In The Inner Channel (Area with The Highest Frequency in SWAC)

4. CONCLUSIONS

The frequency calculation of a ship collision using the Traffic Based Models (TBM) or by Minimum Distance To Collision (MDTC) method, shown similar results, i.e.there is still the frequency of ship collision in SWAC despite the fact that the revitalization of the groove width. Both methods, obtained the frequency of ships collision is highest around the inner channel esp on the spots 19000-30000.

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