FINAL PROJECT -ME 141501

Collision Risk Analysis using Traffic-Conflict Model based on AIS Data
Study Case: Surabaya West Access Channel

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Surabaya
2016

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Analisa Risiko Tubrukan dengan Pemodelan *Traffic-Conflict* menggunakan Data AIS
Studi Kasus: Alur Pelayaran Barat Surabaya

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2016

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APPROVAL SHEET

COLLISION RISK ANALYSIS USING TRAFFIC-CONFLICT MODEL BASED ON AIS DATA STUDY CASE: SURABAYA WEST ACCESS CHANNEL

FINAL PROJECT

Submitted as one of the requirements to get Bachelor of Engineering Degree in Reliability, Availability, Maintainability and Safety (RAMS) field of study

Undergraduate Program of Marine Engineering Department

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

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SURABAYA
JULI 2016

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COLLISION RISK ANALYSIS USING TRAFFIC-CONFLICT MODEL BASED ON AIS DATA STUDY CASE: SURABAYA WEST ACCESS CHANNEL

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ABSTRACT

Surabaya West Access Channel is a channel located in Madura Strait with 25 mile long, 100m wide and 9.5m deep between East Java and Madura Island. The access channel in Madura Strait is an essential access to Port of Tanjung Perak. However, the channel is often considered as one of the most dangerous routes for navigation. The most critical black spot lies at the entrance of the channel or between the buoys of No. 8 to No.11. Using traffic conflict model as a safety Model approach, it is expected to give us a better result of collision risk analysis which is in a form of systematic method by analyzing traffic interactions for evaluating and compensating any potential sources of safety hazards in Surabaya West Access Channel. The data collecting will be gained through AIS (Automatic Identification System) located in Reliability and Safety Laboratory, ITS Surabaya. The calculation of collision risk will be done through traffic-conflict modelthat relies on the speed, course and distance of the objects—which *resulting DCPA and TCPA value from each crossing encounter of each vessel route scenarios. The result of DCPA and TCPA will later be used for analyzing the λ (threshold) of every scenario and giving us the general picture of risk level in each encounter and area in Surabaya West Access Channel, which is divided into 5 categories of risk level such as Safe Risk level in the value range of λ from 0 – 0.4, Low Risk level in the value range of λ from 0.2-0.6, Medium Risk level in the value range of λ from 0.4-0.8, High Risk level in the value range of λ from 0.6-1.0 and Very High Risk level in the value range of λ from 0.8-1.0. The output of this risk level calculation will later be inputted into a source code for AIS online web.*

Keyword: AIS, collision risk, DCPA &TCPA, traffic-conflict model, Surabaya West Access Channel

ANALISA RISIKO TUBRUKAN DENGAN PEMODELAN *TRAFFIC-CONFLICT* BERDASARKAN DATA AIS STUDI KASUS: ALUR PELAYARAN BARAT SURABAYA

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ABSTRAK

Alur Pelayaran Barat Surabaya adalah alur yang terletak di Selat Madura dengan panjang 25 mil, lebar 100 m dan kedalaman 9.5m yang terletak diantara Jawa Timur dan Pulau Madura. Alur pelayaran ini merupakan alur akses yang penting untuk Pelabuhan Tanjung Perak. Namun, alur ini sering dianggap sebagai salah satu rute alur yang paling berbahaya untuk navigasi kapal. Salh satu titik yang berbahaya di alur ini terdapat di pintu masuk alur pelayaran ini atau diantara buoy No. 8 hingga No.11. Dengan menggunakan pemodelan traffic-conflict sebagai salah satu bentuk pemodelan untuk keselamatan navigasi, diharapkan metode tersebut dapat memberikan hasil yang lebih baik dari analisis risiko tabrakan konvensional dengan menganalisa interaksi lalu lintas untuk mengevaluasi dan mengkompensasi segala bentuk potensi sumber bahaya keamanan di Alur Pelayaran Barat Surabaya. Pengumpulan data akan diperoleh melalui AIS (Automatic Identification System) *yang terletak di Laboratorium Keandalan dan Keselamatan, ITS Surabaya. Perhitungan risiko tabrakan akan dilakukan melalui pemodelan traffic-conflict yang mengandalkan kecepatan, lintasan dan jarak dari setiap kapal—yang menghasilkan nilai DCPA dan TCPA dari setiap pertemuan crossing dari masing-masing skenario rute kapa. Hasil nilai DCPA dan TCPA ini nantinya akan digunakan untuk menganalisa nilai ambang batas risiko dari setiap skenario dan memberikan kita gambaran umum dari tingkat risiko di setiap pertemuan dan wilayah diAlur Pelayaran Barat Surabaya, yang terbagi menjadi 5 kategori tingkat risiko yaitu tingkat risiko aman dalam kisaran nilai 0-0,4, tingkat risiko rendah di kisaran nilai 0,2-0,6, tingkat risiko menengah di kisaran nilai 0,4-0,8, tingkat risiko tinggi dalam kisaran nilai 0,6-1,0 dan tingkat risiko yang sangat tinggi dalam kisaran nilai 0,8-1,0. Output dari perhitungan tingkat risiko ini nantinya akan dimasukkan ke dalam website AIS secara online.*

Kata Kunci: AIS, DCPA & TCPA, Pemodelan traffic-conflict, Risiko Tubrukan, Surabaya West Access Channel

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CHAPTER 1
PREFACE

1.1 Introduction

Navigational safety is one of the urgencies to be concerned in worldwide maritime. This concern have been increasing over time due to the loaded maritime traffic as shipping through waterborne transport raised its demand and popularity over the past decades (Soares and Teixeira, 2001). The impact of navigational safety in maritime traffic is often linked to port operation, accident prevention and shipping efficiency. Based on those impacts, maritime based organizations around the world have concern to enhance the safety assessment and management in maritime transportation.

It has been shown that risk on navigational accident is prone to be higher in port waters or narrow waterway if compared to open sea. A survey conducted on ship's accidents (Llyod's List Intelligence, 2015) stated that there are 649 cases of ships going through collisions and other type of accident since 2009, with 61% within are cases on navigational accident and 20% of them is caused by collisions both in open sea and port waters. This is mainly caused by dense traffic movements, insufficient port's area and limited depth of water in port waters.

As revealed in many studies (Yip, 2008; C.P. Liu, 2006), collisions are in account as one of the major reason in shipping accident on port. It is also described as one of the most severe types of accidents (IMO, 1998). Moreover, as marine traffic in port waters is increasing, the risk of collisions and conflicts will also be higher.

Therefore, a thorough method of risk analysis is needed to ensure a safe traffic within port waters.

1.2 Background Analysis

Problems

Surabaya West Access Channel is a channel located in Madura Strait with 25 mile long, 100m wide and 9.5m deep between East Java and Madura Island. The access channel in Madura Strait is often considered as an essential access to Port of Tanjung Perak. However, as the maritime activity is developing, it is getting difficult for the large ships to pass through the access channel, and these ships sometimes are waiting in front of the access channel. This situation making the channel will not be able to meet the requirement of competitive maritime activities and endangering the navigational operation within. There are several challanges faced by the Surabaya West Access Channel that need to be solved immediately.

First problem is the limited channel passage. The existing access channel is narrow and shallow, especially, from buoy No.8 to No.10, the water depth is around 10.5 m and the width is around 100 m. In this section, the large ships guided by pilot services have to carefully pass, and the travel speed is only 5-6 knots. Some ships with drafts more than 10 m have to wait for the high tide. Nowadays, approximately 25-30 large ships (actual draft around 10 m) per day are coming to this channel. It means that 62-74% of the ship calls in Surabaya port are affected by the channel’s limitations (JICA Study Team, 2012). Although this section is narrow, the large ships can pass through both directions by pilot navigation. For this reason, traffic congestion apparently pretty serious as this section doesn’t have the capacity for both directions, and it will be a bottle neck for passing vessel traffic in the future.

Second problem is the difficulties it has to upgrade the depth of the channel. There are 14 wrecks and 5 obstructions along the west channel. In addition, there are 24 wrecks are in front of Tanjung Perak. Furthermore, there are submarine gas pipelines that run along the west channel at the Gresik side; a training wall of 13 km was constructed during the Dutch era at the Madura side; and, the PLN power cable crosses the channel to provide electricity to Madura Island. Lastly, one hidden shoal of hard seabed material with a depth of only 4.7 m lies in front of PT. Smelting Pier. This has caused a lot of safety concern and increasing the risk of its navigational operation.

It also affecting the high shipping cost of ships passing through the channel due to the limitation of the vessel size which can’t accomodate vessels with port-panamax specification.

Those problems coming from the West Access Channel is makes it to be considered as one of the more dangerous routes for navigation. The most critical black spot lies at the entrance of the channel or between the buoys of No. 8 to No.11. Frequent accident types are brushing and crashing between two ships. Running aground also sometimes happened. Moreover, the PLN’s submarine power cables have been cut off by the anchors of drifting ships 10 times since its installation in 1987.

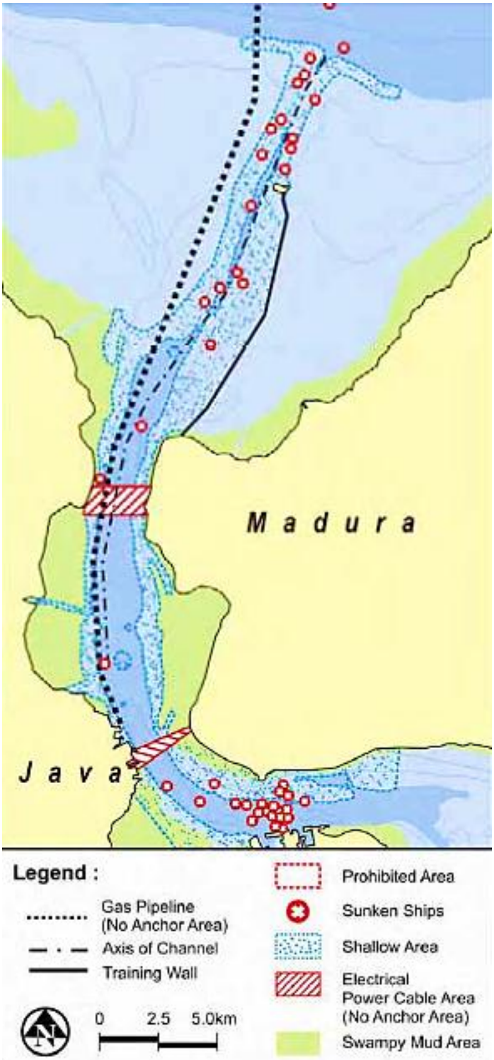

Figure 1 Surabaya West Access Channel Mapping

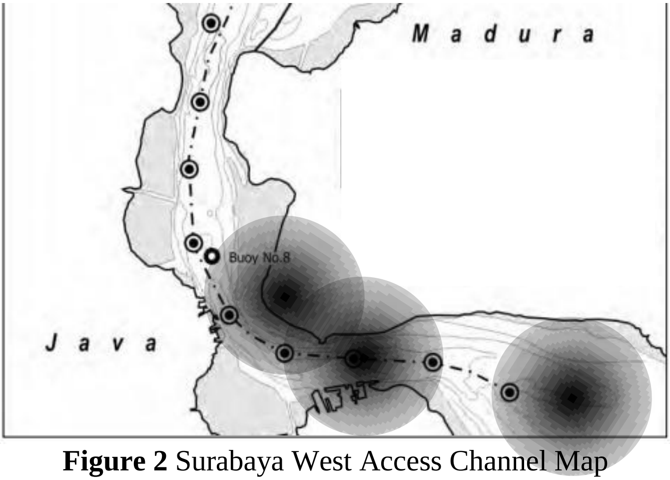

Figure 2 Surabaya West Access Channel Map

To solve these problems, a study of the collision risk analysis and its approach have been conducted by many experts. In the context of collision risk analysis in port waters, the qualitative and semi-quantitative methods might be useful for some preliminary safety investigation purposes, but to attain a higher degree of understanding, it is better to employ a quantitative method with a better approach that would not rely solely on collision data for collision risk analysis in port waters area. The context of collision risk analysis is often hindered with limitations such as large number of collisions database, low sample problem and the insufficiency in recorded data of navigational databases. While the collision itself is an outcome of a complex process of interaction involving vessels, pilots, crews, port operators and marine environment that can't be defined if it is analyzed through the numbers of outcome. Therefore, to overcome the shortcomings of model and analysis limitation, this final project propose some evaluation, such as:

a. The need for a new alternative model method of collision risk analysis
b. The need of a new navigational safety analysis to improve the vessel traffic in port waters area

Scope of Problem:

This final project scope will be:

a. Research will be conducted using ship movement data gained from Automatic Identification System (AIS) in a certain period as a representative of navigational condition in Surabaya West Access Channel
b. Model technique will not be based on risk collision techniques. Instead, it will use a traffic-conflict-based model that will be evaluated in its measurement and prediction model
c. The traffic-conflict model will not cover a multi-ship traffic. It will only calculate the conflict between ships in Surabaya West Access Channel area
d. Adjustment of variable in data is needed to enable this method to be applied in other terminal

1.3 Research Objectives

The objectives of this final project are:

a. Analyzing the collision risk in Surabaya West Access Channel (Buoy no. 8-13)
b. Applying a better approach in collision risk analysis by using a non-collision data through traffic-conflict-based model

c. Optimizing Automatic Identification System (AIS) application to enhance the maritime traffic in Surabaya West Access Channel

1.4 Research Significance

This research is conducted in order to give significance towards the subject, such as:

a. Providing more insight to understand the collision risk analysis and learn on how to manage it in an active manner
b. A better and reliable safety evaluation in port waters area
c. A breakthrough in the navigational safety research

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CHAPTER 2
LITERATURE REVIEW

Generally, a model in navigational collision risk relies on the record of collisions data. But as stated before, collisions data record is not always available and required to be used as a thorough safety analysis. Therefore, it needs expert judgments to complete its preliminary safety assessment. However, these approaches have several limitations when it is applied. First, the model risk relies on collision data is often hindered by a low number of assessments, insufficient elaboration on the causes and its approach to safety measures. Second, model risk on expert judgments will not give a consistent assessment due to a relatively different insight between the experts themselves. An alternative to overcome this problem is a Traffic Conflict model, which is instead relying on collisions causes, it will be developed and reviewed in the concept of critical traffic interaction.

2.1 Collision Risk Analysis

Collision Risk Analysis is widely used to estimate the probability of collision with obstacle by certain approach. The variable contain the dynamic data from record gained both from historical or real-time data such as location, dimensions, heading, course, distance and path.

Safety in port water navigation is often interconnected with the safety of its port operation and loss prevention. Thus, many navigational safety models are developed to enhance its capability to handle any safety hazards especially in maritime domain.

Safety model, which is in this case is applicable to water port area are categorized into two types; online and offline model. The online models deal with the real-time traffic information as a prevention of navigational collision model. On the contrary, the offline models solely deal with the historical data of collision and expert judgments.

Online models are focusing on different aspects of collision avoidance, such as prevention system development (Chin and Debnath, 2009), enhancement of danger regions (Lenart, 1983), the use of Automatic Identification System (AIS) in prevention system (Harati-Mokhtari, 2007; Harding, 2002; Norris, 2007) and the capability of Vessel Traffic Service (Kao, 2007).

Offline models or usually regarded as the traditional models can be divided into three types; qualitative, semi-quantitative and quantitative models. Generally, qualitative models provide the least understanding. While quantitative models provide greater detailed understanding and semi-quantitative lies in between.

2.1.1 Qualitative Models

Qualitative Models are commonly used to identify hazards, to evaluate its significance and identify the measures to be taken in order to reduce its consequence. In this models, there are several method used such as Hazard Identification (HAZID) and risk matrix.

HAZID is a structured process of identifying the hazards associated with a collision event (Molland, 2008). The possible hazard can be identified through group interaction to overlook the reduced hazard. This method does not require any collision data record as input, rather it relied on expert judgement and collisions analysis experience. Hazard checklist is often used as its identification process.

Risk Matrix is a matrix with framework for consideration of frequency and consequence of the hazard. A typical matrix (see Figure 1) has columns representing consequences and rows representing consequences severity.

CONSEQUENCE					INCREASING LIKELIHOOD				
					A	B	C	D	E
Severity rating	People	Assets	Environment	Reputation	Rarely occurred in E&P industry	Happened several times per year in industry	Has occurred in operating company	Happened several times per year in operating company	Happened several times per year in location
0	Zero injury	Zero damage	Zero effect	Zero impact	Negligible (Manage for continued improvement)				
1	Slight injury	Slight damage	Slight effect	Slight impact					
2	Minor injury	Minor damage	Minor effect	Limited impact					
3	Major injury	Local damage	Local effect	Considerable impact					
4	Single fatality	Major damage	Major effect	Major national impact	Intermediate (Incorporate risk reducing measures)				
5	Multiple fatality	Extensive damage	Massive effect	Major international impact			Intolerable		

Figure 3 Typical Risk Matrix (ISO, 1997)

In the process of identifying hazard through HAZID process, generally each hazard is evaluated by identifying it into a different region in risk matrix.

A different approach of risk matrix can be developed based on the general two-way matrix structure while considering the inconsistencies between the consequence and its severity. For example, the IMO (1997) risk matrix configuration is developed into a seven types of severity and four types of consequences in 7x4 matrix to identify the risk regions needed. Although it is easy to be developed, confusion in the risk matrix application is the downside of its lack of standardization.

There are several limitations in the methods provided by qualitative models, such as:

- Risk matrix makes it difficult to explain a hazard that produces multiple consequences
- Categorization of consequences and its severity is often defined in a qualitative categories
- Inconsistency within the judgments due to differences of insight between experts
- Novel hazard is difficult to be identified using HAZID and risk matrix

2.1.2 Semi-Quantitative Models

Semi-Quantitative models are commonly known to be achieved in two approaches; applying qualitative models, but producing quantitative results and vice versa.

In these approaches, HAZID and risk matrix is used solely to gain quantification as in numeral data. The purpose of gaining the quantification is to obtain a degree of priority towards a set of hazards. An example can be seen in the revision of IMO guidelines on Formal Safety Assessment (IMO, 1997). It uses terms of Frequencies Indices and Severity Indices to define its risk of hazard that can be seen as follows

$$Risk\ Index = FI + SI$$

Another study (Hu, 2007) is also proposing a different definition of FI and SI. If we relate the risk index towards our case navigational accidents, FI will be defined as the ratio number of accidents to the number of traffic per unit time while SI will be defined as the ratio of consequences to the number of accidents per unit time.

Thus, from the definition we can conclude that collision data record is useful and necessary to obtain respective indices.

2.1.3 Quantitative Models

Quantitative models force all assumptions to be explicit and hence provide a better understanding towards the models than solely relying on expert judgements.

Traditionally, quantitative models in the context of collision risk analysis only rely on the collision data. Several studies have used the collision data to examine the trends and causes of collision (Dabra and Casal, 2004; Yip, 2008) whereas some of the have examined consequences by using the statistics (Yip, 2008; Talley, 2002). Other studies (MARIN, 2009) have also focused on model probability and predicting frequency of collision by utilizing collision data.

To analyze the collision data record, a number of tools have been employed such as statistical models, Fault Tree Analysis (FTA) and Event Tree Analysis (ETA).

A FTA is a logical representation of a number of events and component failures that may contribute to cause one critical event, such as a collision. It is commonly used to quantify the likelihood of a critical event based on estimates of the failure rates of each component.

On the other hand, an ETA represents a number of events (consequences) that may result from an initiating event (component failure). It quantitatively estimates the probability of outcomes by using probabilities of preceding outcomes and the originating event. A comprehensive review of FTA and ETA, their applications, advantages and disadvantages can be found in Kristiansen (2005).

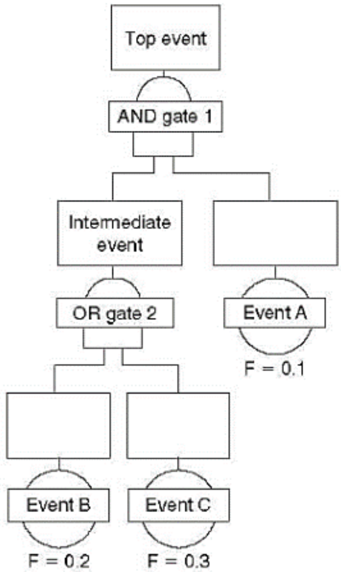


Figure 4 A Typical Fault Tree

Among these tools, statistical models are used commonly in the analysis. These models can be categorized into two types: Descriptive Models and Regression Models.

A descriptive model analysis provides a simple and quick assessment of prevailed collision risk. The collision frequency and consequences is the indicator to represent its collision records. It uses a single variable model which assuming that the effect of explanatory variables are independent to each other which would lead to a biased estimation.

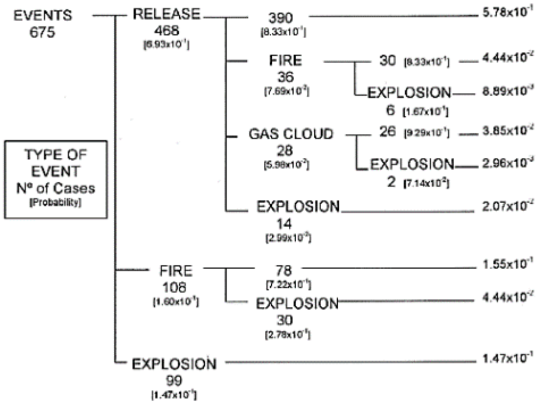


Figure 5 A Typical Event Tree of Ship-Ship Collision

A regression model analysis is a multi-variable model which estimates the effects of all explanatory variables together. This is also the reasons why regression model is often used for a detailed analysis. Based on its purposes of analysis, the regression models can be divided into two categories, such as (1) Accident Probability analysis and (2) Accident Consequences analysis. The former focuses on model the frequency of accident (probability of occurance) while the later focuses on model the fatalities in an accident.

In the traditional quantitative models of collision risk, it mostly relies on collision data. It is natural to use collision data as measure of safety because of its common acceptability to researchers and practitioners. However, safety model relying on collision data is often hampered by several shortcomings, such as:

- It is necessary to have a large number of collisions database
- There are restrictions for safety analysists from using statistical methods, such as regression techniques
- The navigational accident databases are often insufficient for an in-depth analysis
- Collision can’t be measured through the number of outcome only, because it is a complex process of interaction involving many factors

These shortcomings generate motivations among researcher to use an alternative approach which will not rely solely on collision data.

2.2 Traffic Conflict Model

Traffic conflict model is one of the most developed surrogate safety model approach which is a systematic method of analyzing traffic interactions for evaluating and compensating any potential sources of safety hazards. The most appealing aspect of traffic conflict model is that a larger database can be obtained within a shorter period of time as traffic conflicts occur considerably more frequently than collisions. This advantage of the traffic conflict model solves the ethical problem associated with the need of long collision history and facilitates obtaining statistically sound results. Thus, this technique could be an ethically appealing alternative rather than the traditional approach of safety model based on collision data.

The traffic conflict model has primarily been developed in the context of road traffic safety model

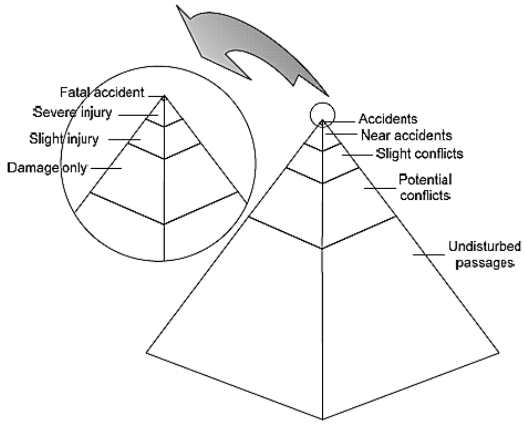


Figure 6 A Safety Pyramid of Road Traffic Event

with a long history of development. Though highway engineers have long been using the idea of traffic conflicts in identifying hazardous locations on highways (Baker, 1977), Perkins and Harris (1967) first formally stated this safety evaluation approach, which came to be called the traffic conflict model.

The use of this technique generated immediate interest among safety researchers around the world who accepted this approach as supplement to, rather than replacement for, the traditional accident-data-based safety evaluation method.

In the recent decades, developments and practices of the traffic conflict model has grabbed considerable attention of safety researchers in recent times. The concepts and definitions of traffic conflicts, the issues related to measurement and validity, and applicability of the technique have extensively been reviewed in literature (see Chin and Quek, 1997; Williams, 1981).

2.2.1 Definitions and Concepts

In the landmark paper on traffic conflict model (Perkins and Harris, 1967), the approach adopted was to observe and record unsafe interactions between vehicles, determined by the use of evasive action to avoid a potential collision. Thus, conflicts were defined based on evasive actions which are readily observable in traffic stream. Chin and Quek (1997) argued that the insistence of regarding conflicts in terms of evasive actions may have resulted in a diversity of ways in defining, interpreting and identifying conflicts. They suggested that an exhaustive list of possible evasive actions in all traffic situations might be needed in order for conflict observers to understand what is to be observed.

To define conflicts more clearly, researchers proposed definitions of conflicts with stricter specifications. Some have defined conflicts by considering accident as a process preceded by conflicts which eventually has established a logical relationship between exposure, conflicts and accidents. Hyden (1977) defined the relationship as a safety pyramid.

Although these representations describe the concept of traffic conflict model more clearly, still the severity levels of conflicts are not well-defined.

To define the severity levels more precisely, researcher (Hyden, 1977) concentrated on the more serious conflicts by setting a threshold value. However, Chin and Quek (1997) criticized this approach because ignoring the information of slight and moderate conflicts contradicts the main intention of traffic conflict model, which is aimed at using the more extensive information available in conflicts than in accident data.

2.2.2 Past Developments and Practices

The traffic conflict model has primarily been employed as a tool for diagnosing safety problems in road traffic systems. In particular, it has been applied to estimate the level of safety at intersections and roadway segments. Safety levels of different operating conditions (such as day and night conditions or dry or wet surface conditions) or different localities have also been compared by using traffic conflict model. In addition, this model has often been used in evaluating before-after studies of safety countermeasures.

Traffic conflicts are analyzed and interpreted in different ways. One common way that was used at the early stage of traffic conflict model development is using number of observed conflicts. To get more insights, sometimes number of serious conflicts is also used. Spicer (1971) used number of conflicts to study safety at a rural dual carriageway intersection.

With the development of traffic conflict model, the conflict is now interpreted objectively. Detailed analysis of conflicts, such as distribution and variation is now being developed and it is found to be followed by Weibull distribution. By identifying the serious conflicts from the tail end of the distribution, the probability of a near accident per event can be calculated.

2.2.3 Traffic-Conflict Measurement

The measurement of conflict has been one of the concerns in the traffic conflict model development. There are research efforts to develop method in measuring the conflicts in order to get an objective and repeatable results.

In the study of traffic conflict model, the measurement relies on the speed and distance of the objects. It is necessary to measure the conflict severities of all vessel interaction to measure its collision risk. A suitable measure of conflict severity is then necessary to measure navigational traffic conflicts (NTC) quantitatively. After critically examining the suitability of conflict measures that were primarily developed to measure road traffic conflicts (RTC), a suitable measure is developed to measure NTC. With the measured conflict severities of all interactions in a waterway, risk of collision in the context of port water can be measured.

A quantitative measure of NTC is developed which expresses risk of collision in an interaction by employing two proximity indicators. These indicators, *Distance at Closest Point of Approach* (DCPA) and *Time to Closest Point of Approach* (TCPA), represent spatial and temporal closeness between a pair of vessels.

DCPA and TCPA are respectively the probable distance between a vessel pair at their *Closest Point of Approach* (CPA) and the time required to reach CPA, given that the course and speed of both vessels remain unchanged. Both indicators are independent of collision course existence criteria and are capable of measuring all types of NTC. Furthermore, the indicators can easily be calculated from vessels' position and speed vectors.

To derive DCPA and TCPA in a vessel interaction, let vessels v_1 and v_2 are approaching each other from their current positions $\left(r_{v_1}, s_{v_1}\right)$ and $\left(r_{v_2}, s_{v_2}\right)$ at speeds of $\left(\dot{r}_{v_1}, \dot{s}_{v_1}\right)$ and $\left(\dot{r}_{v_2}, \dot{s}_{v_2}\right)$ respectively at time (t). If they maintain their speeds and courses, they will reach at CPA after a time period equal to TCPA. By making use of this condition, DCPA and TCPA can be derived in terms of the vessels' current positions and speeds in flowchart and calculation as follows.

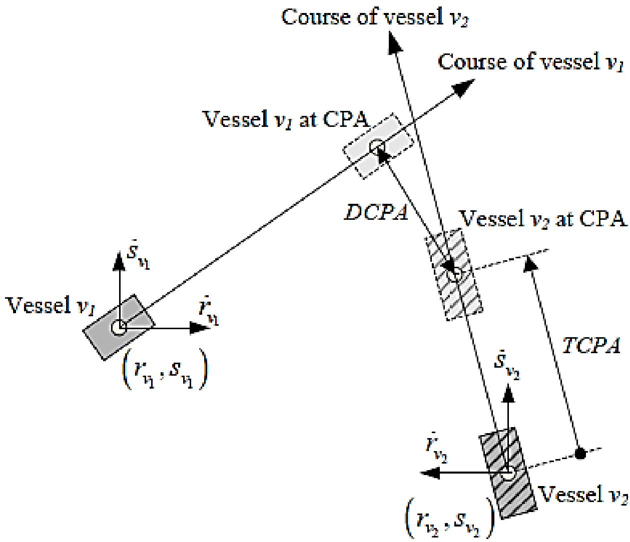


Figure 7 A typical Interaction of Spatial and Temporal Proximity Indicators

$$DCPA(t) = \sqrt{\left[\left(s_{v_2} - s_{v_1}\right) + \left(\dot{s}_{v_2} - \dot{s}_{v_1}\right) \times TCPA\right]^2 + \left[\left(r_{v_2} - r_{v_1}\right) + \left(\dot{r}_{v_2} - \dot{r}_{v_1}\right) \times TCPA\right]^2}$$

$$TCPA(t) = \frac{-\left[\left(s_{v_2} - s_{v_1}\right)\left(\dot{s}_{v_2} - \dot{s}_{v_1}\right) + \left(r_{v_2} - r_{v_1}\right)\left(\dot{r}_{v_2} - \dot{r}_{v_1}\right)\right]}{\left(\dot{s}_{v_2} - \dot{s}_{v_1}\right)^2 + \left(\dot{r}_{v_2} - \dot{r}_{v_1}\right)^2}$$

2.2.4 Traffic Conflict Validity

The validity of traffic conflict model is generally judge by a sufficient number of accidents (Hauer and Garder, 1986). This approach of validation was considered to be important as it is developed in order to search for a new alternative of traffic conflict data analysis.

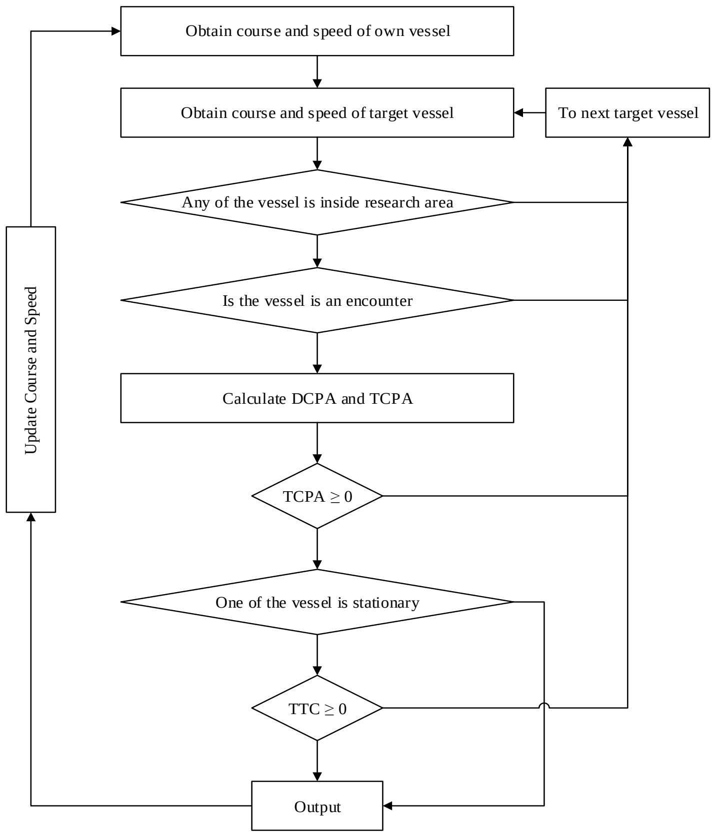


Figure 8 Traffic-Conflict Model Framework

2.3 Automatic Identification System (AIS)

Automatic Identification System (AIS) is a data exchange system which was introduced to improve shipping safety and the possibility of exchanging data, at a country and international level, about ships heading to or from ports, as well as exchanging data relating to passengers and dangerous or environment-polluting cargo carried by ships. The main purpose of introducing AIS was to offer a wider spectrum of available, continuous and reliable navigational data. It became common to use data transmitted through AIS in order to enhance shipping safety. Apart from being useful for traffic control in a marine area, AIS data can be a very important source of information used in collision avoidance process (Pitana, et al. 2011)

Since 2002, new ships and later all larger sea-going vessels (>300 GT) and all passenger vessels are required to carry an Automatic Identification System (AIS) on board. Through dedicated VFH frequencies, AIS information is transmitted between vessels, from vessel to shore or vice versa. As an aid to collision avoidance, it records the information of ship behavior, including the effects of human action and ship maneuverability. The information includes the vessel's name, its particulars, ship type, registration numbers and destination as well as the vessel's position, speed and heading.

The scope that will be evaluated in AIS will cover the area of Surabaya West Access Channel. The data in AIS are transmitted at frequent intervals of approximately 3-10s. This intervals allows some important parameters of collision avoidance to be easily obtained, for examples the closest point of approach

(CPA) and time to closest point to approach (TCPA) between own ship (OS) and any desired target ship (TS).

Figure 9 Surabaya West Access Channel Mapping from AIS

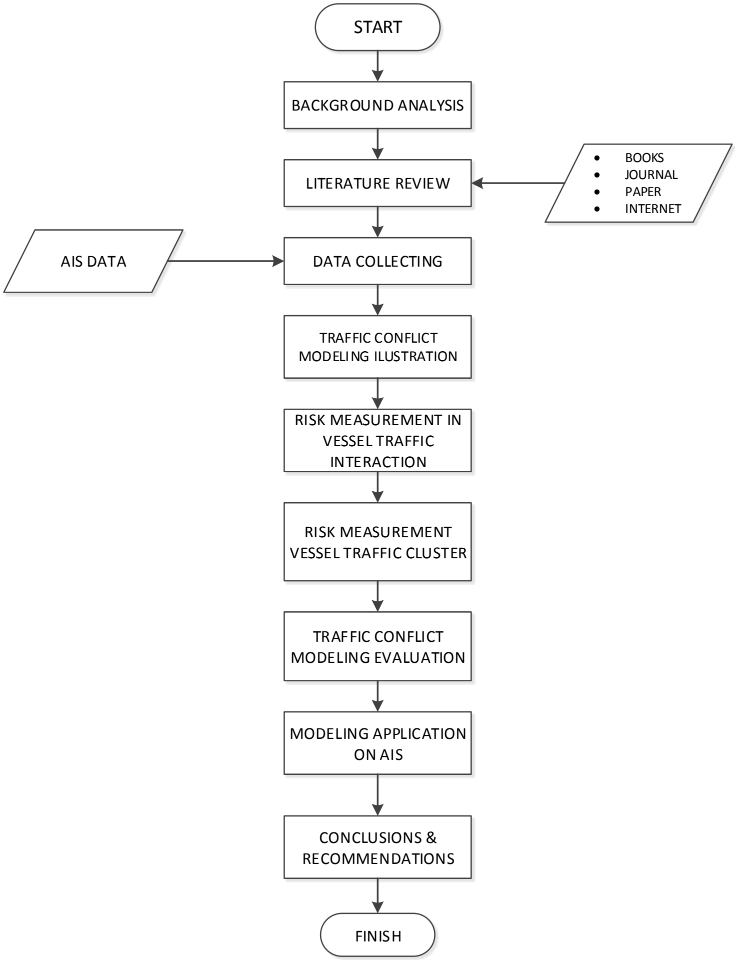
CHAPTER 3
RESEARCH METHODOLOGY

In order to create a systematical report, this chapter will further elaborate how to obtain the goal of my final project. The steps can be seen as below

1. **Background Analysis**
   Background Analysis is the first step in this final project. This step will explain on the problems that should be solved and become the issue of this research. Furthermore, this chapter will also elaborate on the scope of problem and the objectives and significance of this research.
2. **Literature Review**
   Literature Review is the next step after background analysis. This step will elaborate on the methods that will be used in this research and its background of understanding.
3. **Data Collecting**
   Data collecting will be the step where AIS will take a great part on the research. Data will be taken through AIS on the subject of navigational operation occurred within the channel in March 2015
4. **Illustration of Model**
   The process of illustration is needed for the data to be applied in the model method. The data will be measured after illustration as a risk in interaction and risk in waterways in order to do an evaluation of traffic conflict.

5. **Evaluation of Model**
   The process of evaluation will be done by doing an estimation of parameter and doing a model comparison between AIS simulation and the models.
6. **AIS Application on Traffic-Conflict Model**
   After evaluation, the mapping will be done to show the risk level of each conflict happened in the interaction and cluster on Surabaya West Access Channel that can be seen in aisits.cf
7. **Conclusions and Recommendations**
   The conclusions will answer the problems that needed to be solved in the background analysis and give recommendations for the future research.

Research Methodology Flow Chart



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CHAPTER 4
ANALYSIS AND RESULT

This chapter is meant to give us the result of collision risk analysis through traffic-conflict model on each measurement in both interaction between ships and channel clustering. Before gaining the result, there are several steps of analysis than can be seen as follows:

a. Collecting Surabaya West Access Channel traffic data through AIS
b. Illustrating vessel traffic density distribution in Surabaya West Access Channel
c. Measuring collision risk in vessel traffic interaction
d. Measuring collision risk in vessel traffic channel clustering
e. Applying traffic-conflict map in AIS online interface

4.1 AIS Data Collecting

The AIS data is capable and effective to be taken as a model of vessel traffic in a certain area. A large quantity data and some statistical tools are needed to estimate the density of its vessel traffic. By utilizing the AIS data into the model, it can be considered as a real-time judgment that is more reliable than assuming through engineering formulas.

The vessel traffic density data were obtained from FA-30 Furuno AIS receiver installed at RAMS Laboratory in Marine Engineering Department, ITS, Surabaya. The data collected by AIS is stored and updated in a PC hard disk.

Currently, AIS can recognize 500 GT ships in domestic routes to be taken for each static and dynamic

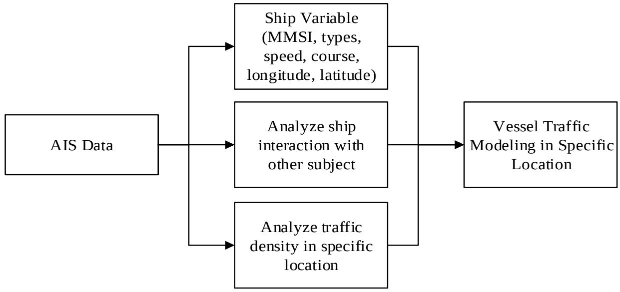


Figure 10 Model using AIS Data Work Flow

data. The static data consists of the identity of the ships, such as vessel's Maritime Mobile Service Identity (MMSI), name of vessel, calling name, ship dimensions, IMO number and type of ship. The dynamic data consists of the movement of the ships, such as longitude, latitude, time, course, rate of turn, Speed over Ground (SOG) and destination, which is updated every 2-10 seconds depending on the speed of the vessel.

From AIS data, raw data of ship's pattern movement in the area of Madura Strait are gained and will be used for calculating its DCPA and TCPA's score. Below are some results of the processed data for model gain through AIS for vessel traffic density in March 2015.

Table 1 "My Hung" vessel traffic data from AIS

Latitude	Longitude	Name	MMSI	Speed_Kts	Course_Deg	Type	Time
-7.1915	112.7019	MY HUNG	574230000	9.8	112.5	AIS	04/12/2015 19:20:04
-7.191317	112.7015	MY HUNG	574230000	9.9	112.1	AIS	04/12/2015 19:20:14
-7.190617	112.6997	MY HUNG	574230000	10.5	112.2	AIS	04/12/2015 19:20:24
-7.190433	112.6992	MY HUNG	574230000	10.7	111.8	AIS	04/12/2015 19:20:35
-7.189467	112.6969	MY HUNG	574230000	10.8	113.1	AIS	04/12/2015 19:20:45

Table 2 "Meratus Batam" vessel traffic data from AIS

Latitude	Longitude	Name	MMSI	Speed_Kts	Course_Deg	Type	Time
-7.1915	112.6972	MERATUS BATAM	525025078	10.8	291	AIS	04/12/2015 19:20:04
-7.191167	112.6967	MERATUS BATAM	525025078	10.9	292	AIS	04/12/2015 19:20:14
-7.190833	112.6962	MERATUS BATAM	525025078	10.9	293	AIS	04/12/2015 19:20:24
-7.190667	112.6958	MERATUS BATAM	525025078	10.9	294	AIS	04/12/2015 19:20:35
-7.190333	112.6953	MERATUS BATAM	525025078	10.9	295	AIS	04/12/2015 19:20:45
-7.19	112.695	MERATUS BATAM	525025078	10.8	297	AIS	04/12/2015 19:20:54

Table 3 "Sam Ho T7" vessel traffic data from AIS

Latitude	Longitude	Name	MMSI	Speed_Kts	Course_Deg	Type	Time
-7.19151	112.7013	SAMHO T7	525023379	5	206	AIS	04/12/2015 19:20:04
-7.190595	112.7012	SAMHO T7	525023379	0.3	70	AIS	04/12/2015 19:20:14
-7.190593	112.7012	SAMHO T7	525023379	0.4	80.6	AIS	04/12/2015 19:20:24
-7.190425	112.6935	SAMHO T7	525023379	8.6	122.3	AIS	04/12/2015 19:20:34
-7.189457	112.6911	SAMHO T7	525023379	3	213.3	AIS	04/12/2015 19:20:44
-7.189332	112.6911	SAMHO T7	525023379	2.8	210.8	AIS	04/12/2015 19:20:54

Table 4 "Meratus Kalabahi" vessel traffic data from AIS

Latitude	Longitude	Name	MMSI	Speed_Kts	Course_Deg	Type	Time
-7.191583	112.698	MERATUS KALABAHI	525025090	6.7	110	AIS	04/12/2015 19:20:04
-7.191492	112.6977	MERATUS KALABAHI	525025090	6.8	110.8	AIS	04/12/2015 19:20:14
-7.19138	112.6974	MERATUS KALABAHI	525025090	6.9	112.2	AIS	04/12/2015 19:20:24
-7.191257	112.6971	MERATUS KALABAHI	525025090	7.1	114.9	AIS	04/12/2015 19:20:35
-7.19113	112.6968	MERATUS KALABAHI	525025090	7.2	118	AIS	04/12/2015 19:20:45
-7.190957	112.6965	MERATUS KALABAHI	525025090	7.4	121	AIS	04/12/2015 19:20:54

4.2 Traffic-Conflict Model Illustration

4.2.1 Vessel Traffic Density Analysis

The vessel density data monitored through AIS within the Surabaya West Access Channel is taken in the interval of year 2015.

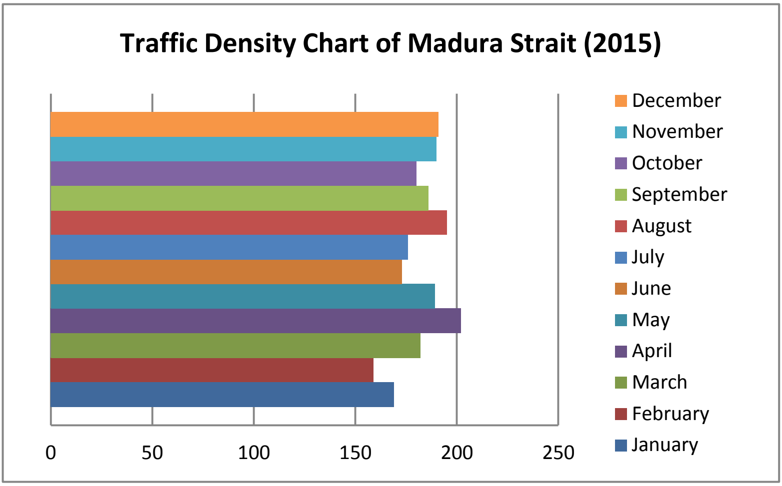


Figure 11 Traffic Density in Madura Strait 2015

After gaining the vessel traffic density, to fulfill the criteria of traffic-conflict model in this research, there should be at least two potential routes conflict for each area in the certain amount of time.

Madura Strait in March 2015 has 182 ships going through the West Access Channel recorded by AIS, which is a big amount that can create a bigger risk and possibility for traffic-conflict to exist.

Figure 12 Crossing Route Plotting in Buoy no. 8-13 on March 2015

The possibilities is proved to be true, whereas the plotting illustration of traffic density in March 2015 shown that there are a lot of ships with overlapping routes at each other.

Figure 12 shows that there are 12 ships with qualified parameter—crossing in one point between ships and passing through buoy no.8 – 13—that can be taken as potential traffic-conflict routes. After plotting those 12 ships within the area taken as subject, the illustrating of conflict routes can be done by calculating its TCPA & DCPA for each route in order to gain the risk between ships (Risk of Interaction).

In this research, there are 24 scenarios throughout all 12 ships passing through the routes of Buoy no. 8 – 13. The scenarios are identifying the routes of conflicting routes between ships in the same area and time. Each ship are coded into Nx and coded into Nx_1-Nx_2 to indicate its conflicting relationship.

4.2.2 Routes Conflict Illustration

As stated in Chapter 2 Part 2.2.3, the illustration is based on A.K. Debnath research in 2009, whereas the measurement relies on the speed and distance of the objects. A quantitative measure of NTC is developed which expresses risk of collision in an interaction by employing two proximity indicators. These indicators, *Distance at Closest Point of Approach* (DCPA) and *Time to Closest Point of Approach* (TCPA), represent spatial and temporal closeness between a pair of vessels.

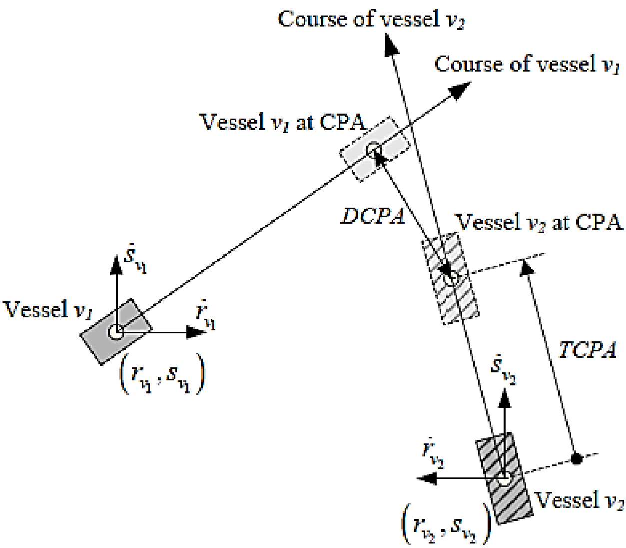
The calculation of TCPA in each ships are formulated as follow,

$$\boldsymbol{TCPA(t)} = \frac{-\left[\left(s_{v_2} - s_{v_1}\right)\left(\dot{s}_{v_2} - \dot{s}_{v_1}\right) + \left(r_{v_2} - r_{v_1}\right)\left(\dot{r}_{v_2} - \dot{r}_{v_1}\right)\right]}{\left(\dot{s}_{v_2} - \dot{s}_{v_1}\right)^2 + \left(\dot{r}_{v_2} - \dot{r}_{v_1}\right)^2}$$

$$\boldsymbol{DCPA(t)} = \sqrt{\begin{array}{c}\left[\left(s_{v_2} - s_{v_1}\right) + \left(\dot{s}_{v_2} - \dot{s}_{v_1}\right) \times TCPA\right]^2 + \\ \left[\left(r_{v_2} - r_{v_1}\right) + \left(\dot{r}_{v_2} - \dot{r}_{v_1}\right) \times TCPA\right]^2\end{array}}$$

In TCPA (t) calculation, ‘r’ and ‘s’ represents the course of each vessel.

The calculation of DCPA between ships are formulated as follow,



In DCPA (t) calculation, ‘r’ and ‘s’ also represents the course of each vessel, but in the case of DCPA, it is multiplied with the TCPA value.

4.2.3 Routes Conflict Calculation (TCPA & DCPA)

The calculation begin with identifying each components needed in the formula of TCPA and DCPA. The TCPA calculation are generally illustrated in (x,y) vector as follows.

Figure 15 pictures the vessel movement of *O* which is maneuvering towards the Northeast while the vessel *T* is maneuvering towards the Northwest. Both the vessels are moving with different speed and course.

To find the DCPA and TCPA between vessel *O* and *T*, first, we must calculate the relative speed of own ship to the target ship using equation as follows.

$$V_r = \sqrt{V_o{}^2 + V_T{}^2 - 2|V_o.V_T|\cos(\theta_T\theta_O)}$$

We defined the slope intercept form of line TP is $Y-y_r = k(X-x_r)$ which parallel with relative speed and start from target ship’s position.

The figure 15 shows that a perpendicular line is drawn on the own ship from the parallel vector of the target ship. The distance between the parallel vector of target ship’s direction and the own ship’s position is DCPA that can be calculated in a breakdown equation of three elements—where k is the slope of line TP, Θ_r is the relative angle and Θ is the angle between relative velocity V_r and target velocity of current time that can be seen as follows.

$$\theta = arc\cos\left(\frac{{V_r}^2 + {V_T}^2 - {V_O}^2}{2V_r.V_T}\right)$$

$$\theta_r = \theta_T + \theta$$

$$k = \tan\theta_r$$

Therefore, at the current time, the DCPA between vessel *O* and *T* according to the routes in general can be calculated by using following equations:

$$DCPA = |OP| = \frac{|y_T - x_T\tan\theta_r|}{\sqrt{\tan\theta_r + 1}}$$

After calculating the DCPA through vector equation breakdown, we can calculate the TCPA between vessels *O* and *T* where OT is the distance between own ship and target ship and OP is the perpendicular line formed from own ship to line TP at the current time that can be seen as follows.

$$|TP| = \sqrt{|OT|^2 - |OP|^2}$$
$$= \sqrt{({x_T}^2 + y^2)} - DCPA^2$$

Therefore, at the current time, the DCPA between vessel *O* and *T* according to the routes in general can be calculated by using following equations:

$$TCPA = \frac{|OP|}{V_r} = \frac{\sqrt{{x_T}^2 + {y_T}^2 - DCPA^2}}{V_r}$$

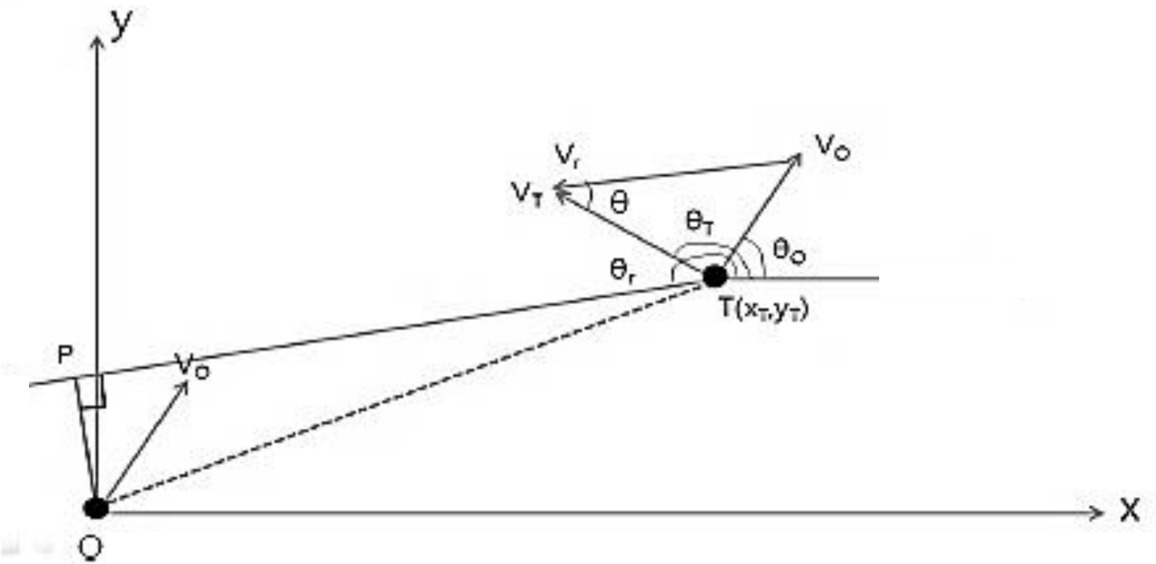


Figure 14 TCPA and DCPA vector (x,y) concept

Below are some of the examples of TCPA and DCPA calculation based on the calculation above.

Table 5 TCPA and DCPA value of Scenario N1-N10

V1	V2	S1	S2	R1	R2	TCPA	DCPA
	SAMHO T7 1	9.8	5	112.5	206	0.003544	0.00206
	SAMHO T7 2	9.9	0.3	112.1	70	0.004198	0.04414
MY HUNG	SAMHO T7 3	10.5	0.4	112.2	80.6	-0.009871	0.04516
	SAMHO T7 4	10.7	8.6	111.8	122.3	-0.048686	-0.042915
	SAMHO T7 5	10.8	3	113.1	213.3	0.033803	-0.057640
	SAMHO T7 6	10.7	2.8	114.8	210.8	0.034704	-0.071623

Table 5 is showing one of the routes from crossing encounter between N1 and N10 which belong to ships called My Hung and Samho T7.

In general, the point of encounter needed for calculating TCPA and DCPA are 3 points before the point of encounter and 3 points after the point of encounter. The S represents the speed of each vessel while the R are the result of vector from each course based on the calculation above.

Figure 15 is showing the result of DCPA and TCPA in the type of crossing encounter which is represented in grey and black respectively. The characteristic of TCPA and DCPA in the type of crossing encounter is when the point of crossing in each ship are shown to be crossing each other based on the maps given, therefore the DCPA in the start point will usually following the track of TCPA.

But after the crossing point, it will go further from the result of of TCPA and forming a crossing-like figure from each other based on the calculation. The figure above is showing the DCPA and TCPA dynamic result between N1 and N10 which belong to ships called My Hung and Samho T7.

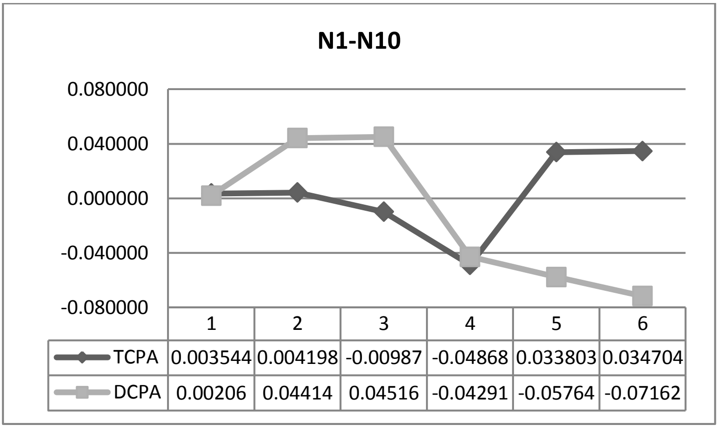


Figure 15 TCPA and TCPA charts on N1-N10 scenario

It is shown in the Figure 15 that at the start point, the DCPA and TCPA value is almost in the same region, while on the next point it is getting further to each other because it is affected by the speed and its course. In the point 4, it is shown that it cross each other's point which is indicating that the crossing point of the routes based on the map is in the point 4. While in point 5, it is overlapping each other and going further from each other value forming a crossing-like figure.

Table 6 TCPA and DCPA value of Scenario N2-N3

V1	V2	S1	S2	R1	R2	TCPA	DCPA
HOANG HAI 68	NN1	9.6	10.4	288.9	115.1	-0.002873	-0.017538
	NN2	9.4	10.5	291.8	115.5	-0.005508	-0.009984
	NN3	9.4	10.6	293.2	116	-0.005479	-0.010038
	NN4	9.4	10.7	293.7	116.8	-0.004440	-0.011856
	NN5	9.4	10.9	294.9	117.6	-0.004913	-0.007550
	NN6	9.5	10.9	298.3	118.3	-0.006860	-0.003762

Table 6 is showing one of the routes from crossing encounter between N2 and N3 which belong to ships called Hoang Hai 86 and NN. The method of calculation for all scenarios gotten is all the same. The point of encounter needed for calculating TCPA and DCPA are 3 points before the point of encounter and 3 points after the point of encounter. The S represents the speed of each vessel while the R is the result of vector from each course based on the calculation above. After gaining the value of TCPA and DCPA, we validate it through charts to determine whether it is the right type of encounter—which should be crossing in this research.

Figure 16 is showing the result of DCPA and TCPA between N2-N3 in the type of crossing encounter which is represented in grey and black respectively. The characteristic of TCPA and DCPA in the type of crossing encounter is when the point of crossing in each ship are shown to be crossing each other based on the maps given, therefore the DCPA in the start point will usually following the track of TCPA. But after the crossing point, it will go further from the result of of TCPA and forming a crossing-like figure from each other based on the calculation. The figure above is showing the DCPA and TCPA dynamic result between N2 and N3 which belong to ships called Hoang Hai 86 and NN.

It is shown in the Figure 16 that at the start point, the DCPA and TCPA value—unlike the previous scenario—are far away from each other. This might also be happening in the crossing type of encounter due to its course and speed of each vessel in the routes.

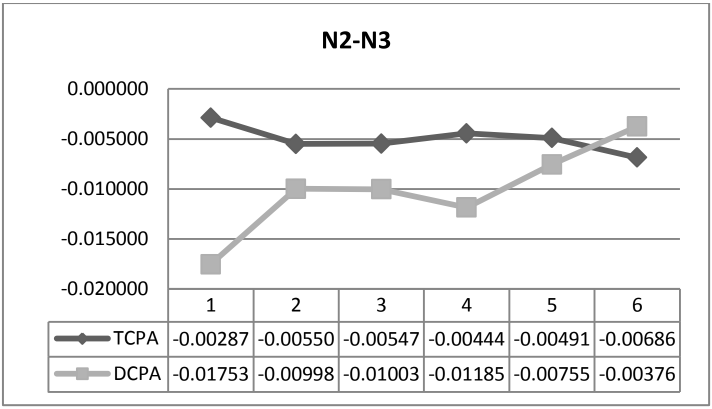


Figure 16 TCPA and TCPA charts on N2-N3 scenario

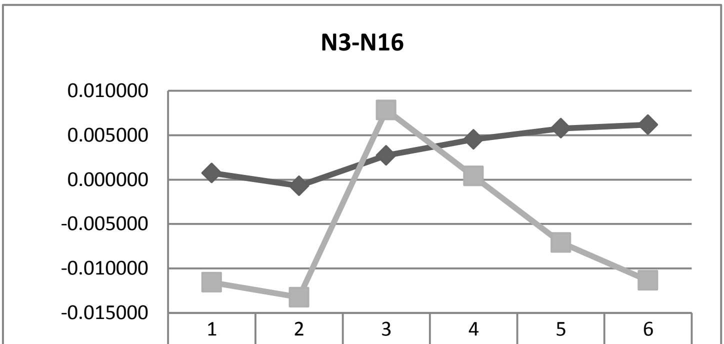
The dynamic for the next several points indicate that both of the ships are gradually get closer to each other and overlapping each other's routes at point 5 and finally crossing each other at point 6 and forming a crossing-like figure which is indicating that this route is also indeed categorized in a crossing type of encounter.

Table 7 TCPA and DCPA value of Scenario N3-N16

V1	V2	S1	S2	R1	R2	TCPA	DCPA
NN	KARINA 3 1	10.4	11.7	115.1	287.6	0.000740	-0.011571
	KARINA 3 2	10.5	11	115.5	291.9	-0.00070	-0.01325
	KARINA 3 3	10.6	11.3	116	290.7	0.002719	0.007837
	KARINA 3 4	10.7	11.4	116.8	292.5	0.004528	0.000398
	KARINA 3 5	10.9	11.6	117.6	293.8	0.005772	-0.00708
	KARINA 3 6	10.9	11.7	118.3	295.2	0.006177	-0.011362

Table 7 is showing one of the routes from crossing encounter between N3 and N16 which belong to ships called NN and Karina 3. The method of calculation for all scenarios gotten is all the same. The point of encounter needed for calculating TCPA and DCPA are 3 points before the point of encounter and 3 points after the point of encounter. The S represents the speed of each vessel while the R are the result of vector from each course based on the calculation above. After gaining the value of TCPA and DCPA, we validate it through charts to determine whether it is the right type of encounter—which should be crossing in this research.

Figure 17 is showing the result of DCPA and TCPA between N3-N16 in the type of crossing encounter which is represented in grey and black respectively. The characteristic of TCPA and DCPA in the type of crossing encounter is when the point of crossing in each ship are shown to be crossing each other based on the maps given, therefore the DCPA in the start point will usually following the track of TCPA. But after the crossing point, it will go further from the result of TCPA and forming a crossing-like figure from each other based on the calculation. The figure above is showing the DCPA and TCPA dynamic result between N3 and N16 which belong to ships called NN and Karina 3.



	1	2	3	4	5	6
TCPA	0.000740	-0.00070	0.002719	0.004528	0.005772	0.006177
DCPA	-0.01157	-0.01325	0.007837	0.000398	-0.00708	-0.01136

Figure 17 TCPA and DCPA charts on N3-N16 scenario

It is shown in the Figure 17 that at the start point, the DCPA and TCPA value are far away from each other just like in the scenario of N2-N3. As stated before, this might also be happening in the crossing type of encounter due to its course and speed of each vessel in the routes. At point 3, it is shown to be overlapping each other's routes and finally crossing each other and on several next points while forming a crossing-like figure which is indicating that this route is also in a crossing type of encounter.

There are also several other scenario—given that they are 22 scenarios taken from 14 ships on the routes between in March 2015. Those examples above are some of the examples of crossing type of encounter that is validated through DCPA and TCPA values that is also representing all the scenarios happened in the subject area of the research.

The value of TCPA and DCPA shown in these tables are not calibrated yet into the real distance due to its scale in GIS application when it is mapped.

4.3 Collision Risk Calculation

Ship collision risk calculation is done through several stages of assessment. The first one is analyzing the traffic routes using encounter type and historical data of collision in the area to evaluate the collision risk in the area. The second is calculating the DCPA (Distance at Closest Point of Approach) and TCPA (Time at Closest Point of Approach) in formulas that are mentioned in previous sub-chapter. In the third stage, the results of DCPA and TCPA are combined through finding the value of threshold (λ)—which is the result of calculation from the risk and the two proximity indicators. There are several factors effecting threshold (λ). In this final project, only major factors are considered, such as distance between own ship and target ship (d), the course of ships route encounter (ϴ) and DCPA-TCPA.

The calculation of threshold (λ) can be seen as follows.

$$\lambda = \left[\frac{O_d P_d + O_\theta P_\theta + O_{DCPA} P_{DCPA} + O_{TCPA} P_{TCPA}}{10000}\right]$$

The calculation is divided into 10000 due to prior un-calibrated scale of distance gained when counting the TCPA and DCPA.

Below are some of the results on the calculation from threshold (λ) of each scenario:

Table 8 N1-N10 scenario's threshold (λ)

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ
N1 - N10	MY HUNG	SAMHO T7 1	9.8	5	112.5	206	0.003544	0.00206	0.23
		SAMHO T7 2	9.9	0.3	112.1	70	0.004198	0.04414	0.08
		SAMHO T7 3	10.5	0.4	112.2	80.6	-0.009871	0.04516	0.09
		SAMHO T7 4	10.7	8.6	111.8	122.3	-0.048686	-0.042915	0.14
		SAMHO T7 5	10.8	3	113.1	213.3	0.033803	-0.057640	0.24
		SAMHO T7 6	10.7	2.8	114.8	210.8	0.034704	-0.071623	0.24

Table 8 shows the result of threshold (λ) in the scenario of N1-N10 between My Hung and Samho T7 in 6 points calculated in the prior calculation of TCPA and DCPA. The threshold indicated the value of risk level in each points of interaction.

Table 9 N2-N3 scenario's threshold (λ)

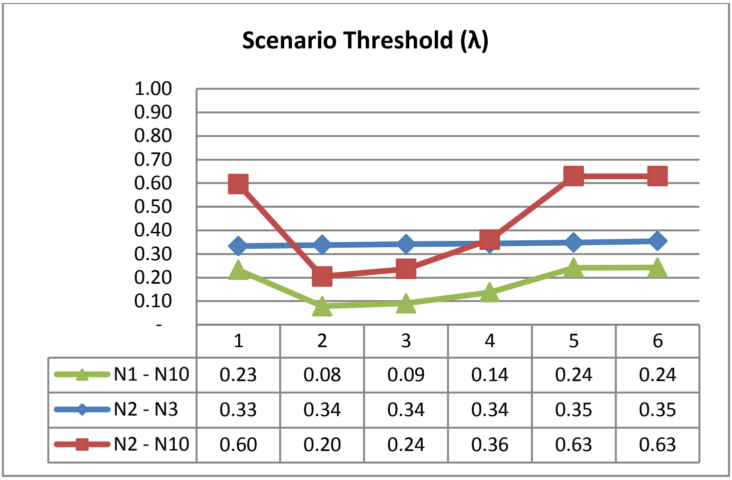
SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ
N2 - N3	HOANG HAI 68	NN1	9.6	10.4	288.9	115.1	-0.002873	-0.017538	0.33
		NN2	9.4	10.5	291.8	115.5	-0.005508	-0.009984	0.34
		NN3	9.4	10.6	293.2	116	-0.005479	-0.010038	0.34
		NN4	9.4	10.7	293.7	116.8	-0.004440	-0.011856	0.34
		NN5	9.4	10.9	294.9	117.6	-0.004913	-0.007550	0.35
		NN6	9.5	10.9	298.3	118.3	-0.006860	-0.003762	0.35

Table 9 shows the result of threshold (λ) in the scenario of N2-N3 between Hoang Hai 68 and NN in 6 points calculated in the prior calculation of TCPA and DCPA. The threshold indicated the value of risk level in each points of interaction.

Table 10 N2-N10 scenario's threshold (λ)

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ
N2 - N10	HOANG HAI 68	SAMHO T7 1	9.6	5	288.9	206	-0.008190	0.054195	0.60
		SAMHO T7 2	9.4	0.3	291.8	70	-0.017421385	0.065414	0.20
		SAMHO T7 3	9.4	0.4	293.2	80.6	0.0203931	-0.068203	0.24
		SAMHO T7 4	9.4	8.6	293.7	122.3	-0.015617	0.154350	0.36
		SAMHO T7 5	9.4	3	294.9	213.3	-0.036811	0.269880	0.63
		SAMHO T7 6	9.5	2.8	298.3	210.8	-0.018006	0.2175990	0.63

Table 10 shows the result of threshold (λ) in the scenario of N2-N10 between Hoang Hai 68 and Samho T7 in 6 points calculated in the prior calculation of TCPA and DCPA. The threshold indicated the value of risk level in each points of interaction.



	1	2	3	4	5	6
N1 - N10	0.23	0.08	0.09	0.14	0.24	0.24
N2 - N3	0.33	0.34	0.34	0.34	0.35	0.35
N2 - N10	0.60	0.20	0.24	0.36	0.63	0.63

Figure 18 Threshold (λ) chart of 3 model scenarios

4.4 Collision Risk Measurement

The measurement of risk will be based on the threshold that is symbolized into 'λ' gained from each value calculated in each model scenario. It is divided into 5 categories; Very High Risk, High Risk, Moderate Risk, Low Risk and Safe. The risk score interval is between 0-1 as seen in Figure 19.

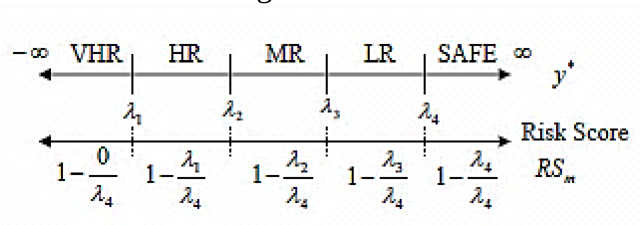


Figure 19 Measurement Score for Risk Level

In order to determine the limits of each threshold area, the threshold calculation from average value of each model scenario are calculated based on Figure 16. The results of calculation are as follows.

Table 11 Risk Level Range

CONDITION	λ_{RS}
Safe	0 – 0.4
Low Risk	0.2 – 0.6
Medium Risk	0.4 – 0.8
High Risk	0.6 – 1.0
Very High Risk	0.8 – 1.0

Therefore in each area of scenario, we can determine its risk score that can be seen demonstrated below in Table 11.

Table 12 Scenario N1-N10 Risk Level Measurement

SCENARIO	V1	V2	TCPA	DCPA	λ	Risk Level
N1 - N10	MY HUNG	SAMHO T7 1	0.003544	0.00206	0.23	Low Risk
		SAMHO T7 2	0.004198	0.04414	0.08	Safe
		SAMHO T7 3	-0.009871	0.04516	0.09	Safe
		SAMHO T7 4	-0.048686	-0.042915	0.14	Safe
		SAMHO T7 5	0.033803	-0.057640	0.24	Low Risk
		SAMHO T7 6	0.034704	-0.071623	0.24	Low Risk

In the scenario of route N1-N10 shown in table 12, the risk level of each point is considered low and safe at some point. It indicates that despite the crossing encounter between ships, the encounter itself didn’t bring any fatal severity towards each other. The low risk level only occurs in the start of the routes point scenario and in the crossing routes in point 4 and 5.

Table 13 Scenario N2-N3 Risk Level Measurement

SCENARIO	V1	V2	TCPA	DCPA	λ	Risk Level
N2 - N3	HOANG HAI 68	NN1	-0.002873	-0.017538	0.33	Low Risk
		NN2	-0.005508	-0.009984	0.34	Low Risk
		NN3	-0.005479	-0.010038	0.34	Low Risk
		NN4	-0.004440	-0.011856	0.34	Low Risk
		NN5	-0.004913	-0.007550	0.35	Low Risk
		NN6	-0.006860	-0.003762	0.35	Low Risk

In the scenario of route N2-N3 shown in table 13, the risk level of each point is all in low risk level. It indicates that the crossing encounter between ships Hoang Hai 68 and NN are not in fatal severity but still considered in risk of collision. The low risk level of this scenario is mainly in the score of 0.3 even in the point of crossing which is in point 5.

Table 14 Scenario N2-N10 Risk Level Measurement

SCENARIO	V1	V2	TCPA	DCPA	λ	Risk Level
N2 - N10	HOANG HAI 68	SAMHO T7 1	-0.008190	0.054195	0.60	Low Risk
		SAMHO T7 2	-0.017421385	0.065414	0.20	Low Risk
		SAMHO T7 3	0.0203931	-0.068203	0.24	Low Risk
		SAMHO T7 4	-0.015617	0.154350	0.36	Low Risk
		SAMHO T7 5	-0.036811	0.269880	0.63	Medium Risk
		SAMHO T7 6	-0.018006	0.2175990	0.63	Medium Risk

In the scenario of route N2-N10 shown in table 14, the risk level of each point is in low and medium risk. It indicates that in the crossing encounter between ships, the starts of encounter routes only indicated the low risk while the risk itself gives medium risk in the point 5 and 6 which is the path of crossing in this routes scenario.

There are still other scenarios that showing the risk level measurement based on the threshold calculation of each scenarios given from 14 ships taken as model in this research.

4.5 AIS Model Application

The goal of this final project didn’t stop in the model calculation of collision risk in Surabaya West Access Channel. In order to enhance its uses, the model and risk level analysis and calculation will be applied into an online website with a real-time data collection so it can enhance the real-time traffic in Surabaya West Access Channel through AIS.

The first step to do the model application is by making the PHP script of manual calculator as a dropdown to the database needed so it can be inputted with the data for calculation such as speed , course, distance and bearing of both target and own vessel that can be seen in the source code as follows in Figure 20.

```php
<?php
$tspeed = 0;
$tcourse = 0;
$tdistance = 0;
$tbearing = 0;
$vspeed = 0;
$vcourse = 0;
$msg = FALSE;
$reslt = FALSE;
if(isset($_POST['tspeed'])){
    $tspeed = $_POST['tspeed'];
    $tcourse = $_POST['tcourse'];
    $tdistance = $_POST['tdistance'];
    $tbearing = $_POST['tbearing'];
    $vspeed = $_POST['vspeed'];
    $vcourse = $_POST['vcourse'];
    if($tspeed==0 || $tspeed==null){
        $msg = TRUE;
    }elseif($tcourse==0 || $tcourse==null){
        $msg = TRUE;
    }elseif($tdistance==0 || $tdistance==null){
        $msg = TRUE;
    }elseif($tbearing==0 || $tbearing==null){
        $msg = TRUE;
    }elseif($vspeed==0 || $vspeed==null){
        $msg = TRUE;
    }elseif($vcourse==0 || $vcourse==null){
        $msg = TRUE;
```

Figure 20 Source Code of Manual Data Input for CPA Model Calculator

After creating the input codes for each value needed for calculation, the next step to do is creating the formulation codes in order to calculate its TCPA and DCPA through the equations in the prior sub-chapter 4.2.3 that can be seen in Figure 21.

```
    }else{
        $angle_vctc_deg = fmod($vcourse-$tcourse,360);
        $angle_vctc_rad = ($angle_vctc_deg*M_PI)/180;
        $area_deg = atan($vspeed*sin($angle_vctc_rad)/($tspeed-$vspeed*cos($angle_vctc_rad)))*(180/M_PI);
        $area_rad = ($area_deg*M_PI)/180;
        $trc_to_cpa_deg = 180-$angle_vctc_deg-$area_deg;
        $trc_to_cpa_rad = ($trc_to_cpa_deg*M_PI)/180;
        $trs_to_cpa = $vspeed * sin($angle_vctc_rad) / sin($area_rad);
        $target_abs_course = $trc_to_cpa_deg+$vcourse+180;
        $angle_tbtc_deg = 180-$target_abs_course+$tbearing;
        $angle_tbtc_rad = ($angle_tbtc_deg*M_PI)/180;
        $dist_to_cpa = $tdistance* sin($angle_tbtc_rad);
        $bearing_at_cpa = 90-$angle_tbtc_deg+$tbearing;
        $rel_dist_cpa = $tdistance*cos($angle_tbtc_rad);
        $time_to_cpa = $rel_dist_cpa/$trs_to_cpa;
        $reslt = TRUE;
    }
```

Figure 21 Source Code of DCPA and TCPA Calculation for CPA Model Calculator

Therefore, the basic input and calculation of its DCPA and TCPA based on data provided by AIS database has been done and through the output, we can do manual input in blank form calculator as a validation whether the codes are succeeded or not that can be seen in Figure 22.

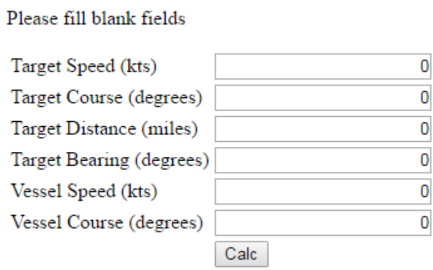


Figure 22 Output for Validation of CPA Model Calculator

An example of application validating process is shown in Figure 23—whereas the data inputted is one of the model scenario's (N1-N10) between My Hung and Samho T7. The Target and Vessel speed and course can be seen in Appendix 1 to be referred as $r_{1\text{-}2}$ and $s_{1\text{-}2}$ respectively. The target distance and bearing are obtained through GIS Application's ruler which is not yet to be calibrated with the real scale of distance between vessels—which makes its distance to be appeared in decimal value.

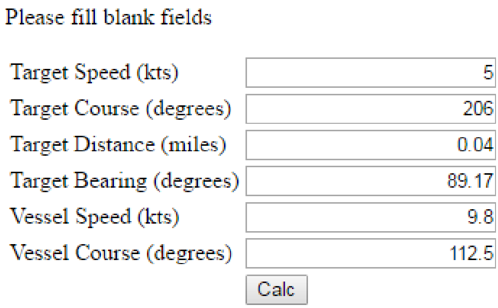


Figure 23 Input Value to Traffic-Conflict Model Calculator as Validating Process

The calculator works as the 'calc' (abbreviation for calculate) button is pressed. As shown in Figure 24, the calculation formulas are shown in the calculator as an elaboration of formula inputted in the source code that will give us the Distance and Time of CPA between vessels. Those calculation are showing the elements of formula such as angle, area, relative course, relative speed, angle between course, bearing of target at CPA, distance to CPA and TCPA and DCPA that can be seen as follows.

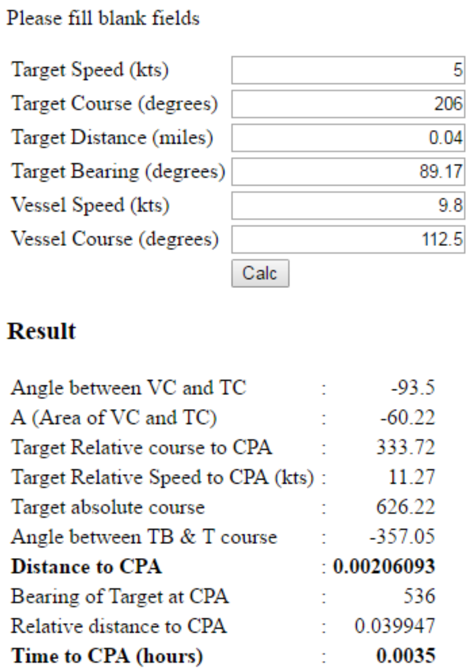


Figure 24 Traffic-Conflict Model Calculator Result

The validating process of this source code can be seen through the result of DCPA and TCPA on Appendix 1 which must be in the same value in both sides. Until this is written, the source code of this calculation is not yet tested in the real-time routes of vessel.

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APPENDIX 1

This appendix contains the calculation of TCPA and DCPA of model scenario based on 12 ships within buoy 8-13 in Surabaya West Access Channel on March, 2015.

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N1 - N10	MY HUNG	SAMHO T7 1	9.8	5	112.5	206	**3.544394**	**2.06093**	CROSSING	-7.1915	112.6971667	-7.19138	112.69741
		SAMHO T7 2	9.9	0.3	112.1	70	**4.198168**	**44.14411**		-7.191166667	112.6966667	-7.19113	112.6967967
		SAMHO T7 3	10.5	0.4	112.2	80.6	**-9.870640**	**45.16487**		-7.190833333	112.6961667	-7.190763333	112.6961517
		SAMHO T7 4	10.7	8.6	111.8	122.3	**-48.686492**	**-42.915112**		-7.190666667	112.6958333	-7.1906	112.69588
		SAMHO T7 5	10.8	3	113.1	213.3	**33.803436**	**-57.640156**		-7.190333333	112.6953333	-7.190196667	112.6952483
		SAMHO T7 6	10.7	2.8	114.8	210.8	**34.703604**	**-71.623129**		-7.19	112.695	-7.190041667	112.6949967
N2 - N3	HOANG HAI 68	NN1	9.6	10.4	288.9	115.1	**-2.873175**	**-17.538175**	CROSSING	-7.191115	112.6998433	-7.191615	112.7004667
		NN2	9.4	10.5	291.8	115.5	**-5.507683**	**-9.984312**		-7.19063	112.6986067	-7.191408333	112.6999917
		NN3	9.4	10.6	293.2	116	**-5.478680**	**-10.038380**		-7.190438333	112.6982117	-7.191216667	112.6995583
		NN4	9.4	10.7	293.7	116.8	**-4.440209**	**-11.855938**		-7.190381667	112.6980917	-7.191031667	112.6991183
		NN5	9.4	10.9	294.9	117.6	**-4.913403**	**-7.550481**		-7.190061667	112.6974217	-7.190795	112.69864
		NN6	9.5	10.9	298.3	118.3	**-6.860266**	**-3.762477**		-7.18893	112.6951883	-7.190545	112.69821
N2 - N10	HOANG HAI 68	SAMHO T7 1	9.6	5	288.9	206	**-0.819012**	**5.419472**	CROSSING	-7.191115	112.6998433	-7.19138	112.69741
		SAMHO T7 2	9.4	0.3	291.8	70	**-1.7421385**	**6.541356**		-7.19063	112.6986067	-7.19113	112.6967967
		SAMHO T7 3	9.4	0.4	293.2	80.6	**2.0393116**	**-6.820323**		-7.190438333	112.6982117	-7.190763333	112.6961517
		SAMHO T7 4	9.4	8.6	293.7	122.3	**-1.561689**	**15.434972**		-7.190381667	112.6980917	-7.1906	112.69588
		SAMHO T7 5	9.4	3	294.9	213.3	**-3.681126**	**26.987964**		-7.190061667	112.6974217	-7.190196667	112.6952483
		SAMHO T7 6	9.5	2.8	298.3	210.8	**-1.800620**	**21.7598964**		-7.18893	112.6951883	-7.190041667	112.6949967

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N3 - N16	NN	KARINA 3 1	10.4	11.7	115.1	287.6	**0.739716**	**-11.571135**	CROSSING	-7.191615	112.7004667	-7.191541667	112.70071
		KARINA 3 2	10.5	11	115.5	291.9	**-0.69703**	**-13.25289**		-7.191408333	112.6999917	-7.191171667	112.699865
		KARINA 3 3	10.6	11.3	116	290.7	**2.719162**	**7.836517**		-7.191216667	112.6995583	-7.190811667	112.6988867
		KARINA 3 4	10.7	11.4	116.8	292.5	**4.528035**	**0.398164**		-7.191031667	112.6991183	-7.190415	112.6978117
		KARINA 3 5	10.9	11.6	117.6	293.8	**5.772379**	**-7.07752**		-7.190795	112.69864	-7.190026667	112.6968617
		KARINA 3 6	10.9	11.7	118.3	295.2	**6.176513**	**-11.362092**		-7.190545	112.69821	-7.18981	112.6963717
N3 - N10	NN	SAMHO T7 1	10.4	5	115.1	206	**-5.12031**	**8.126192**	CROSSING	-7.191615	112.7004667	-7.19138	112.69741
		SAMHO T7 2	10.5	0.3	115.5	70	**-4.68366**	**87.614936**		-7.191408333	112.6999917	-7.19113	112.6967967
		SAMHO T7 3	10.6	0.4	116	80.6	**-7.71269**	**90.099143**		-7.191216667	112.6995583	-7.190763333	112.6961517
		SAMHO T7 4	10.7	8.6	116.8	122.3	**174.447194**	**-3.35747**		-7.191031667	112.6991183	-7.1906	112.69588
		SAMHO T7 5	10.9	3	117.6	213.3	**-45.69304**	**22.130772**		-7.190795	112.69864	-7.190196667	112.6952483
		SAMHO T7 6	10.9	2.8	118.3	210.8	**-42.96754**	**36.905250**		-7.190545	112.69821	-7.190041667	112.6949967
N4 - N5	MERATUS KALABAHI	MERATUS BATAM1	6.7	10.8	110.0	291.0	**-3.34300**	**13.330839**	CROSSING	-7.191583333	112.6979567	-7.1915	112.6971667
		MERATUS BATAM2	6.8	10.9	110.8	292.0	**4.51028**	**-5.24477**		-7.191491667	112.697715	-7.191166667	112.6966667
		MERATUS BATAM3	6.9	10.9	112.2	293.0	**5.617200**	**1.79779**		-7.19138	112.69741	-7.190833333	112.6961667
		MERATUS BATAM4	7.1	10.9	114.9	294.0	**5.554898**	**1.71907**		-7.191256667	112.6970717	-7.190666667	112.6958333
		MERATUS BATAM5	7.2	10.9	118.0	295.0	**6.625462**	**5.33203**		-7.19113	112.6967967	-7.190333333	112.6953333
		MERATUS BATAM6	7.4	10.8	121.0	297.0	**-7.12036**	**-11.22576**		-7.190956667	112.6964783	-7.19	112.695

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N4 - N10	MERATUS KALABAHI	SAMHO T7 1	6.7	5.0	110.0	206.0	**-25.51753**	**-53.21003**	CROSSING	-7.191583333	112.6979567	-7.19138	112.69741
		SAMHO T7 2	6.8	0.3	110.8	70.0	**30.371248**	**-150.37795**		-7.191491667	112.697715	-7.19113	112.6967967
		SAMHO T7 3	6.9	0.4	112.2	80.6	**33.237905**	**-159.12182**		-7.19138	112.69741	-7.190763333	112.6961517
		SAMHO T7 4	7.1	8.6	114.9	122.3	**-92.12964**	**-199.67255**		-7.191256667	112.6970717	-7.1906	112.69588
		SAMHO T7 5	7.2	3.0	118.0	213.3	**50.156781**	**70.752853**		-7.19113	112.6967967	-7.190196667	112.6952483
		SAMHO T7 6	7.4	2.8	121.0	210.8	**47.677839**	**49.274579**		-7.190956667	112.6964783	-7.190041667	112.6949967
N5 - N10	MERATUS BATAM	SAMHO T7 1	10.8	5	291	206	**91.090618**	**16.469204**	CROSSING	-7.1915	112.6971667	-7.19138	112.69741
		SAMHO T7 2	10.9	0.3	292	70	**54.035300**	**26.146180**		-7.191166667	112.6966667	-7.19113	112.6967967
		SAMHO T7 3	10.9	0.4	293	80.6	**58.751431**	**27.833649**		-7.190833333	112.6961667	-7.190763333	112.6961517
		SAMHO T7 4	10.9	8.6	294	122.3	**20.048947**	**12.400088**		-7.190666667	112.6958333	-7.1906	112.69588
		SAMHO T7 5	10.9	3	295	213.3	**93.755709**	**19.671749**		-7.190333333	112.6953333	-7.190196667	112.6952483
		SAMHO T7 6	10.8	2.8	297	210.8	**87.354804**	**17.906366**		-7.19	112.695	-7.190041667	112.6949967
N5 - N11	MERATUS BATAM	KM. NIKI SAE 1	10.8	12.9	291	109	**11.2102070**	**12.2228660**	CROSSING	-7.1915	112.6971667	-7.19155	112.6993167
		KM. NIKI SAE 2	10.9	12.5	292	296	**0.0000000**	**0.0000000**		-7.191166667	112.6966667	-7.190766667	112.6968
		KM. NIKI SAE 3	10.9	13.1	293	116	**10.4254490**	**9.0896300**		-7.190833333	112.6961667	-7.189766667	112.69485
		KM. NIKI SAE 4	10.9	12.7	294	301	**0.0000000**	**0.0000000**		-7.190666667	112.6958333	-7.18965	112.6948
		KM. NIKI SAE 5	10.9	13	295	118	**90.0568700**	**7.1512420**		-7.190333333	112.6953333	-7.189483333	112.6942833
		KM. NIKI SAE 6	10.8	13	297	119	**10.6857900**	**7.9397000**		-7.19	112.695	-7.189233333	112.6938

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N6 - N10	MATARAM EXPRESS	SAMHO T7 1	7.2	5	116.7	206	**0.000000**	**0.000000**	CROSSING	-7.191518333	112.6991167	-7.19138	112.69741
		SAMHO T7 2	7.2	0.3	118.6	70	**0.000000**	**0.000000**		-7.191206667	112.698525	-7.19113	112.6967967
		SAMHO T7 3	7.3	0.4	126.4	80.6	**0.000000**	**0.000000**		-7.190705	112.6976517	-7.190763333	112.6961517
		SAMHO T7 4	7.3	8.6	124.2	122.3	**369.369540**	**20.428790**		-7.190295	112.6971083	-7.1906	112.69588
		SAMHO T7 5	7.3	3	124.3	213.3	**0.000000**	**0.000000**		-7.19012	112.6968533	-7.190196667	112.6952483
		SAMHO T7 6	7.3	2.8	123.5	210.8	**0.000000**	**0.000000**		-7.189118333	112.6954033	-7.190041667	112.6949967
N6 - N11	MATARAM EXPRESS	KM. NIKI SAE 1	7.2	12.9	116.7	109	**1.694240**	**0.986285**	CROSSING	-7.191518333	112.6991167	-7.19155	112.6993167
		KM. NIKI SAE 2	7.2	12.5	118.6	296	**0.000000**	**0.000000**		-7.191206667	112.698525	-7.190766667	112.6968
		KM. NIKI SAE 3	7.3	13.1	126.4	116	**41.421220**	**17.506280**		-7.190705	112.6976517	-7.189766667	112.69485
		KM. NIKI SAE 4	7.3	12.7	124.2	301	**0.000000**	**0.000000**		-7.190295	112.6971083	-7.18965	112.6948
		KM. NIKI SAE 5	7.3	13	124.3	118	**57.140368**	**15.017530**		-7.19012	112.6968533	-7.189483333	112.6942833
		KM. NIKI SAE 6	7.3	13	123.5	119	**41.240430**	**9.185537**		-7.189118333	112.6954033	-7.189233333	112.6938
N6 - N15	MATARAM EXPRESS	DHARMA KENCANA III 1	7.2	6.7	116.7	105.5	**0.000000**	**0.000000**	CROSSING	-7.191518333	112.6991167	-7.191276667	112.7000767
		DHARMA KENCANA III 2	7.2	6.8	118.6	106.8	**0.000000**	**0.000000**		-7.191206667	112.698525	-7.190915	112.6988267
		DHARMA KENCANA III 3	7.3	7	126.4	108.2	**0.000000**	**0.000000**		-7.190705	112.6976517	-7.19042	112.6972867
		DHARMA KENCANA III 4	7.3	7.6	124.2	112.6	**0.000000**	**0.000000**		-7.190295	112.6971083	-7.189521667	112.6947333
		DHARMA KENCANA III 5	7.3	7.7	124.3	118.2	**0.000000**	**0.000000**		-7.19012	112.6968533	-7.189365	112.6944083
		DHARMA KENCANA III 6	7.3	7.8	123.5	125.1	**743.316550**	**4.337700**		-7.189118333	112.6954033	-7.189166667	112.6941

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N6 - N16	MATARAM EXPRESS	KARINA 3 1	7.2	11.7	116.7	287.6	**0.000000**	**0.000000**	CROSSING	-7.191518333	112.6991167	-7.191541667	112.70071
		KARINA 3 2	7.2	11	118.6	291.9	**0.000000**	**0.000000**		-7.191206667	112.698525	-7.191171667	112.699865
		KARINA 3 3	7.3	11.3	126.4	290.7	**0.000000**	**0.000000**		-7.190705	112.6976517	-7.190811667	112.6988867
		KARINA 3 4	7.3	11.4	124.2	292.5	**0.000000**	**0.000000**		-7.190295	112.6971083	-7.190415	112.6978117
		KARINA 3 5	7.3	11.6	124.3	293.8	**0.000000**	**0.000000**		-7.19012	112.6968533	-7.190026667	112.6968617
		KARINA 3 6	7.3	11.7	123.5	295.2	**0.000000**	**0.000000**		-7.189118333	112.6954033	-7.18981	112.6963717
N7 - N10	CAKRA KEMBAR	SAMHO T7 1	9.4	5	296	206	**31.917400**	**4.1135896**	CROSSING	-7.191528333	112.7001317	-7.19138	112.69741
		SAMHO T7 2	9.5	0.3	294.8	70	**24.678966**	**9.1668930**		-7.191343333	112.6997283	-7.19113	112.6967967
		SAMHO T7 3	9.6	0.4	300.6	80.6	**67.753630**	**20.0941720**		-7.190155	112.6973883	-7.190763333	112.6961517
		SAMHO T7 4	9.5	8.6	301.8	122.3	**33.411463**	**16.1063000**		-7.189663333	112.69656	-7.1906	112.69588
		SAMHO T7 5	9.5	3	302.8	213.3	**144.156112**	**19.7724800**		-7.189451667	112.6962233	-7.190196667	112.6952483
		SAMHO T7 6	9.4	2.8	303.5	210.8	**129.274190**	**18.0530300**		-7.189211667	112.6958483	-7.190041667	112.6949967
N7 - N15	CAKRA KEMBAR	DHARMA KENCANA III 1	9.4	6.7	296	105.5	**2.759004**	**1.8591307**	CROSSING	-7.191528333	112.7001317	-7.191276667	112.7000767
		DHARMA KENCANA III 2	9.5	6.8	294.8	106.8	**8.100649**	**5.5839000**		-7.191343333	112.6997283	-7.190915	112.6988267
		DHARMA KENCANA III 3	9.6	7	300.6	108.2	**3.115630**	**1.8070400**		-7.190155	112.6973883	-7.19042	112.6972867
		DHARMA KENCANA III 4	9.5	7.6	301.8	112.6	**18.005820**	**9.7382400**		-7.189663333	112.69656	-7.189521667	112.6947333
		DHARMA KENCANA III 5	9.5	7.7	302.8	118.2	**19.629745**	**9.4543700**		-7.189451667	112.6962233	-7.189365	112.6944083
		DHARMA KENCANA III 6	9.4	7.8	303.5	125.1	**21.584560**	**9.0951200**		-7.189211667	112.6958483	-7.189166667	112.6941

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N7 - N16	CAKRA KEMBAR	KARINA 3 1	9.4	11.7	296	287.6	**18.2897900**	**3.9101380**	CROSSING	-7.191528333	112.7001317	-7.191541667	112.70071
		KARINA 3 2	9.5	11	294.8	291.9	**0.0000000**	**0.0000000**		-7.191343333	112.6997283	-7.191171667	112.699865
		KARINA 3 3	9.6	11.3	300.6	290.7	**87.4933930**	**9.2656592**		-7.190155	112.6973883	-7.190811667	112.6988867
		KARINA 3 4	9.5	11.4	301.8	292.5	**53.8146550**	**8.7066420**		-7.189663333	112.69656	-7.190415	112.6978117
		KARINA 3 5	9.5	11.6	302.8	293.8	**19.5874170**	**4.9234967**		-7.189451667	112.6962233	-7.190026667	112.6968617
		KARINA 3 6	9.4	11.7	303.5	295.2	**8.1614091**	**4.8959200**		-7.189211667	112.6958483	-7.18981	112.6963717
N11 - N10	KM. NIKI SAE	SAMHO T7 1	12.9	5	109	206	**1.0224510**	**11.9974930**	CROSSING	-7.19155	112.6993167	-7.19138	112.69741
		SAMHO T7 2	12.5	0.3	296	70	**53.9201310**	**24.4690000**		-7.190766667	112.6968	-7.19113	112.6967967
		SAMHO T7 3	13.1	0.4	116	80.6	**0.0000000**	**0.0000000**		-7.189766667	112.69485	-7.190763333	112.6961517
		SAMHO T7 4	12.7	8.6	301	122.3	**13.2566480**	**7.6717180**		-7.18965	112.6948	-7.1906	112.69588
		SAMHO T7 5	13	3	118	213.3	**0.0000000**	**0.0000000**		-7.189483333	112.6942833	-7.190196667	112.6952483
		SAMHO T7 6	13	2.8	119	210.8	**0.0000000**	**0.0000000**		-7.189233333	112.6938	-7.190041667	112.6949967
N15 - N10	DHARMA KENCANA III	SAMHO T7 1	6.7	5	105.5	206	**13.830220**	**6.68115800**	CROSSING	-7.191276667	112.7000767	-7.19138	112.69741
		SAMHO T7 2	6.8	0.3	106.8	70	**0.000000**	**0.00000000**		-7.190915	112.6988267	-7.19113	112.6967967
		SAMHO T7 3	7	0.4	108.2	80.6	**0.000000**	**0.00000000**		-7.19042	112.6972867	-7.190763333	112.6961517
		SAMHO T7 4	7.6	8.6	112.6	122.3	**315.243622**	**1.34356654**		-7.189521667	112.6947333	-7.1906	112.69588
		SAMHO T7 5	7.7	3	118.2	213.3	**0.000000**	**0.00000000**		-7.189365	112.6944083	-7.190196667	112.6952483
		SAMHO T7 6	7.8	2.8	125.1	210.8	**0.000000**	**0.00000000**		-7.189166667	112.6941	-7.190041667	112.6949967

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA (h)	DCPA (nm)	ENCOUNTER	LAT V1	LONG V1	LAT V2	LONG V2
N15 - N31	DHARMA KENCANA III	PETRO OCEAN XVI 1	6.7	8.7	105.5	295.3	**0.00000000**	**0.00000000**	CROSSING	-7.191276667	112.7000767	-7.190958333	112.6979283
		PETRO OCEAN XVI 2	6.8	8.7	106.8	295.2	**0.00000000**	**0.00000000**		-7.190915	112.6988267	-7.190645	112.6972183
		PETRO OCEAN XVI 3	7	8.6	108.2	300.1	**0.00000000**	**0.00000000**		-7.19042	112.6972867	-7.189426667	112.695075
		PETRO OCEAN XVI 4	7.6	8.6	112.6	303.6	**0.00000000**	**0.00000000**		-7.189521667	112.6947333	-7.189041667	112.6944767
		PETRO OCEAN XVI 5	7.7	8.5	118.2	305.5	**0.00000000**	**0.00000000**		-7.189365	112.6944083	-7.188531667	112.69377
N16 - N10	KARINA 3	SAMHO T7 1	11.7	5	287.6	206	**9.984273**	**2.233935**	CROSSING	-7.191541667	112.70071	-7.19138	112.69741
		SAMHO T7 2	11	0.3	291.9	70	**1.714364**	**8.409111**		-7.191171667	112.699865	-7.19113	112.6967967
		SAMHO T7 3	11.3	0.4	290.7	80.6	**2.432581**	**13.179502**		-7.190811667	112.6988867	-7.190763333	112.6961517
		SAMHO T7 4	11.4	8.6	292.5	122.3	**3.518798**	**23.225136**		-7.190415	112.6978117	-7.1906	112.69588
		SAMHO T7 5	11.6	3	293.8	213.3	**11.430032**	**27.307549**		-7.190026667	112.6968617	-7.190196667	112.6952483
		SAMHO T7 6	11.7	2.8	295.2	210.8	**9.931786**	**24.123783**		-7.18981	112.6963717	-7.190041667	112.6949967
N31 - N10	PETRO OCEAN XVI	SAMHO T7 1	8.7	5	295.3	206	**5.4605348**	**18.280950**	CROSSING	-7.190958333	112.6979283	-7.19138	112.69741
		SAMHO T7 2	8.7	0.3	295.2	70	**6.5272192**	**21.953686**		-7.190645	112.6972183	-7.19113	112.6967967
		SAMHO T7 3	8.6	0.4	300.1	80.6	**11.8704703**	**32.529474**		-7.189426667	112.695075	-7.190763333	112.6961517
		SAMHO T7 4	8.6	8.6	303.6	122.3	**1.8974719**	**8.391455**		-7.189041667	112.6944767	-7.1906	112.69588
		SAMHO T7 5	8.5	3	305.5	213.3	**9.1244657**	**9.826824**		-7.188531667	112.69377	-7.190196667	112.6952483

APPENDIX 2

This appendix contains the calculation of Threshold (λ) of model scenario based on 12 ships within buoy 8-13 in Surabaya West Access Channel on March, 2015.

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ	LAT V1	LONG V1	LAT V2	LONG V2
N1 - N10	MY HUNG	SAMHO T7 1	9.8	5	112.5	206	**3.544394**	**2.06093**	**0.23**	-7.1915	112.6971667	-7.19138	112.69741
		SAMHO T7 2	9.9	0.3	112.1	70	**4.198168**	**44.14411**	**0.08**	-7.191166667	112.6966667	-7.19113	112.6967967
		SAMHO T7 3	10.5	0.4	112.2	80.6	**-9.870640**	**45.16487**	**0.09**	-7.190833333	112.6961667	-7.190763333	112.6961517
		SAMHO T7 4	10.7	8.6	111.8	122.3	**-48.686492**	**-42.915112**	**0.14**	-7.190666667	112.6958333	-7.1906	112.69588
		SAMHO T7 5	10.8	3	113.1	213.3	**33.803436**	**-57.640156**	**0.24**	-7.190333333	112.6953333	-7.190196667	112.6952483
		SAMHO T7 6	10.7	2.8	114.8	210.8	**34.703604**	**-71.623129**	**0.24**	-7.19	112.695	-7.190041667	112.6949967
N2 - N3	HOANG HAI 68	NN1	9.6	10.4	288.9	115.1	**-2.873175**	**-17.538175**	**0.33**	-7.191115	112.6998433	-7.191615	112.7004667
		NN2	9.4	10.5	291.8	115.5	**-5.507683**	**-9.984312**	**0.34**	-7.19063	112.6986067	-7.191408333	112.6999917
		NN3	9.4	10.6	293.2	116	**-5.478680**	**-10.038380**	**0.34**	-7.190438333	112.6982117	-7.191216667	112.6995583
		NN4	9.4	10.7	293.7	116.8	**-4.440209**	**-11.855938**	**0.34**	-7.190381667	112.6980917	-7.191031667	112.6991183
		NN5	9.4	10.9	294.9	117.6	**-4.913403**	**-7.550481**	**0.35**	-7.190061667	112.6974217	-7.190795	112.69864
		NN6	9.5	10.9	298.3	118.3	**-6.860266**	**-3.762477**	**0.35**	-7.18893	112.6951883	-7.190545	112.69821
N2 - N10	HOANG HAI 68	SAMHO T7 1	9.6	5	288.9	206	**-0.819012**	**5.419472**	**0.60**	-7.191115	112.6998433	-7.19138	112.69741
		SAMHO T7 2	9.4	0.3	291.8	70	**-1.7421385**	**6.541356**	**0.20**	-7.19063	112.6986067	-7.19113	112.6967967
		SAMHO T7 3	9.4	0.4	293.2	80.6	**2.0393116**	**-6.820323**	**0.24**	-7.190438333	112.6982117	-7.190763333	112.6961517
		SAMHO T7 4	9.4	8.6	293.7	122.3	**-1.561689**	**15.434972**	**0.36**	-7.190381667	112.6980917	-7.1906	112.69588
		SAMHO T7 5	9.4	3	294.9	213.3	**-3.681126**	**26.987964**	**0.63**	-7.190061667	112.6974217	-7.190196667	112.6952483
		SAMHO T7 6	9.5	2.8	298.3	210.8	**-1.800620**	**21.7598964**	**0.63**	-7.18893	112.6951883	-7.190041667	112.6949967

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ	LAT V1	LONG V1	LAT V2	LONG V2
N3 - N16	NN	KARINA 3 1	10.4	11.7	115.1	287.6	0.000740	-0.011571	**0.33**	-7.191615	112.7004667	-7.191541667	112.70071
		KARINA 3 2	10.5	11	115.5	291.9	-0.00070	-0.01325	**0.34**	-7.191408333	112.6999917	-7.191171667	112.699865
		KARINA 3 3	10.6	11.3	116	290.7	0.002719	0.007837	**0.34**	-7.191216667	112.6995583	-7.190811667	112.6988867
		KARINA 3 4	10.7	11.4	116.8	292.5	0.004528	0.000398	**0.34**	-7.191031667	112.6991183	-7.190415	112.6978117
		KARINA 3 5	10.9	11.6	117.6	293.8	0.005772	-0.00708	**0.35**	-7.190795	112.69864	-7.190026667	112.6968617
		KARINA 3 6	10.9	11.7	118.3	295.2	0.006177	-0.011362	**0.35**	-7.190545	112.69821	-7.18981	112.6963717
N3 - N10	NN	SAMHO T7 1	10.4	5	115.1	206	-0.00512	0.008126	**0.24**	-7.191615	112.7004667	-7.19138	112.69741
		SAMHO T7 2	10.5	0.3	115.5	70	-0.00468	0.087615	**0.08**	-7.191408333	112.6999917	-7.19113	112.6967967
		SAMHO T7 3	10.6	0.4	116	80.6	-0.00771	0.090099	**0.09**	-7.191216667	112.6995583	-7.190763333	112.6961517
		SAMHO T7 4	10.7	8.6	116.8	122.3	0.174447	-0.00336	**0.14**	-7.191031667	112.6991183	-7.1906	112.69588
		SAMHO T7 5	10.9	3	117.6	213.3	-0.04569	0.022131	**0.25**	-7.190795	112.69864	-7.190196667	112.6952483
		SAMHO T7 6	10.9	2.8	118.3	210.8	-0.04297	0.036905	**0.25**	-7.190545	112.69821	-7.190041667	112.6949967
N4 - N5	MERATUS KALABAHI	MERATUS BATAM1	6.7	10.8	110.0	291.0	-0.00334	0.013331	**0.32**	-7.191583333	112.6979567	-7.1915	112.6971667
		MERATUS BATAM2	6.8	10.9	110.8	292.0	0.00451	-0.00524	**0.32**	-7.191491667	112.697715	-7.191166667	112.6966667
		MERATUS BATAM3	6.9	10.9	112.2	293.0	0.005617	0.00180	**0.33**	-7.19138	112.69741	-7.190833333	112.6961667
		MERATUS BATAM4	7.1	10.9	114.9	294.0	0.005555	0.00172	**0.34**	-7.191256667	112.6970717	-7.190666667	112.6958333
		MERATUS BATAM5	7.2	10.9	118.0	295.0	0.006625	0.00533	**0.35**	-7.19113	112.6967967	-7.190333333	112.6953333
		MERATUS BATAM6	7.4	10.8	121.0	297.0	-0.00712	-0.01123	**0.36**	-7.190956667	112.6964783	-7.19	112.695

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ	LAT V1	LONG V1	LAT V2	LONG V2
N6 - N10	MATARAM EXPRESS	SAMHO T7 1	7.2	5	116.7	206	0.000000	0.000000	**0.24**	-7.191518333	112.6991167	-7.19138	112.69741
		SAMHO T7 2	7.2	0.3	118.6	70	0.000000	0.000000	**0.08**	-7.191206667	112.698525	-7.19113	112.6967967
		SAMHO T7 3	7.3	0.4	126.4	80.6	0.000000	0.000000	**0.10**	-7.190705	112.6976517	-7.190763333	112.6961517
		SAMHO T7 4	7.3	8.6	124.2	122.3	3.693695	0.204288	**0.15**	-7.190295	112.6971083	-7.1906	112.69588
		SAMHO T7 5	7.3	3	124.3	213.3	0.000000	0.000000	**0.27**	-7.19012	112.6968533	-7.190196667	112.6952483
		SAMHO T7 6	7.3	2.8	123.5	210.8	0.000000	0.000000	**0.26**	-7.189118333	112.6954033	-7.190041667	112.6949967
N6 - N11	MATARAM EXPRESS	KM. NIKI SAE 1	7.2	12.9	116.7	109	0.016942	0.009863	**0.13**	-7.191518333	112.6991167	-7.19155	112.6993167
		KM. NIKI SAE 2	7.2	12.5	118.6	296	0.000000	0.000000	**0.35**	-7.191206667	112.698525	-7.190766667	112.6968
		KM. NIKI SAE 3	7.3	13.1	126.4	116	0.414212	0.175063	**0.15**	-7.190705	112.6976517	-7.189766667	112.69485
		KM. NIKI SAE 4	7.3	12.7	124.2	301	0.000000	0.000000	**0.37**	-7.190295	112.6971083	-7.18965	112.6948
		KM. NIKI SAE 5	7.3	13	124.3	118	0.571404	0.150175	**0.15**	-7.19012	112.6968533	-7.189483333	112.6942833
		KM. NIKI SAE 6	7.3	13	123.5	119	0.412404	0.091855	**0.15**	-7.189118333	112.6954033	-7.189233333	112.6938
N6 - N15	MATARAM EXPRESS	DHARMA KENCANA III 1	7.2	6.7	116.7	105.5	0.000000	0.000000	**0.12**	-7.191518333	112.6991167	-7.191276667	112.7000767
		DHARMA KENCANA III 2	7.2	6.8	118.6	106.8	0.000000	0.000000	**0.13**	-7.191206667	112.698525	-7.190915	112.6988267
		DHARMA KENCANA III 3	7.3	7	126.4	108.2	0.000000	0.000000	**0.14**	-7.190705	112.6976517	-7.19042	112.6972867
		DHARMA KENCANA III 4	7.3	7.6	124.2	112.6	0.000000	0.000000	**0.14**	-7.190295	112.6971083	-7.189521667	112.6947333
		DHARMA KENCANA III 5	7.3	7.7	124.3	118.2	0.000000	0.000000	**0.15**	-7.19012	112.6968533	-7.189365	112.6944083
		DHARMA KENCANA III 6	7.3	7.8	123.5	125.1	7.433166	0.043377	**0.16**	-7.189118333	112.6954033	-7.189166667	112.6941

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ	LAT V1	LONG V1	LAT V2	LONG V2
N6 - N16	MATARAM EXPRESS	KARINA 3 1	7.2	11.7	116.7	287.6	0.000000	0.000000	**0.34**	-7.191518333	112.6991167	-7.191541667	112.70071
		KARINA 3 2	7.2	11	118.6	291.9	0.000000	0.000000	**0.35**	-7.191206667	112.698525	-7.191171667	112.699865
		KARINA 3 3	7.3	11.3	126.4	290.7	0.000000	0.000000	**0.37**	-7.190705	112.6976517	-7.190811667	112.6988867
		KARINA 3 4	7.3	11.4	124.2	292.5	0.000000	0.000000	**0.36**	-7.190295	112.6971083	-7.190415	112.6978117
		KARINA 3 5	7.3	11.6	124.3	293.8	0.000000	0.000000	**0.37**	-7.19012	112.6968533	-7.190026667	112.6968617
		KARINA 3 6	7.3	11.7	123.5	295.2	0.000000	0.000000	**0.37**	-7.189118333	112.6954033	-7.18981	112.6963717
N7 - N10	CAKRA KEMBAR	SAMHO T7 1	9.4	5	296	206	0.3191740	0.0411359	**0.61**	-7.191528333	112.7001317	-7.19138	112.69741
		SAMHO T7 2	9.5	0.3	294.8	70	0.2467897	0.0916689	**0.21**	-7.191343333	112.6997283	-7.19113	112.6967967
		SAMHO T7 3	9.6	0.4	300.6	80.6	0.6775363	0.2009417	**0.24**	-7.190155	112.6973883	-7.190763333	112.6961517
		SAMHO T7 4	9.5	8.6	301.8	122.3	0.3341146	0.1610630	**0.37**	-7.189663333	112.69656	-7.1906	112.69588
		SAMHO T7 5	9.5	3	302.8	213.3	1.4415611	0.1977248	**0.65**	-7.189451667	112.6962233	-7.190196667	112.6952483
		SAMHO T7 6	9.4	2.8	303.5	210.8	1.2927419	0.1805303	**0.64**	-7.189211667	112.6958483	-7.190041667	112.6949967
N7 - N15	CAKRA KEMBAR	DHARMA KENCANA III 1	9.4	6.7	296	105.5	0.0275900	0.0185913	**0.31**	-7.191528333	112.7001317	-7.191276667	112.7000767
		DHARMA KENCANA III 2	9.5	6.8	294.8	106.8	0.0810065	0.0558390	**0.32**	-7.191343333	112.6997283	-7.190915	112.6988267
		DHARMA KENCANA III 3	9.6	7	300.6	108.2	0.0311563	0.0180704	**0.33**	-7.190155	112.6973883	-7.19042	112.6972867
		DHARMA KENCANA III 4	9.5	7.6	301.8	112.6	0.1800582	0.0973824	**0.34**	-7.189663333	112.69656	-7.189521667	112.6947333
		DHARMA KENCANA III 5	9.5	7.7	302.8	118.2	0.1962975	0.0945437	**0.36**	-7.189451667	112.6962233	-7.189365	112.6944083
		DHARMA KENCANA III 6	9.4	7.8	303.5	125.1	0.2158456	0.0909512	**0.38**	-7.189211667	112.6958483	-7.189166667	112.6941

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ	LAT V1	LONG V1	LAT V2	LONG V2
N7 - N16	CAKRA KEMBAR	KARINA 3 1	9.4	11.7	296	287.6	0.1828979	0.0391014	**0.85**	-7.191528333	112.7001317	-7.191541667	112.70071
		KARINA 3 2	9.5	11	294.8	291.9	0.4387728	0.2331099	**0.86**	-7.191343333	112.6997283	-7.191171667	112.699865
		KARINA 3 3	9.6	11.3	300.6	290.7	0.8749339	0.0926566	**0.87**	-7.190155	112.6973883	-7.190811667	112.6988867
		KARINA 3 4	9.5	11.4	301.8	292.5	0.5381466	0.0870664	**0.88**	-7.189663333	112.69656	-7.190415	112.6978117
		KARINA 3 5	9.5	11.6	302.8	293.8	0.1958742	0.0492350	**0.89**	-7.189451667	112.6962233	-7.190026667	112.6968617
		KARINA 3 6	9.4	11.7	303.5	295.2	0.0816141	0.0489592	**0.90**	-7.189211667	112.6958483	-7.18981	112.6963717
N11 - N10	KM. NIKI SAE	SAMHO T7 1	12.9	5	109	206	0.0102245	0.1199749	**0.23**	-7.19155	112.6993167	-7.19138	112.69741
		SAMHO T7 2	12.5	0.3	296	70	0.5392013	0.2446900	**0.21**	-7.190766667	112.6968	-7.19113	112.6967967
		SAMHO T7 3	13.1	0.4	116	80.6	0.0000000	0.0000000	**0.09**	-7.189766667	112.69485	-7.190763333	112.6961517
		SAMHO T7 4	12.7	8.6	301	122.3	0.1325665	0.0767172	**0.37**	-7.18965	112.6948	-7.1906	112.69588
		SAMHO T7 5	13	3	118	213.3	0.0000000	0.0000000	**0.25**	-7.189483333	112.6942833	-7.190196667	112.6952483
		SAMHO T7 6	13	2.8	119	210.8	0.0000000	0.0000000	**0.25**	-7.189233333	112.6938	-7.190041667	112.6949967
N15 - N10	DHARMA KENCANA III	SAMHO T7 1	6.7	5	105.5	206	0.13830220	0.06681158	**0.22**	-7.191276667	112.7000767	-7.19138	112.69741
		SAMHO T7 2	6.8	0.3	106.8	70	0.00000000	0.00000000	**0.07**	-7.190915	112.6988267	-7.19113	112.6967967
		SAMHO T7 3	7	0.4	108.2	80.6	0.00000000	0.00000000	**0.09**	-7.19042	112.6972867	-7.190763333	112.6961517
		SAMHO T7 4	7.6	8.6	112.6	122.3	3.15243622	0.01343567	**0.14**	-7.189521667	112.6947333	-7.1906	112.69588
		SAMHO T7 5	7.7	3	118.2	213.3	0.00000000	0.00000000	**0.25**	-7.189365	112.6944083	-7.190196667	112.6952483
		SAMHO T7 6	7.8	2.8	125.1	210.8	0.00000000	0.00000000	**0.26**	-7.189166667	112.6941	-7.190041667	112.6949967

SCENARIO	V1	V2	S1	S2	R1	R2	TCPA	DCPA	λ	LAT V1	LONG V1	LAT V2	LONG V2
N15 - N31	DHARMA KENCANA III	PETRO OCEAN XVI 1	6.7	8.7	105.5	295.3	0.00000000	0.00000000	**0.31**	-7.191276667	112.7000767	-7.190958333	112.6979283
		PETRO OCEAN XVI 2	6.8	8.7	106.8	295.2	0.00000000	0.00000000	**0.32**	-7.190915	112.6988267	-7.190645	112.6972183
		PETRO OCEAN XVI 3	7	8.6	108.2	300.1	0.00000000	0.00000000	**0.33**	-7.19042	112.6972867	-7.189426667	112.695075
		PETRO OCEAN XVI 4	7.6	8.6	112.6	303.6	0.00000000	0.00000000	**0.34**	-7.189521667	112.6947333	-7.189041667	112.6944767
		PETRO OCEAN XVI 5	7.7	8.5	118.2	305.5	0.00000000	0.00000000	**0.36**	-7.189365	112.6944083	-7.188531667	112.69377
N16 - N10	KARINA 3	SAMHO T7 1	11.7	5	287.6	206	99.842731	0.02233935	**0.59**	-7.191541667	112.70071	-7.19138	112.69741
		SAMHO T7 2	11	0.3	291.9	70	17.143635	0.08409111	**0.20**	-7.191171667	112.699865	-7.19113	112.6967967
		SAMHO T7 3	11.3	0.4	290.7	80.6	24.325806	0.13179502	**0.23**	-7.190811667	112.6988867	-7.190763333	112.6961517
		SAMHO T7 4	11.4	8.6	292.5	122.3	35.187985	0.23225136	**0.36**	-7.190415	112.6978117	-7.1906	112.69588
		SAMHO T7 5	11.6	3	293.8	213.3	114.300316	0.27307549	**0.63**	-7.190026667	112.6968617	-7.190196667	112.6952483
		SAMHO T7 6	11.7	2.8	295.2	210.8	99.317860	0.24123783	**0.62**	-7.18981	112.6963717	-7.190041667	112.6949967
N31 - N10	PETRO OCEAN XVI	SAMHO T7 1	8.7	5	295.3	206	0.54605348	0.18280950	**0.61**	-7.190958333	112.6979283	-7.19138	112.69741
		SAMHO T7 2	8.7	0.3	295.2	70	0.65272192	0.21953686	**0.21**	-7.190645	112.6972183	-7.19113	112.6967967
		SAMHO T7 3	8.6	0.4	300.1	80.6	1.18704703	0.32529474	**0.24**	-7.189426667	112.695075	-7.190763333	112.6961517
		SAMHO T7 4	8.6	8.6	303.6	122.3	0.18974719	0.08391455	**0.37**	-7.189041667	112.6944767	-7.1906	112.69588
		SAMHO T7 5	8.5	3	305.5	213.3	0.91244657	0.09826824	**0.65**	-7.188531667	112.69377	-7.190196667	112.6952483

APPENDIX 3

This appendix contains the routes illustration of model scenario based on 12 ships within buoy 8-13 in Surabaya West Access Channel on March, 2015.

Figure 25 N1-N10 Scenario in Surabaya West Access Channel on March, 2015

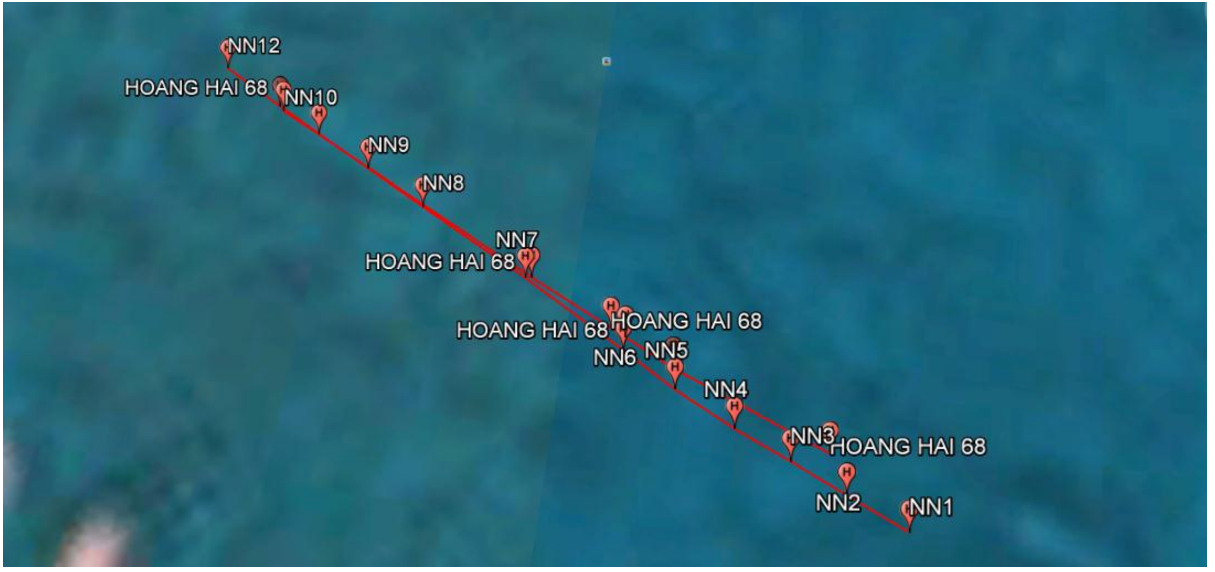

Figure 26 N2-N3 Scenario in Surabaya West Access Channel on March, 2015

Figure 27 N2-N10 Scenario in Surabaya West Access Channel on March, 2015

Figure 28 N3-N10 Scenario in Surabaya West Access Channel on March, 2015

Figure 29 N3-N16 Scenario in Surabaya West Access Channel on March, 2015

Figure 30 N4-N5 Scenario in Surabaya West Access Channel on March, 2015

Figure 31 N4-N10 Scenario in Surabaya West Access Channel on March, 2015

Figure 32 N5-N10 Scenario in Surabaya West Access Channel on March, 2015

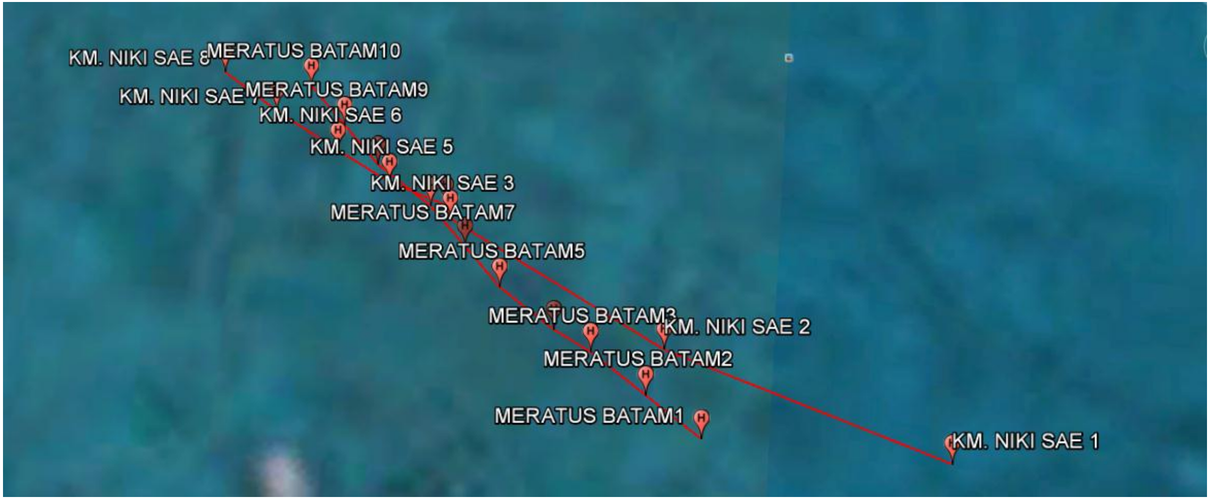

Figure 33 N5-N11 Scenario in Surabaya West Access Channel on March, 2015

Figure 34 N6-N10 Scenario in Surabaya West Access Channel on March, 2015

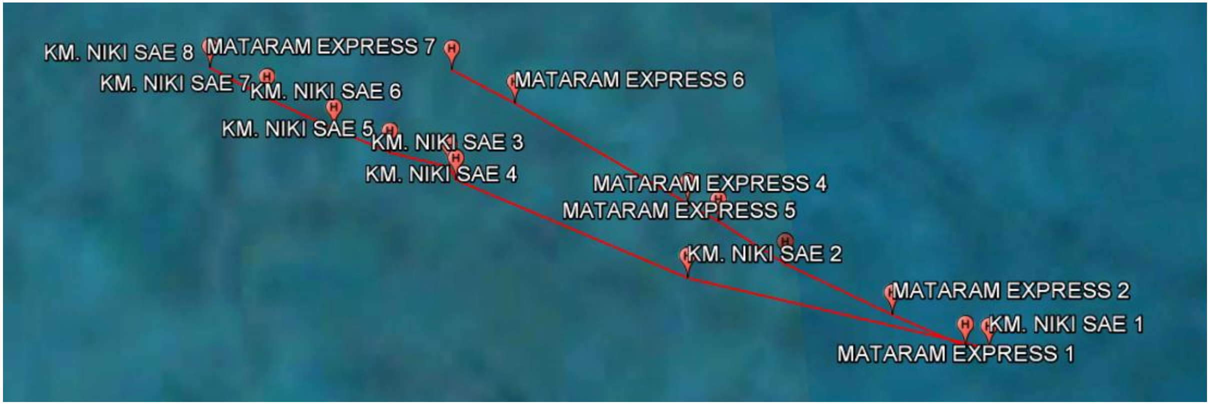

Figure 35 N6-N11 Scenario in Surabaya West Access Channel on March, 2015

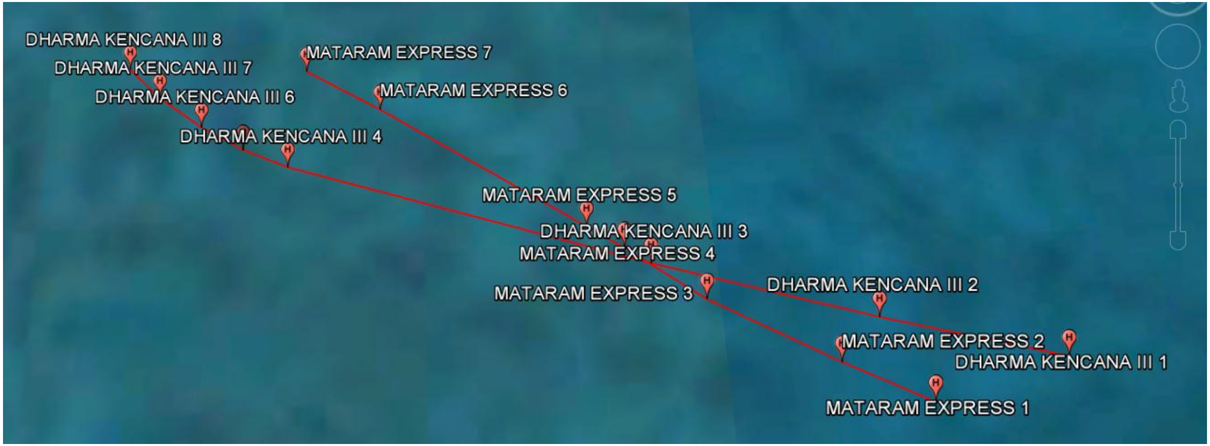

Figure 36 N6-N15 Scenario in Surabaya West Access Channel on March, 2015

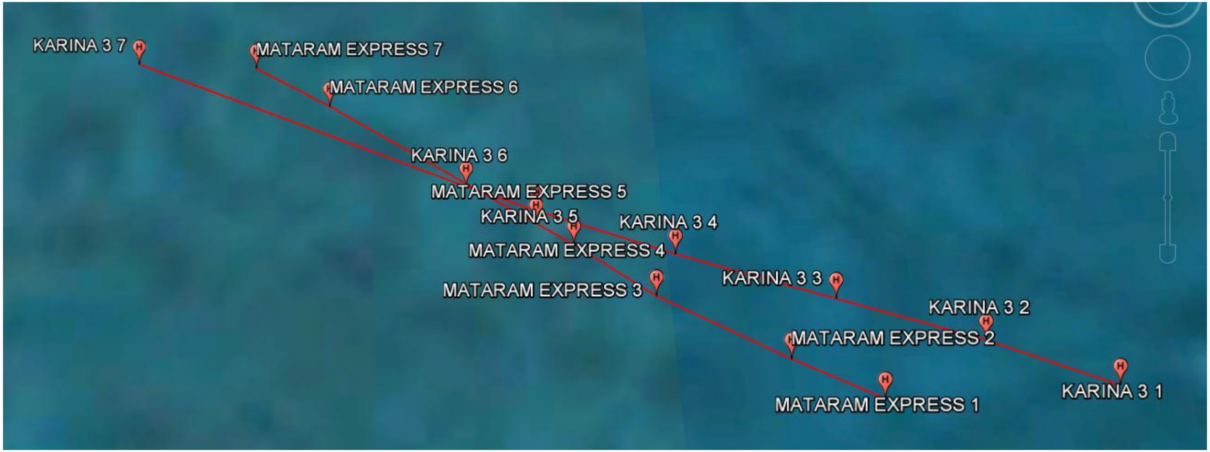

Figure 37 N6-N16 Scenario in Surabaya West Access Channel on March, 2015

Figure 38 N7-N10 Scenario in Surabaya West Access Channel on March, 2015

Figure 39 N7-N15 Scenario in Surabaya West Access Channel on March, 2015

Figure 40 N7-N16 Scenario in Surabaya West Access Channel on March, 2015

Figure 41 N11-N10 Scenario in Surabaya West Access Channel on March, 2015

Figure 42 N15-N10 Scenario in Surabaya West Access Channel on March, 2015

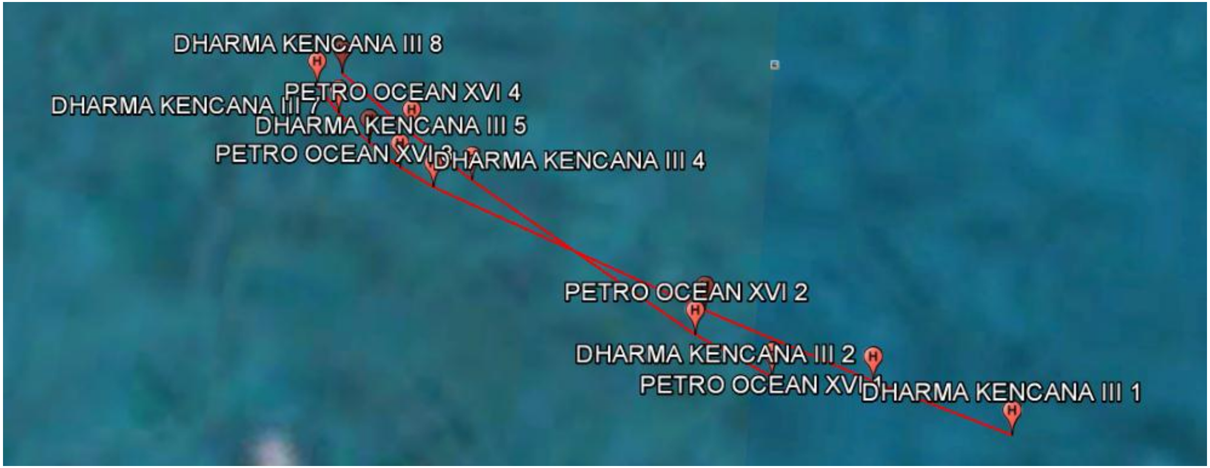

Figure 43 N15-N31 Scenario in Surabaya West Access Channel on March, 2015

Figure 44 N16-N10 Scenario in Surabaya West Access Channel on March, 2015

Figure 45 N31-N10 Scenario in Surabaya West Access Channel on March, 2015

APPENDIX 4

This appendix contains the codes of AIS CPA Calculator based on the model calculation through manual input in Surabaya West Access Channel

```
<?php
$tspeed = 0;
$tcourse = 0;
$tdistance = 0;
$tbearing = 0;
$vspeed = 0;
$vcourse = 0;
$msg = FALSE;
$reslt = FALSE;
if(isset($_POST['tspeed'])){
	$tspeed = $_POST['tspeed'];
	$tcourse = $_POST['tcourse'];
	$tdistance = $_POST['tdistance'];
	$tbearing = $_POST['tbearing'];
	$vspeed = $_POST['vspeed'];
	$vcourse = $_POST['vcourse'];
	if($tspeed==0 || $tspeed==null){
		$msg = TRUE;
	}elseif($tcourse==0 || $tcourse==null){
		$msg = TRUE;
	}elseif($tdistance==0 || $tdistance==null){
		$msg = TRUE;
	}elseif($tbearing==0 || $tbearing==null){
		$msg = TRUE;
	}elseif($vspeed==0 || $vspeed==null){
		$msg = TRUE;
	}elseif($vcourse==0 || $vcourse==null){
		$msg = TRUE;
```

```
}else{
        $angle_vctc_deg = fmod($vcourse-
$tcourse,360);
        $angle_vctc_rad =
($angle_vctc_deg*M_PI)/180;
        $area_deg =
atan($vspeed*sin($angle_vctc_rad)/($tspeed-
$vspeed*cos($angle_vctc_rad)))*(180/M_PI);
        $area_rad = ($area_deg*M_PI)/180;
        $trc_to_cpa_deg = 180-$angle_vctc_deg-
$area_deg;
        $trc_to_cpa_rad =
($trc_to_cpa_deg*M_PI)/180;
        $trs_to_cpa = $vspeed *
sin($angle_vctc_rad) / sin($area_rad);
        $target_abs_course =
$trc_to_cpa_deg+$vcourse+180;
        $angle_tbtc_deg = 180-
$target_abs_course+$tbearing;
        $angle_tbtc_rad =
($angle_tbtc_deg*M_PI)/180;
        $dist_to_cpa = $tdistance*
sin($angle_tbtc_rad);
        $bearing_at_cpa = 90-
$angle_tbtc_deg+$tbearing;
        $rel_dist_cpa =
$tdistance*cos($angle_tbtc_rad);
        $time_to_cpa =
```

```
$rel_dist_cpa/$trs_to_cpa;
			$reslt = TRUE;
		}

}

?>
<!DOCTYPE html>
<html>
		<head>
			<meta charset="utf-8">
			<title>CPA Calculator</title>
			<style>
				body{
					font-family: tahoma;
					font-size: 12pt;
				}
				input{
					text-align:right;
					font-size: 12pt;
				}
				button{
					font-weight: bold;
					padding: 5px;
				}
				.rj{
					text-align:right;
				}
```

```
			.lj{
				text-align: left;
			}
			.leftcolumn{
				width: 49%;
				float: left;
			}
			.rightcolumn{
				width: 50%;
				float: right;
			}
			.clr{
				clear: both;
			}
			#savecalc{
				width: 100%;
				float: right;
			}
		</style>
	</head>
	<body>
		<h1>CPA Calculator</h1>
		<div class="leftcolumn">
		<h3>Finding the closest point of
approach</h3>
		<form method="post">
			<table>
				<tr>
```

```
                                        <td>Target Speed
(kts)</td>
                                        <td><input
type="text" name="tspeed" id="tspeed"
value="<?=$tspeed?>"/></td>
                                </tr>
                                <tr>
                                        <td>Target Course
(degrees)</td>
                                        <td><input
type="text" name="tcourse" id="tcourse"
value="<?=$tcourse?>"/></td>
                                </tr>
                                <tr>
                                        <td>Target
Distance (miles)</td>
                                        <td><input
type="text" name="tdistance" id="tdistance"
value="<?=$tdistance?>"/></td>
                                </tr>
                                <tr>
                                        <td>Target
Bearing (degrees)</td>
                                        <td><input
type="text" name="tbearing" id="tbearing"
value="<?=$tbearing?>"/></td>
                                </tr>
                                <tr>
```

```
                                        <td>Vessel Speed
(kts)</td>
                                        <td><input
type="text" name="vspeed" id="vspeed"
value="<?=$vspeed?>"/></td>
                                </tr>
                                <tr>
                                        <td>Vessel Course
(degrees)</td>
                                        <td><input
type="text" name="vcourse" id="vcourse"
value="<?=$vcourse?>"/></td>
                                </tr>
                                <tr>
                                        <td></td>
                                        <td><button
type="submit">Calculate</button></td>
                                </tr>
                        </table>
                </form>
                </div>
                <div class="rightcolumn">
                <?php if($msg)print
"<script>alert('Please fill blank fields')</script>";
                if($reslt){     ?>
                        <h3>Result</h3>
                        <table>
                                <tr>
```

```
                        <td>Angle
between VC and TC</td><td>:</td><td class="rj"><?=
number_format($angle_vctc_deg,1) ?></td>
                </tr>
                <tr>
                        <td>A (Area of
VC and TC)</td><td>:</td><td class="rj"><?=
number_format($area_deg,2) ?></td>
                </tr>
                <tr>
                        <td>Target
Relative course to CPA</td><td>:</td><td
class="rj"><?=
number_format($trc_to_cpa_deg,2) ?></td>
                </tr>
                <tr>
                        <td>Target
Relative Speed to CPA (kts)</td><td>:</td><td
class="rj"><?= number_format($trs_to_cpa,2) ?></td>
                </tr>
                <tr>
                        <td>Target
absolute course</td><td>:</td><td class="rj"><?=
number_format($target_abs_course,2) ?></td>
                </tr>
                <tr>
                        <td>Angle
between TB & T course</td><td>:</td><td
```

```
class="rj"><?=
number_format($angle_tbtc_deg,2) ?></td>
                                        </tr>
                                        <tr>
                                                <td><b>Distance
to CPA</b></td><td>:</td><td class="rj"><b><?=
number_format($dist_to_cpa,8) ?></b></td>
                                        </tr>
                                        <tr>
                                                <td>Bearing of
Target at CPA</td><td>:</td><td class="rj"><?=
number_format($bearing_at_cpa) ?></td>
                                        </tr>
                                        <tr>
                                                <td>Relative
distance to CPA</td><td>:</td><td class="rj"><?=
number_format($rel_dist_cpa,6) ?></td>
                                        </tr>
                                        <tr>
                                                <td><b>Time to
CPA (hours)</b></td><td>:</td><td
class="rj"><b><?=
number_format($time_to_cpa,4) ?></b></td>
                                        </tr>
                                </table>
                                <p>
                                         <br>
                                        <b>Do you want to save
```

```
this calculation data?</b>
                    <input type="radio"
id="radioff">no
                    <input type="radio"
id="radion">yes
               </p>
               <div id="savecalc">
               <table>
                    <tr>
                         <td>Vessel
Reference Name</td>
                         <td><input
type="text" value="" id="v1" class="lj"></td>
                    </tr>
                    <tr>
                         <td>Google Earth
Coordinate</td>
                         <td><input
type="text" value="" id="ge" style="width: 300px"
class="lj"></td>
                    </tr>
                    <tr>
                         <td>Vessel Target
Name</td>
                         <td><input
type="text" value="" id="v2" class="lj"></td>
                    </tr>
                    <tr>
```

```
                                        <td>Google Earth
Coordinate</td>
                                        <td><input
type="text" value="" id="ge1" style="width: 300px"
class="lj"></td>
                                </tr>
                                <tr>
                                        <td>Scenario</td>
                                        <td><input
type="text" value="" id="scenario" class="lj"></td>
                                </tr>
                                <tr>

        <td>Encounter</td>
                                        <td><input
type="text" value="CROSSING" id="encounter"
class="lj"></td>
                                </tr>
                                <tr>
                                        <td></td>
                                        <td><button
id="savedata">Save</button></td>
                                </tr>
                        </table>
                        </div>
                        <script src="jquery.js"></script>
                        <script src="jquery-
ui.js"></script>
```

```
<link rel="stylesheet"
href="jquery-ui.css"/>
<script>
var dcpa
=<?=$dist_to_cpa?>;
var tcpa =
<?=$time_to_cpa?>;

$("document").ready(function(){

$("#savecalc").hide();

$("#radioff").prop('checked',true);
});

$("#radion").click(function(){

$("#savecalc").show();

$("#radioff").prop('checked',false);
});

$("#radioff").click(function(){

$("#savecalc").hide();

$("#radion").prop('checked',false);
});
```

```
$("#savedata").click(function(){
                                        var val_s1 =
$("#tspeed").val();
                                        var val_s2 =
$("#vspeed").val();
                                        var val_r1 =
$("#tcourse").val();
                                        var val_r2 =
$("#vcourse").val();
                                        var v1 =
$("#v1").val();
                                        var v2 =
$("#v2").val();
                                        var sc =
$("#scenario").val();
                                        var enc =
$("#encounter").val();
                                        var gps =
$("#ge").val();
                                        var gpst =
$("#ge1").val();
                                        if(v1=='' || v2=='' ||
sc=='' || enc=='' || gps=='' || gpst==''){

        alert('please completing needed data');
                                        }else{
                                                $.ajax({
```

```
            url:'responder.php',

            type:'POST',

            data:{opt:'save',s1:val_s1,s2:val_s2,r1:val_r1,r2:
val_r2,vsl1:v1,vsl2:v2,scn:sc,enco:enc,coord:"'"+gps+"'
",coord2:"'"+gpst+"'",ddcpa:dcpa,dtcpa:tcpa},

            success:function(data){

            alert(data);
                                                    }
                                                });

                                            }
                                        });

            $("#scenario").autocomplete({
                                            minLength: 1,
                                            delay: 0,
                                            source:
function( request, response ) {
                                                $.ajax({

            url:'responder.php',

            dataType: "json",
```

```
type:
"POST",
data:
{key:request.term,opt:'scenario'},
success:
function( data ) {
response(data);
}
})
}
});
$("#v1").autocomplete({
minLength: 1,
delay: 0,
source:
function( request, response ) {
$.ajax({

url:'responder.php',

dataType: "json",
type:
"POST",
data:
{key:request.term,opt:'vessel'},
success:
function( data ) {
response(data);
```

```
}
})
}
});
$("#v2").autocomplete({
minLength: 1,
delay: 0,
source:
function( request, response ) {
$.ajax({

url:'responder.php',

dataType: "json",
type:
"POST",
data:
{key:request.term,opt:'vessel'},
success:
function( data ) {
response(data);
}
})
}
});
</script>
<?php } ?>
</div>
```

```
        <div class="clr"></div>
    </body>
</html>
```

APPENDIX 5

This appendix contains the codes of AIS Dropdown CPA Calculator based on the model calculation for real-time data in Surabaya West Access Channel

```
<?php
/* function class */
class CPA {
	private $conn;

	function __construct() {
		/* buat koneksi database ketika class dipanggil
		 * ganti user dan password jika dipasang di server lain
		 */
		$host = 'localhost';
		$user = 'root';
		$password = '';
		$database = 'cpa';
		$this->conn = mysqli_connect($host, $user, $password, $database);
	}

	function insertData($array){
		$rec = $this->chekData($array);
		if($rec==0){
			$fields='(';
			$values='(';
			foreach ($array as $key => $value) {
				$fields.= $key.",";
```

```
                                        $values.=
"'$value',";
                              }
                              $fields = substr($fields, 0,-
1);
                              $values = substr($values,
0,-1);
                              $query = "INSERT INTO
cpadata".$fields.") VALUE".$values.")";
                              $this->conn-
>query($query);
                              print "Data Saved";
                    }else{
                              print "Data already in
database";
                    }
          }

          function chekData($array){
                    $query = "select count(id) from
cpadata where ";
                   foreach ($array as $key => $value)
{
                              $query.=
$key."='".$value."' and ";
                    }
                    $query = substr($query, 0,-4);
```

```
		$exec		=		$this->conn->query($query);
		$rec = 0;
		while($result		=		$exec->fetch_array()){
			$rec = $result[0];
		}
		return $rec;
	}

	function readData($query){
		$resultData = array();
		$exec		=		$this->conn->query($query);
		while($result		=		$exec->fetch_array()){
			$resultData[]=$result;
		}
		return $resultData;
	}
}

if(isset($_POST['opt'])){
	$opt = $_POST['opt'];
	$cpa = new CPA;
	switch ($opt) {
		case 'save':
```

```
$v1 = strtoupper($_POST['vsl1']);
$v2 = strtoupper($_POST['vsl2']);
$s1 = $_POST['s1'];
$s2 = $_POST['s2'];
$r1 = $_POST['r1'];
$r2 = $_POST['r2'];
$scn = strtoupper($_POST['scn']);
$enc = strtoupper($_POST['enco']);
$gps = $_POST['coord'];
$gps2 = $_POST['coord2'];
$dcpa = $_POST['ddcpa'];
$tcpa = $_POST['dtcpa'];

$gps = str_replace('@','', $gps);
$gps = str_replace('"','', $gps);
$exp_gps = explode(",", $gps);
$lat1 = $exp_gps[0];
$long1 = $exp_gps[1];

$gps2 = str_replace('@','', $gps2);
```

```
$gps2 = str_replace("'",'',
$gps2);
$exp_gps2 = explode(",",
$gps2);
$lat2 = $exp_gps2[0];
$long2 = $exp_gps2[1];
$insert_data =
array('scenario'=>$scn,'v1'=>$v1,'v2'=>$v2,'s1'=
>$s1,'s2'=>$s2,'r1'=>$r1,'r2'=>$r2,'tcpa'=>$tcpa,'
dcpa'=>$dcpa,'encounter'=>$enc,'latv1'=>$lat1,'l
atv2'=>$lat2,'longv1'=>$long1,'longv2'=>$long2);
$cpa-
>insertData($insert_data);
break;
case 'scenario':
$key = $_POST['key'];
$query = "select distinct
scenario from cpadata where scenario like
'%$key%'";
$data = $cpa-
>readData($query);
$scenario = array();
foreach ($data as $key =>
$value) {
$scenario[] =
array('label'=>$value['scenario']);
}
```

```
                print
json_encode($scenario);
                break;
            case 'vessel':
                $key = $_POST['key'];
                $query = "select distinct
v1 as vessel from cpadata where v1 like
'%$key%'";
                $data = $cpa-
>readData($query);
                $query = "select distinct
v2 as vessel from cpadata where v2 like
'%$key%'";
                $v2 = $cpa-
>readData($query);
                $vessel = array();
                foreach ($data as $key =>
$value) {

        array_push($vessel,$value['vessel']);
                }
                foreach ($v2 as $key =>
$value) {

        array_push($vessel,$value['vessel']);
                }
                array_unique($vessel);
                $vessel_data = array();
```

```
                    foreach ($vessel as $key =>
$value) {
                        $vessel_data[]      =
array('label'=>$value);
                    }
                    print
json_encode($vessel_data);
                    break;
        }

        $cpa = null;
}
?>
```

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From this final project, we can take several conclusions as follows,

1. The collision risk in Surabaya West Access Channel, especially in buoy 8 to 13 can be considered in terms of level—whereas the level of risk ranged from 0.1 to 0.8 from Low Risk into High Risk. Each of interaction and cluster has its own level depends on its distance and speed of the ships within one area that is affected by its TCPA and DCPA value for each encounter.
2. The approach method using traffic-conflict model can be used as a breakthrough of collision risk analysis by using only the dynamic data of AIS such as speed, course, distance and longitude and latitude to provide a risk level through calculation provided in the research.
3. AIS optimization to enhance the maritime traffic in Surabaya West Access Channel can be achieved through making a PHP script of calculation for CPA that is later be applied in online website that provides the calculation of traffic-conflict model using real time data

5.2 Recommendation

From this final project, there are several recommendations that can be seen as follows,

1. The approach method using traffic-conflict model in this final project only relies on 2D vector calculation

which not including the environmental point of view such as wind, waves and weathers. It is expected for the future research to include those factors and not only giving the 2D vector but can enhance it into 3D vector calculation.

2. The PHP script developed for this model is still in its early stages, therefore a further development for the website is needed

REFERENCES

Chen, Shu. "Collision Avoidance Based on Risk Prediction and Control of Ship." *Master Thesis, Department of Computer Engineering, Graduate School, Jeju National University*, July, 2013.

Chin, H.C., and S.T. Quek. "Measurement of Traffic Conflicts." *Safety Science*, 1997: 169-185.

Darbra, R.M., and J. Casal. "Historical Analysis of Accidents in Seaports." *Safety Science*, 2004: 85-98.

Debnath, A.K. "Traffic-Conflict-Based Modeling of Collision Risk in Port Waters." *PhD Dissertation of National University of Singapore*, 2009.

Debnath, A.K., and H.C. Chin. "Navigational Traffic Conflict Technique: A Proactive Approach to Quantitative Measurement of Collision Risks in Port Waters." *Journal of Navigation*, 2010: 137-152.

Harati-Mokhtari, A., A. Wall, P. Brooks, and J. Wang. "Automatic Identification System (AIS): data reliability and human error implications." *Journal of Navigation*, 2007.

Harding, S.J. " The 'ALVA CAPE'and the Automatic Identification System: The Use of VHF in Collision Avoidance at Sea." *Journal of Navigation*, 2002.

Hauer, E., and P. Garder. "Research into the Validity of the Traffic Conflicts Technique." *Accident Analysis & Prevention*, 1986.

Hayward, J.C. "Near-Miss Determination through Use of a Scale of Danger." *Highway Research Record*, 1972.

IMO. "Casualty Statistics and Investigations." *FSI/Cire 6, 29, International Maritime Organization*, 2005.

Min Mou, Jun, Cees van der Tak, and Han Ligteringen. "Study on Collision Avoidance in Busy Waterways by Using AIS data." *Ocean Engineering*, 2010.

Perkins, S.R., and J.I. Harris. "Traffic Conflict Characteristics: Accident Potential at Intersections." *General Motor Corporation, Warren, MI*, 1967.

Pitana, Trika, A. A. Bagus Dinariyana, Ketut Buda Artana, and M. Badrus Zaman. "Development of Hazard Navigation Map by using AIS Data." *Journal of Maritime Research*, 2011.

Suman, S., V. Nagarajan, O.P. Sha, S. Khanfir, E. Kobayashi, and A.M. bin Abdul Malik. "Ship collision risk assessment using AIS data." *International Journal of Innovative Research and Development|| ISSN 2278–0211*, 2012.

Williams, M.J. "Validity of the Traffic-Conflicts Technique." *Accident Analysis & Prevention*, 1981: 133-145.

Yip, T.L. "Port Traffic Risk - A Study of Accidents in Hong Kong Waters." *Transportation Research Part E: Logistics and Transportation Review*, 2008.

BIOGRAPHY

Putu Sadhvi Sita was born in Surabaya on March 7th, 1994, the first of three siblings in the family. She has been attending formal education on TK Cahaya Nur Kudus, SD Cahaya Nur Kudus, SMP Negeri 1 Kudus, SMA Negeri 3 Semarang. After graduated from Olympiad Class on SMA Negeri 3 Semarang, she started her undergraduate study in Department of Marine Engineering, Institut Teknologi Sepuluh Nopember. While studying in Marine Engineering, Putu Sadhvi Sita was also an active member of HIMASISKAL ITS, ITS Choir and TPKH-ITS. She was also a member of Reliability, Availability, Maintainability and Safety (RAMS) Laboratory since 2015 and began to write her undergraduate thesis under the field of study provided in the laboratory. The writer finished her undergraduate study on Marine Engineering Department for 8 semesters.