BACHELOR THESIS – ME 141502

ANALYSIS EVACUATION ROUTE FOR KM ZAHRO EXPRESS ON FIRE CONDITION USING AGENT – BASED MODELING AND FIRE DYNAMICS SIMULATION

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DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
FACULTY OF MARINE TECHNOLOGY
INSTITUTE OF TECHNOLOGY SEPULUH NOPEMBER
SURABAYA
2017

SKRIPSI – ME 141502

ANALISA RUTE EVAKUASI UNTUK KAPAL KM ZAHRO EXPRESS PADA KONDISI KEBAKARAN MENGGUNAKAN *AGENT – BASED MODELING* DAN *FIRE DYNAMICS SIMULATION*

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APPROVAL FORM

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Submitted to Fulfill One of The Requirement to Obtain a Bachelor Engineering Degree on Reliability, Availability and Management (RAMS) Laboratory

S-1 Double Degree Program of Marine Engineering Departement Faculty of Marine Technology Institute of Technology Sepuluh Nopember

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SURABAYA
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DECLARATION OF HONOR

I, who signed below hereby confirm that:

This final project report has written without any plagiarism act, and confirm consciously that all the data, concepts, design, references, and material in this report own by Reliability, Availability and Management (RAMS) in Department of Marine Engineering ITS which are the product of research study and reserve the right to use for further research study and its development.

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Bachelor Thesis Title:	Analysis Evacuation Route for KM Zahro Express on Fire Condition using Agent-Based Modeling and Fire Dynamics Simulator
Department:	Double Degree Program in Marine

Engineering

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Surabaya, 17 July 2017

Dioco Carlos Kristian Perdana

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ABSTRACT

Sefety is the thing that needs to be preferred by users of transport, passengers should also understand about safety procedures and evacuation procedures in the means of transport. There have been many accidents that happen in the world of transport, particularly in the shipping world, from 2010 to 2016 is no more than 50 accidents of ships in accordance with the cause recorded by KNKT (Komisi Nasional Keselamatan Transportasi).

On this research was discussed the evacuation time on the ship KM Zahro express that occurred earlier in the year 2017 in the Kepulauan Seribu, DKI Jakerta. Fire accident caused almost all the passengers died was caused due to the burning power source in the engine room.The issue will be discussed about the time of the evacuation and the danger of fires that interfere the process of evacuation.

The methods used are Agent Based Modeling and Simulation (ABMS) and Fire Dynamics Simulation (FDS) for modeling fire simulation. As well as using basic rules which refer to the International Maritime Organization (IMO).

Result of Evacuation simulation calculation on normal conditions that match at actual condition is 29,783 minutes (respon in not taken in this simulation), calculation results obtained from simulation of evacuation (Traveling Time) and at the count expanded feet according with the formula.

Keywords : Safety, Evacuation, Fire Accident, ABMS, FDS

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ANALISA RUTE EVAKUASI DI KM ZAHRO EXPRESS PADA KONDISI KEBAKARAN MENGGUNAKAN *AGENT-BASED MODELING* DAN *FIRE DYNAMICS SIMULATOR*

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ABSTRAK

Keselamatan adalah hal utama yang perlu diperhatikan oleh pengguna transportasi, namun penumpang juga harus paham mengenai prosedur keselamatan dan prosedur evakuasi pada alat transportasi tersebut. Sudah banyak kecelakaan yang terjadi di dunia transportasi, khususnya di dunia pelayaran, dari tahun 2010 hingga 2016 sudah tercatat ada lebih dari 50 kecelakaan kapal sesuai dengan penyebabnya yang tercatat oleh KNKT.

Pada penelitian ini membahas mengenai waktu evakuasi pada kapal KM Zahro express yang terjadi pada awal tahun 2017 di kepulauan seribu. DKI Jakarta. Kebakaran kapal yang mengakibatkan hampir semua penumpang meninggal dunia itu diakibatkan karena terbakarnya sumber listrik pada engine room. Permasalahan yang akan dibahas adalah mengenai waktu evakuasi dan bahaya dari kebakaran yang menganggu proses evakuasi.

Metode yang digunakan adalah Agent Based Modeling and Simulation (ABMS) dan Fire Dynamics Simulation (FDS) untuk permodelan simulasi kebakaran. Serta mengunakan aturan dasar yang mengacu kepada International Maritime Organization (IMO).

Perhitungan hasil simulasi evakuasi pada kondisi normal atau siang hari yang sesuai pada kejadian sebenarnya adalah 29.783 menit (tidak mengambil data respon penumpang), perhitungan didapatkan dari hasil simulasi evakuasi (Traveling Time) dan di hitung susuai dengan rumus yang berlaku.

Kata Kunci : Keselamatan, Evakuasi, Kebakaran kapal, ABMS, FDS

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PREFACE

First of all, I would like to thank to Jesus Christ for the grace and bless so the writer could finish the Final Project successfully. The title of Final Project is:

"Analysis Evacuation Route for KM Zahro Express on Fire Condition using Agent-Based Modeling and Fire Dynamics Simulator"

As the requirement to obtain a bachelor engineering degree on Department of Marine Engineering Faculty of Marine Technology Institute Technology Sepuluh Nopember.

Therefore, I would like to thank those who have helped in completing my final project, among others:

1. Jesus Christ who give all of His blessing and a chance to complete this final project.

2. For my parents Minggri Widiati and Kukuh Handani also my Sister Jesica Ceren Kristiane Palevi for supporting me to complete the study on Double Degree Marine Engineering.

3. Mr. Dr. Eng. Muhammad Badrus Zaman, S.T., M.T. as the Head of Marine Engineering Department

4. Mr. Prof. Semin, S.T., M.T., Ph.D as the Secretary of Marine Engineering Department

5. Mr. Ir. Dwi Priyanta, M.SE as Secretary of Double Degree Program in Marine Engineering Department who has giving every necessary information to help finish the bachelor thesis.

6. Mr. Sutopo Purwono Fitri, S.T., M.Eng., Ph.D as Author's Lecturer Advisor since first semester until eighth semester

7. Mr. Dr. Eng. Muhammad Badrus Zaman, S.T., M.T. and Mr. Dr. Eng. Trika Pitana, S.T., M.Sc. as my supervisior who giving me all of the advice on academic and non-academic matters, and the motivation to complete this thesis.

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CHAPTER 1
INTRODUCTION

1.1 Background

Evacuation is a very important matter in a ship accident. Due to ship accident, evacuation is considered important to protect the crew and passengers in a ship. Things need to be done prior to prevent any casualties in a fire accident, is to make efficient evacuation route. Considered efficient when the evacuation processed in short amount of time, as to avoid any casualties in the accident. Data showed that 35% accident in a ship caused by fire (as show in figure 1.1). Causes of fire accident should be notice, like material used, workspace temperature and ventilation in engine room. It is important to note which area that will cause worst impact when fire occur, so while planning the evacuation route it can avoid those area. Because, it can harm the passengers while processing evacuation. [1] [2]

The important thing in the evacuation is the simple evacuation route and the route signs, so the passenger can understand easily the evacuation routes. Otherwise, there are other factors that must be considered, such as passengers characteristics, age, gender, and weight. It has an impact on the passenger walking speed that matter on the evacuation process. And other things to know is awareness time, the time when passengers can recognize the danger. Based on IMO calculation, length of corridors, doors and stairs own its safety factors related to crews speed of walking. Relation between the characteristics of the crew and the condition in a ship will affect in a pattern of evacuation.

The characteristics of the passenger, ship in fire conditions, this can affect the crew in the process of evacuation. Agent-Based Modeling and Simulation (ABMS) can provide models to the level of each individual behavior, as well as the adaptation process that allows any changes the nature of each individual can assist in modeling system, so the model will be similar to reality. [3]

Smokes are made from fire which can affect the human sight and walking speed, Fire Dynamics Simulation (FDS) can simulate the fire model and can spread the smoke while ship in fire condition.
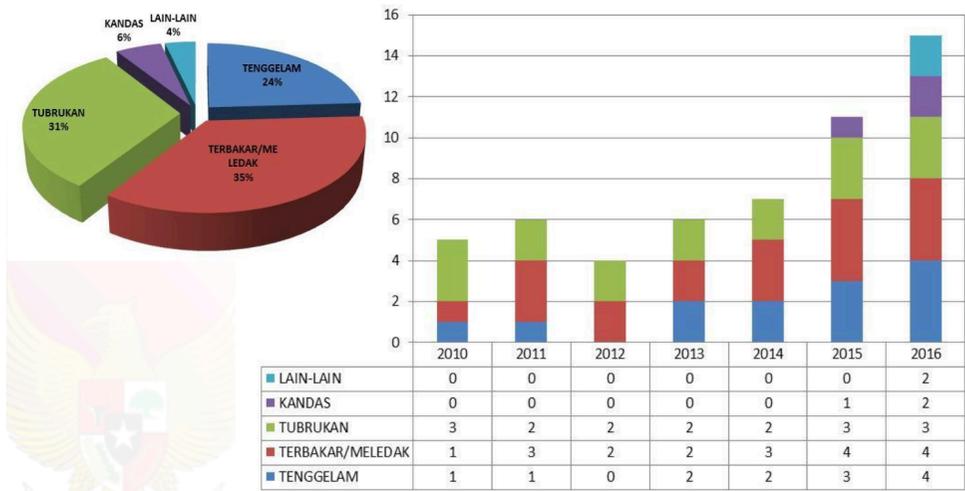
Figure 1.1 Presentation of marine accidents by category (2010 -2016) [1] [4]1

1.2 Statement Problems

Based on the description above, problems of this thesis are:

1. How to determine the most efficient evacuation route?
2. How can fire affect the passenger while evacuation?

1.3 Research Objectives

The objectives of this research are:

1. Predict the effective time to evacuate passengers.
2. Determine how fire can affect the evacuation.

1.4 Research Benefits

The Benefits of this research are:

1. To help ship's designer to design safety plan and efficient evacuation route.
2. To optimize evacuations route to avoid the impact of fire.

1.5 Research Limitations

1. The limitations of this research is only to the cause and evacuation KM Zahro Express Accident.

2. From passenger data, like weight of each shoulder, height and age of passenger are not well known because manifest is not complete.

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CHAPTER 2
LITERATURE STUDY

2.1 The Safety Of Sea Transport

Safety is the most important factor for the passengers. Safety take precedence because of concerns the range of loss, if the safety factor is not met then it can result in a loss of time, material or may even cause fatalities. There is a source of accidents, include:

- Software (regulation, rule, procedure, etc.) that have not been adequately
- Hardware (technology products means & infrastructures) which are already not worth
- Liveware (license, training, and culture) that are less supportive of
- Organoware (institutional, corporate organizations, crew guidance) are not conducive.

2.2 Evacuation Procedure

Evacuation procedure is a thing that should be done when encountering danger and do the process of evacuation from the scene of danger to a place of safe refuge. The application of the proper evacuation procedures are also indispensable in order to anticipate the occurrence of the fire and turned upside down for the sake of the safety of all crew members who were in the boat. Based on International Maritime Organization (IMO).

Evacuation consists of two parts, the first directing passengers to the point of evacuation and then if the situation has allowed, lifeboats and life raft released a collapse to abandon ship. The first part is mainly taken care of by providing adequate lines on evacuation routes considering the number of passengers or crew.

When a larger vessel, the stairs, the door and the assembly point should also have a larger area is proportional to the number of passengers. Therefore the evacuation process from larger ships must be same be safe with a smaller ship. However, the main risk can come from a number of people more, with guide people to the right location, and make them to comply with the instructions in panic situations can be a challenge for many reasons.

2.3 IMO Interm Guidelines

Based on *IMO Interm Guidelines* to analyze passenger ship evacuation, we need to assumed some early calculation, so evacuation time analyzed based on real condition, and hopefully able to come close to real event. There are some assumptions of IMO MSC/Circ.1238, [5] such as:

a. Entire passenger and ship crew will start to evacuate in the same time, where on to another will not crash. Evacuation will start when the alarm sounded, and there is *Awareness Time* (A).

b. The entire passenger and ship crew will evacuate through main rescue tunnel. According to SOLAS regulation II-2/13, about establishment of evacuation route so passengers can quickly and safely heading to assembly point, the ship has to follow the terms :

    •   All passengers and crew will begin evacuation at the same time, and will not hinder each other
    •   Passengers and crew will evacuate via the primary escape route
    •   Walking speed depends on the density of persons and the type of escape facility, assuming that the flow is only in the direction of the escape route, and that there is no overtaking
    •   No passengers or crew have disabilities or medical conditions that will severely hamper their ability to keep up with the flow
    •   Counter-flow is accounted for by a counter-flow factor
    •   Passenger load is assumed to be 100% (full load)
    •   Full availability of escape arrangements is considered
    •   People can move unhindered
    •   Effects of the ship's motions, passengers' age and disability, restricted visibility due to smoke, etc., are accounted for in a safety factor. [5]

c. Based on IMO, there are some common term used in emergency, such as :

    •   Evacuation, condition should be taken when the alarm to leave the ship sounded.
    •   *Mustering* (gathering), planning to collect passenger in assembly point, commonly the assembly point near the place where *lifeboat* or the rescue facilities is placed.
    •   *Abandonment*, where passenger leave the ship by using others rescue facilities, such as *survival craft, life raft*. [5]

d. Common Terms used at evacuation according to IMO:

- Passenger load, maximum passenger number in ship.
- Crush condition, maximum density allowed in escape route, which is 3,5 p/m^2
- Awareness time (A) is time needed by passenger to take action and react in emergency.
- Travel Time (T) means time used by entire human to go out or travel from exact place to the safer place or assembly point.
- Embarcation time (E) and launching time (L), time needed to transfer all passenger to out of the ship.
- Awareness time (A) assumed 10 minutes in night case, and 5 minutes in day case. [5]

2.4 Performance Standard

The following performance standards, should be complied with:
Calculated evacuation time:

$$1.25\ R + T + 2/3\ (E + L) < n\ (1) ....\ (2.1)$$

$$E + L < 30'\ (2) ....\ (2.2)$$
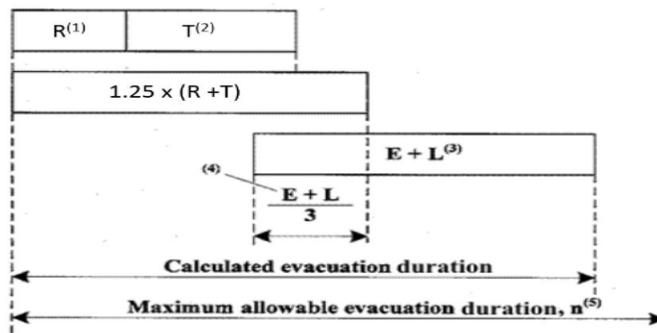
Figure 2.1 Performance Interim Guidelines [6]

(1) 10' in case1 and case 3,5' in case 2 and case 4
(2) calculated as in appendix 1 to these Guidelines
(3) maximum 30' in compliance with SOLAS regulation III/21.1.4
(4) overlap time = 1/3 (E+L)
(5) values of n (min)

Performance standard (1) is derived from resolution 4 of the 1999 SOLAS Conference. Performance standard (2) complies with SOLAS regulation III/21.1.4. Performance standard (3) Revised on 6 June 2016. [6]

Calculation of E + L should be calculated based on the results of full scale trials on similar ships and evacuation systems or data provided by the manufacturers, however, in this case, the method of calculation should be documented including the value of particular safety factor used. In case neither of the two methods can be used, E + L is assumed to be 30 min. [6]

Beside calculate evacuation time, we need take notice about safety route such as *means escape*. According to *SOLAS Chapter II, Part D regulation 13, means escape* is when entire person in ship can safely and quickly escape to embarcation deck *lifeboat* and *life raft*, here are the terms:
- There has to be a safe escape route.
- The escape route should be maintained to be safe and hurtle free.
- There should be extra help, which is as important, access, clear signing, and fulfilling design in emergency.

Parameters need to noticed in calculation:

a. Effective Width (We)
   In order to accommodate lateral body sway and assure balance, persons moving through the escape routes maintain a clearance from walls and/or other fixed items (e.g. handrails, fixed seats, etc.). The effective width of any portion of an escape route is the clear width of that portion reduced by the sum of the clearances. [7]

b. Clear width
   Clear width is:

   - Measured off the handrail(s) for corridors and stairways
   - The actual passage width of a door in its fully open position
   - The space between the fixed seats for aisles in public spaces
   - The space between the most intruding portions of the seats (when unoccupied) in a row of seats in public spaces.

Here are explanations about variable used in calculation [5] [7]:

1. Density of Person (D)
   Density of persons in an escape route is the number of persons (p) divided by the available escape route area pertinent to the space where the persons are originally located expressed in (p/m^2)

2. Speed of persons (S)
   The speed (m/s) of persons along the escape route depends on the density of persons and on the type of escape facility. Values for speed of persons are given in table 1.

3. Specific flow of persons (F_s)
   Specific flow (persons/ms) is the number of evacuating persons past a point in the exit route per unit time per unit of effective width W_e of the route involved. Values for F_e are given in table 1 for various values of density and route characteristics.

4. Calculated flow of persons (F_c)
   The calculated flow of persons (p/s) is the predicted number of persons passing a particular point in an escape route per unit time. It is obtained from:
$$F_c = F_s \times W_e \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.3)$$

5. Flow time (t_F)
   Flow time (s) is the total time needed for N persons to move past a point in the egress system, and is calculated as:
$$t_F = N / F_c \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.4)$$

6. t_{stair}= travel time(s) from the uppermost (or lowermost) deck to the closest embarkation station.

7. t_{deck}= travel time(s) to move from the farthest point of the escape route of a deck to the stairway.

8. Overall Time (t_I)
   The overall time to travel along an escape route to the assigned assembly station is:
$$t_I = t_F + t_{deck} + t_{stair} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.5)$$

9. Travel time (T)
$$T = (\gamma+\delta)\, t_I \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.6)$$
   where:
   γ = Safety factor = 2.0
   δ = Counter flow factor = 0

2.5 Agent-Based Modeling and Simulation (ABMS)

Agent-Based Modeling and Simulator (ABMS) is a modeling method that aims to model complex problems based on real cases. In this case the existing models can be used to plan and prepare an emergency if unwanted things happen. [3] [8]

- The ability to make the environment as the original state, such as chairs, walls, and other boundaries like the real world.
- The ability to simulate the position of fire when the building caught fire so it can make prevention.
- Ability to simulate several safety scenarios, such as a safety line, with no cost.

The purpose of the use Agent-Based Modeling and Simulator (ABMS) are:

- A modeling method suitable to model large systems and more sophisticated modeling for other cases.
- Can be implemented to software with better levels of development.
- Used to resolve the problem in a real state

The Agent-Based Modeling and Simulator (ABMS) is designed to model a place that has a seat, path, exit door, humans, and others. This allows to model a lot of humans and fire on one place (as shown in figure 2.2). The purpose of this system is to simulate the evacuation of such a large crowd on the building, auditorium, stadium or concert hall. The system must able to show how agents interact each other in an emergency state, the fire situation, as well as space management can interfere the evacuation process, as well as agents who must avoid the fire as much as possible. The fire also represented as an agent who created and produced smoke. This system is used to plan and prepare an emergency case and offers the advantage of the evacuation process in the field, to minimalize the victims.

- An ability to describe the environment with chairs, street, exit, and the position of the agent.
- The ability to create adjustable multiple deployment process with fire and smoke production rate.
- Very useful simulation modeling technique, and there are some applications that are created in the last few years, including applications that describe real business. At Agent-Based Modeling and Simulator, the system is modeled as a collection of objects that can make inferences each called an agent.

- The advantages of using Agent-Based Modeling and Simulator to model is flexible, describe the real conditions, and provide a way for the evacuation process to be implemented as quickly as possible without any of the victims. [3]
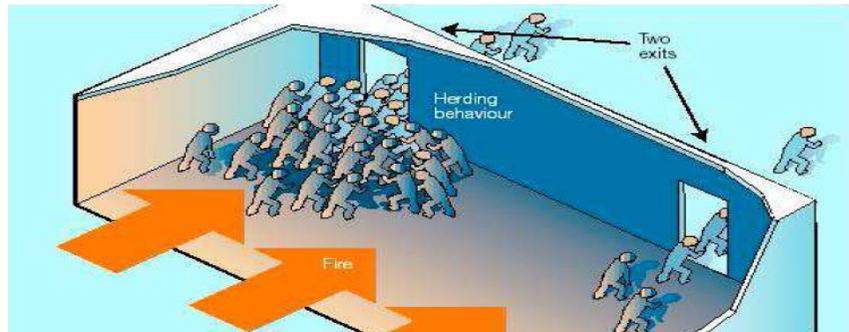
Figure 2.2 Self - Rescue Efforts

2.5.1 Pathfinder

Pathfinder is an emergency egress simulator that includes an integrated user interface and animated 3D results. Pathfinder allows you to evaluate evacuation models more quickly and produce more realistic graphics than with other simulators.

Pathfinder provides support for the import of AutoCAD format with DWG files. Pathfinder's floor extraction tool makes it possible to quickly use the imported geometry to define the occupant walking space for the evacuation model.

Pathfinder supports two simulation modes. In Steering mode, agents proceed independently to their goal, while avoiding other occupants and obstacles. Door flow rates are not specified but result from the interaction of occupants with each other and with boundaries. In SFPE mode, agents use behaviors that follow SFPE guidelines, with density-dependent walking speeds and flow limits to doors.

2.6 Pyrosim

PyroSim is a graphical user interface for the Fire Dynamics Simulator (FDS). FDS models can predict smoke, temperature, carbon monoxide, and other substances during fires. The results of these simulations have been used to ensure the safety of buildings before construction, evaluate safety options of existing buildings, reconstruct fires for post-accident investigation, and assist in firefighter training. [9] [10]

FDS is a powerful fire simulator, which was developed at the National Institute of Standards and Technology (NIST). FDS simulates fire scenarios using computational fluid dynamics (CFD) optimized for low-speed, thermally-driven flow. This approach is very flexible and can be applied to fires ranging from stove-tops to oil storage tanks. It can also model situations that do not include a fire, such as ventilation in buildings. FDS and the Smokeview visualization program are both closely integrated into PyroSim. [9] [10]
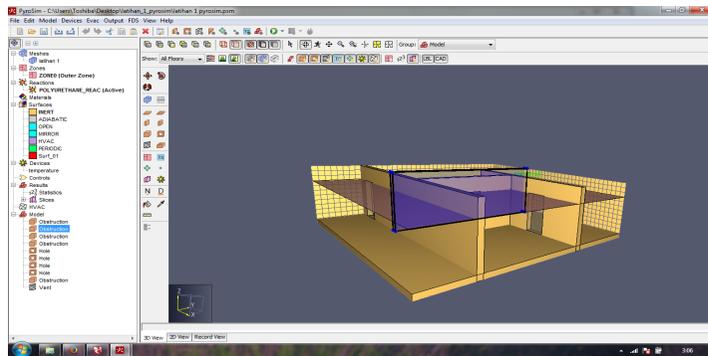
Figure 2.3 Pyrosim Work Page

2.6.1 Fire Dynamics Simulation (FDS)

FDS is a computer program that solves equations that describe the evolution of fire. It is a Fortran program that reads input parameters from a text file, computes a numerical solution to the governing equations, and writes user-specified output data to files. Smoke view is a companion program that reads FDS output files and produces animations on the computer screen. Smoke view has a simple menu-driven interface. FDS does not. However, there are various third-party programs that have been developed to generate the text file containing the input parameters needed by FDS. [11] [9]
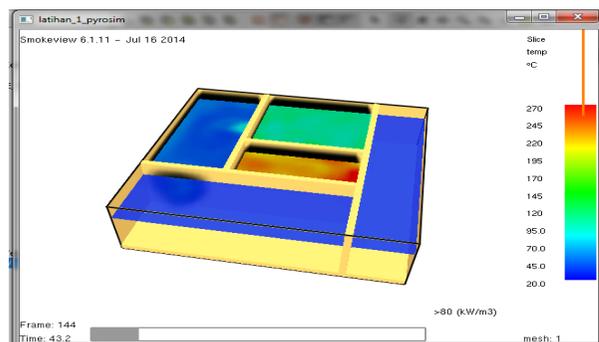
Figure 2.4 Fire Dynamics Simulator

FDS can be used in order to create a model some of the following phenomena:

1. The transformation of heat and combustion products at low speeds
2. Transfer of convection and radiation between gas and surface objects
3. Pyrolisys
4. Spread of flame and fire development
5. Detector and Sprinkler Activation
6. Fire Suppression with sprinkle

There are several major components used in resolving the problem of the FDS fire dynamics, namely:

2.6.1.1 Hydrodynamic Modeling

In this modeling FDS using the Navier-Stokes flow equations for low speed which involves the transformation of heat and smoke from fires that were affected by temperature changes. The calculations can use Direct Numerical Simulation (DNS) or Large Eddy Simulation (LES) that depends on the purpose of use and the resolution of the grid geometry..

2.6.1.2 Fire Modeling

The technique used is the fraction of the combustion mixture. This technique is based on the assumption that transport phenomena in conductive and radiative occurs on a large scale in addition to the physical processes that occur in small scale of time.

2.7 Ship Evacuation Plan

Evacuation procedure is an Ordinance to do when encountering a State of danger and the evacuation process from site of danger to a place of safe refuge. In addition to the completeness of the means of tackling the fire evacuation procedures, the application of the right is also indispensable in order to anticipate the occurrence of fire events for the sake of the safety of all crew members who were in the boat. [2]

According to the International Maritime Organization (IMO), the most important part of Ship Evacuation Plan (SEP) is a landing operation in the form of a computer printout or format in which the mission and duties of crew, stages of basic operation and operating criteria indicated. The tool's main liaison between the evacuation of the crew with the SEP is information

on evacuation routes and instructions out of the ship. Ship Evacuation Plan must be qualified as follows:

- It can be easily set with the definition of a clear evacuation group and travel schedules.
- Count with adequate levels of reability the time arrived to a gathering place for the crew.
- Calculating and minimizing the time between the evacuation of the ship and its crew was the last moment out of the ship.

Therefore, in conducting the evacuation procedures should meet the following basic principles:

1. Evacuation Procedure Policy
   In order to be effective, then there are a few things to note, namely the determination of the evacuation route, the election coordinator in charge of operations in each deck, rescue exercises by the entire crew when emergency conditions, install directions the way out and the information is pleased with the State of emergency at strategic locations in each deck.

2. Coordination of Displacements Movement in the process of Evacuation
   The evacuation team coordination is indispensable to regulate the movement of the ship's crew to the Division of safety and emergency gathering place. There are some things that must be considered in the coordination of the evacuation team, namely the priority use of evacuation, lifeboat, life craft and several other safety tools.

3. Communication in the process of Evacuation
   Perfection and accuracy of communication very or bills to make sure whether the crew is heading at this point in a safe gathering place.

4. Training Program
   Training Program should be given to evacuation team namely the crew on how to rescue the passengers, performing communication between teams, crowd control, Division of safety, tools and techniques in fire-fighting.

5. Inspection and Evaluation
   The inspection of the condition of the ship should be taken to ensure that concerns about the needs of the ship and its passengers. Inspection and evaluation should be done regularly in order to make any changes on the conditions of the safety tools can be detected

early.

2.8 Emergency Types

Vessel that does the activities can have problem caused by several factors such as climate, sailing route condition, vessel, human, and unpredictable things, which finally can caused damage to the vessel. [2] [12] [13]

The sailing disturbance sometimes can be handled, or need help from other parts, even can caused captain and crew to abandon the ship. Sailing disturbance based on situation can be classified according to the even itself, such as:

- Fire / Explosion
- Collision
- Shattered
- Pollution
- Leakage
- Man Over Board

Emergency can cause loss to every part, so we need to understand the condition, due to able to identify condition signs so it can be handled by captain and crew. [13]

1. Fire / Explosion
   Fire in ship can happen in some vulnerable location such as engine room, cargo room, ship equipment storage, electrical installation and captain and crew accommodation room.

2. Collision
   Emergency caused by ships crash, or with port or some material, will possible to damage in ship, casualties, oil spill in the sea, pollution and fire. Other situation is panic crew in the ship, which can slow down the evacuation.

3. Shattered
   Ship shattered initially signed by heavy rotation in propeller, sudden blackened smoke in funnel, ship body vibrate, speed change and suddenly stop. In shatter, the ship motionless, and ship position will very depend to water level, and inside situation very depend on the ship condition.

4. Pollution

   Ocean pollution can happen by trash disposal or oil spilling in bunkering, waste disposal of tank ship cargo, leak tank waste caused by crash.

5. Leakage

   Leakage in ship can caused by shatter, but can also cause by crushed or fire and ship outer plate damage by corrosion. The water come in quickly, while the ability to handle the leakage is limited, even the ship can be leaned, cause the situation hard to handle. This emergency become complicated, is the decision making is not fully supported by the entire crew.

6. Man Over Board

   People fell to the sea is one accident that become emergency in term of rescue. Help given is not easily done, because very depend to the climate, ability of the helper and availability of facilities.

Emergency organization should be made in order to operate emergency. This organization in each situation aim to:

- Alarm Emergency state.
- Find and calculate the situation and possible danger.
- Organize power and tools.

There are four planning point need to be followed:

1. Command Center

   Group that control activity under captain or senior crew coordination, equipped with intern and extern communication tools.

2. Emergency Party

   Group under the senior officer that can calculate situation, reporting to commando center, suggest action need to be done.

3. Support Party

   Supporting group under senior crew should be ready at every time to assist prior group, by the commando center command, and supply supporting assistance such as tools medical support, equipment, etc.

4. Engine Party

This group is under engineer or senior engineer support, supply assistance under commando center command. Main responsible is in engine room, and can help when needed.

2.9 Response to Emergency

Response on an emergency is based on an integrated pattern that is able to integrate activities or the emergency response effort in a fast, precise and controlled for the support of the relevant agencies and human resources as well as the facilities available [14]. By understanding this emergency response pattern can be obtained benefits:

1. Prevent (eliminating) the possibility of damage caused by the widespread occurrence of emergency it is.
2. Minimize the damage of the material and the environment.
3. Can master the circumstances (under control).

To cope with emergencies required some anticipate that consists of:

a. Logging

In the face of any emergency is always decided upon actions that will be done to cope with such events, then for that to be done on logging the extent to which such emergencies can harm humans, ships and the environment as well as how to deal with it that is adapted to the available facilities and infrastructure.

Logging steps:

- The level of damage to the ship.
- Impaired the safety of the ship (stability).
- Human Safety.
- Charge Condition.
- The influence of damage to the environment.
- Possibility of harm against another vessel or pier.

b. Equipment (Rescue Facilities)
The salvation of the soul can be defined as actions or efforts that must be made in order for the crew or passengers of the vessel can safely abandon ship in the event of a hazard on a ship.
In the face of emergencies required means of this support. Such means include:

- Number of Emergency exit that fits on a ship or to access out to the top deck.

- A temporary gathering place is completely safe from harm in case of an emergency.
- Fire alarm systems, fire hydrant and extinguisher.
- Health workers.
- Radio communication.
- Utilities (electricity and water)
- Life Guards.

Basic factors that influence the Self Rescue facilities are:

- Construction of the ship.
- The length of time to get out of the ship.
- The number and nature of activities of passengers.
- The place out.
- Control of the management of boat owners.

2.10 Safety Plan

A safety plan is a plan that is made to help ship owners avoid danger or potential danger to occured. The purpose of the annual safety is when there is an accident the parties can do an appropriate counter-measures.

With a safety equipment on the ship can prevent the occurrence of excess damage on the ship. For example, when there is a fire on the ship, with a safety plan when the fire broke out, the fire could quickly corrected with a sprinkle of an available hydrant or tubes. However, by the presence of a safety plan could not be ascertained that when fires break out on a steamer will soon be extinguished. It could just be the event of a fire, sprinkle the water squirt should work not working. It should be noted by ship owners. This incident could have happened because of an existing sensor is not working properly, or the placement of the security tools that do not fit in place, and could have been planning and safety installation not in accordance with existing procedures.

The primary purpose of the annual safety plan is:
1. To conduct studies and/or analysis on the impact of not fulfillment of standards and conditions of operation.
2. To get an alternative problem solving in terms of guaranteeing the level of operating
3. To estimate the effectiveness of each alternative solution of safety issues.
4. To make recommendations for changes or restrictions associated with the surgical procedure is not the fulfillment of standards and

conditions of operation.

In the Safety Plan, the standard documents are matters of safety operation include, identification of the hazard, risk assessment and mitigation measures and conditions that must be met to maintain the level of safety steps, steps that must be done are:

a. Objectives, targets and programs. The intent was for what he did on this ship.

b. Safety plan and commitment what will be achieved.

c. Risk Assessment, aims to find a balance of resource allocation to all risk and control as well as mitigation. In the management of risk is determined in advance the risk probability and severity /consequences of risk.

d. Environmental impact and Aspect Identification (IADL) was also created, if requested by the Owner/user of the service is the HSE Plan.

e. Mitigation is an action to eliminate the potential danger or reduces the probability or risk level. The frequency of the operations or activities are reduced, or taken action to reduce the level of the consequences of the risk is acceptable. While the last separation, is the action taken to isolate the effects of the risks or implement layered protection to reduce the level of risk. In mitigation, there are three defenses that may be applied:
   • Technology
   • Training
   • Regulations/procedures

f. When these changes are made by placing the defenses, it must be ensured that such changes are not carrying the hazard along, and defenses are working as they should. Monitoring and reviewing is done to see if the defenses can really run so that the probability can be reduced.

g. Conclusion on the safety plan, there is some step that should be designed. A good safety plan will help to ensure the following:
   • Assist fire with the layout and hazards associated with the ship
   • Increase the speed of evacuation of the crew during a fire
   • Indicate if there are any special requirements to assist crew in evacuating

On ship, Things in safety plan that must be understood and considered are:
- Fire control plan
- Fire control booklets
- Live saving appliance plan
- Emergency situations
- Fire control and safety plan
- Safety sign location plan
- Cabin escape plan

2.11 Decreased Walking Speed

Smoke is the result of burning wood can affect the process of walking passengers and disrupting the evacuation process, the following graph between walking speed and the influence of smoke when the evacuation process.
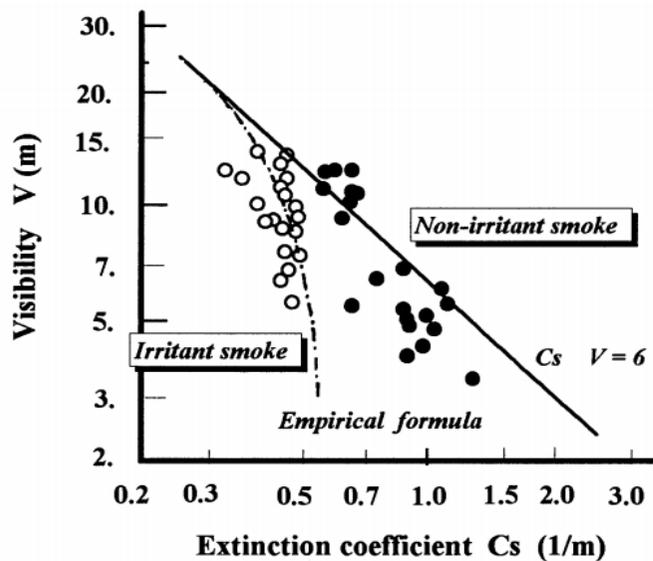

Figure 2.5 Graphic Extinction Coeficient against visibility
Source: Studies on Human Behavior and Tenability in Fire Smoke

The graph (Figure 2.5) shows that visibility can be converted to Cs to get value gradations from the walking speed. The influence of smoke against the process goes very disturbing because of the time the evacuation to be slow.

After determining the overall visibility of the value, then the next is determine the value of the Cs and then determine the value of gradations of walking speed. How to determine your walking speed and decrease in Cs namely the interpolation value graph with the specified visibility. After the value of the degradation speed obtained 0.8 then the walking speed at all agent converted to 0.8 speed running at normal conditions assuming the entire value of constant visibility

These two factors, namely the density of smoke and irritants affects the speed of walking. The selected type of smoke is irritant smoke that comes from the wood-burning results.
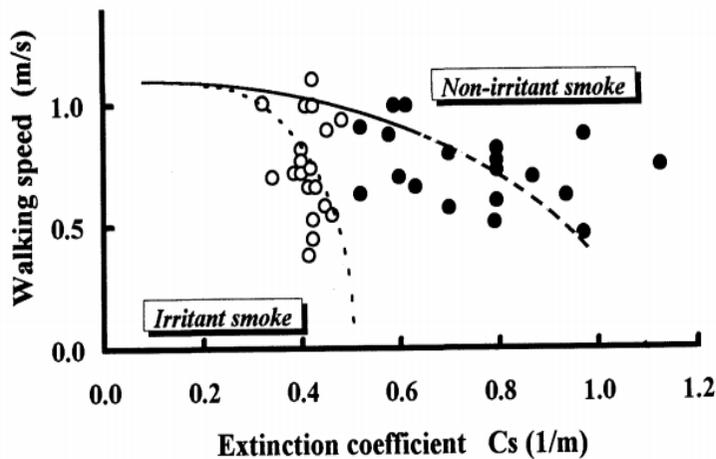
Figure 2.6 Graphics Conversion speed against the influence of smoke
Source: Studies on Human Behavior and Tenability in Fire Smoke

The graph (Figure 2.6) shows that walking speed is reduced gradually in line with the increasing density of the smoke. However, in the smoke which resulted in very significant speed decrease irritation in the area over a certain level of smoke density. In this study, a sharp decline is explained by the motion of the walking speed of agents, they could not keep their eyes open, then they walked a zigzag or step by step along the side walls.

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CHAPTER 3
METHODOLOGY

2.1 Methodology Flow
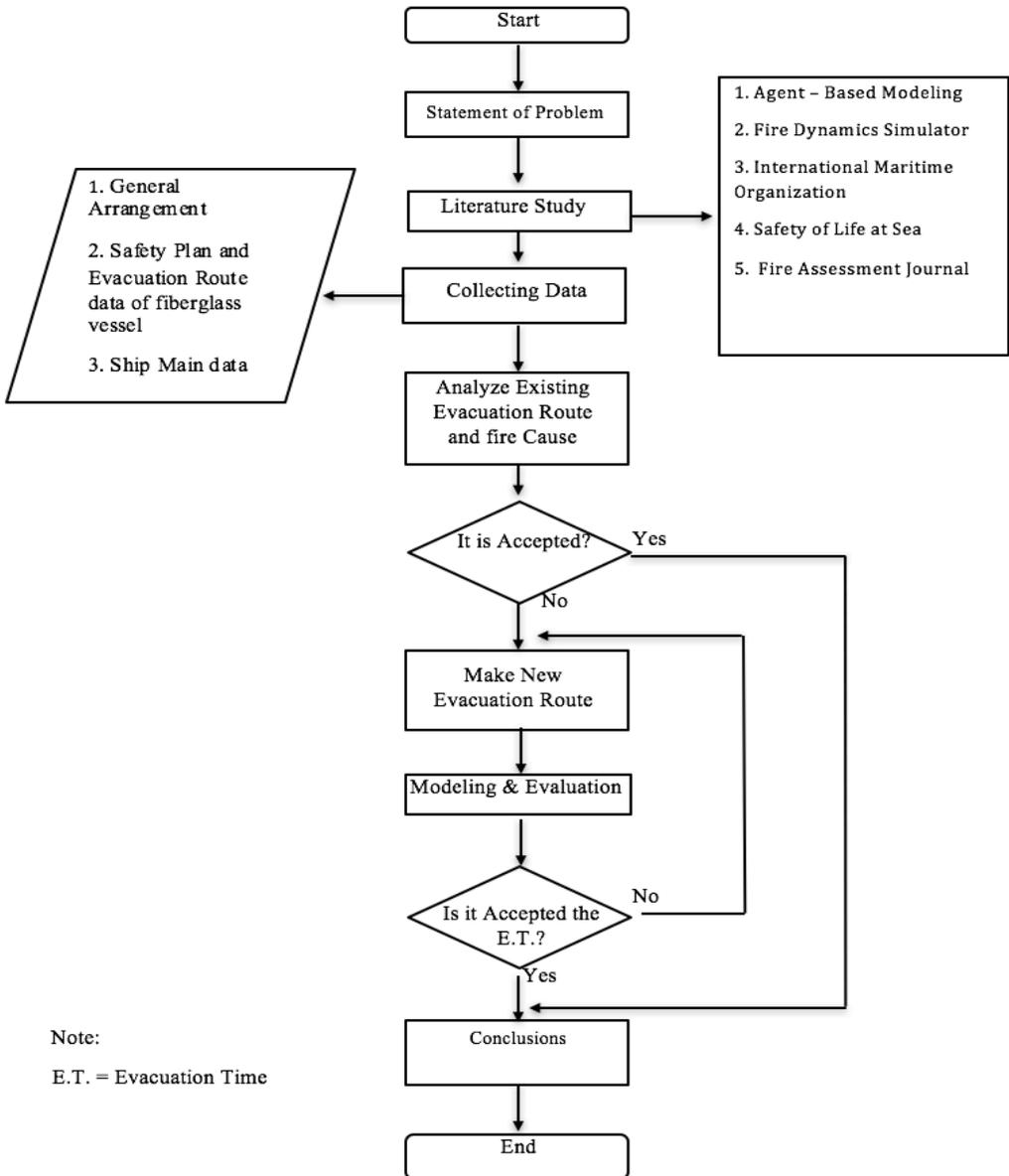
Figure 3.1 Methodology Flow Chart

3.2 Definition of Methodology Flow Chart

In the making of this final assignment, surely need structured process. That need to be planned, so in the future, the making will be more focused and easier. In this research methodology, will be explained each steps that will be done in the making of Final assignment about Analysis Evacuation Route using Agent - Based Modeling and Fire Dynamics Simulation. The stages are:

3.2.1 Statement of Problem

Problem formulation is the early stage of this thesis making. This is the most important stage, where the existing problem should be solve, so it deserve to be the material of this thesis. Finding the problem is done by digging the information about current problem. In this thesis, discussed problem that will be solved is Ship Fire Caused Analysis using Agent - Based Modeling.

3.2.2 Literature Review

After the problem is found, next stage is literature review. In this stage, the problem found and studied, so it can be clear what should be done in this thesis, in term to solve the problem. Literature review can be done by reading books, paper, journal or final assignment report related to the problem.

3.2.3 Fire Analysis

This analysis is done after literature study, that can be used to analyze the fire event. In this stage, the existing methods are used to analyze. In the end, we get the fire cause in the ship analysis.

3.2.4 Analyze Existing Evacuation Route

The next step is evaluating the evacuation routes. From all the data already exists, whether the evacuation route has according to the standard or not. If according to standard, next step proceed to the stage of conclusion and suggestion to be able to minimize the number of casualties in case of an accident the ship and if it does not according to standard it should be through step by step for making a new evacuation route and modeling for simulation of evacuation to produce results that comply with the standard.

3.2.5 Make a New Evacuation Route

The next step, make the evacuation routes is proceed to the next stage. Because the evacuation routes to be used for modeling and simulation of fire evacuation. Make Evacuation Routes can be done by redrawing the General Arrangement and make a Safety Plan.

3.2.6 Fire Modeling

Fire modeling is done after making the new evacuation route by using existing data, the modeling aim to find out the real state of affairs in the case of a fire. In addition to that, fire modeling is also useful to know the location of the dangerous in the case of a fire. Fire modeling and simulation can be processed by using agent-based modelling and fire Dynamics Simulator

3.2.7 Evaluation of Result

The next is evaluate new evacuation route and fire modeling is already according to the standard or not. If according to standard then can proceed to the next stage and if it has not according to the standards then it should be through the previous stage again to produce results that comply with the standard.

3.2.8 Conclusions and Suggestion

The final step is to make the conclusion that the whole process has been done before as well as provide answers to existing problems. The suggestions given based on the results of the analysis on which to base the next research, either directly related to this research or on the data and methodology that will be referenced.

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CHAPTER 4
DATA ANALYSIS AND SIMULATION

4.1 Data of Ship
4.1.1 Main Data of Ship

Figure 4.1 KM Zahro Express [18]

KM Zahro Express (Tanda Selar: GT 106 No.6960/Bc, Call Sign YBA4008) is a traditional Indonesian-flagged passenger vessels which used as passenger transport from Muara Angke to Kepulauan Seribu. KMP. Zahro Express was built with Wooden construction on Pulau Harapan, Kepulauan Seribu by 2013. The ship is operated and owned by the individual. The wooden ship construction using iron wood/ulin to keel, laban wood to frames and mentru wood for strips bar bilge.

The Principal Dimension data about KM Zahro Express:

Name of Ship   : KM Zahro Express

LoA (Length Over all)   : 26.20 M

Lpp (Length Between Perpendicular)   : 24.18 M

B (Breadth)   : 6.00 M

D (Depth)   : 1.64 M

GT (Gross Tonnage)   : 106 GT

NT (Net Tonnage)   : 32 NT

Material	: Wood (Mentru) - Fiber Glass
Flag	: Indonesia
Type	: Ro-Ro (Roll on-Roll Off) Ship
Year Build	: 2013

4.1.2 General Arrangement of Ship
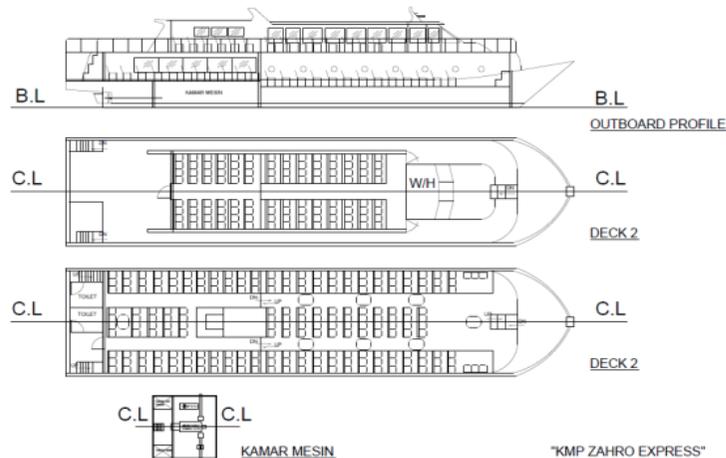
Figure 4.2 General Arrangement of KM Zahro Express [15]

KM Zahro Express is a wooden vessel with a single hull construction is built with traditional methods. Based on the safety certificate of passenger ship, the ship is approved to be able 285 of passengers and 5 persons crew.

KM Zahro Express has 2 decks which are divided into main deck and the upper deck. The decks are the spaces for passenger accommodation with seating facilities (as shown in figure 4.2). Passenger seating located on the main deck and the upper deck materials made of fiber reinforced plastic (FRP). On the topside there is also navigation control room or the Pavilion located at the bow.

KM Zahro Express has the engine room is located at the stern of ship, there are the main engine, engine generators, generator and fuel tank (right side) and the fresh water tank (as shown in figure 4.3). Access to the engine room through the sliding doors in the middle of the back wall of the engine room.

4.1.3 Engine and Fuel System

KM Zahro Express has 1 unit of diesel engine (NISSAN RH10). This machine is a type of V-line, 10 cylinders with engine power of 500 HP at 1800 rotations per minute. This machine is a land use type that have been reconditioned and modified for use on board.

The fuel tank made from FRP and mounted permanently on the right rear of the engine room with a capacity of 1 ton. Outlet pipes located in the fuel tank in the engine room.
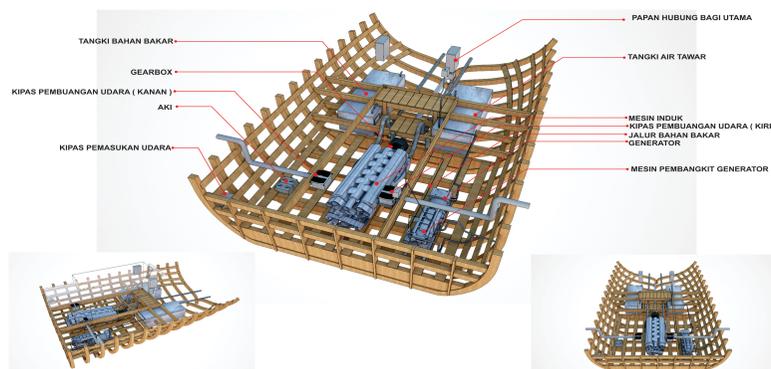

Figure 4.3 Engine Room Layout of KM Zahro Express [15]

4.1.4 Ship Generator

The ship's electrical power produced from 1 set of generators. According to information from the owner of the ship, specification of prime mover is an ISUZU engine with a 54 HP and an electric generator power is MARELLI brand 21 kVA or 16.8 kW, 3-phase and 4 wires that produces a 220/380 volt AC current with frequency 50 Hz. The prime mover and generator are a land use type engine.

Prime mover generator can be used with motor starter which include in the engine. Prime mover is turned on with the key that installed in the right of electric panel in engine room. To turned off the prime mover of generator, we can set the speed control lever by reposition the lever to the off-position.

The information from chief engineer in June 2016 while the ship sail, there was flare from generator several times that made short circuit in

mini mini circuit breaker air condition and chief engineer turned off the generator. Next, chief engineer tried to operate the generator but it could not generate electrical power.

4.1.5 Ship Evacuation Route

KM Zahro Express has two main accommodation area, namely the main passenger deck located on the main deck with a capacity of 172 seats. There are also passenger accommodation decks on the upper deck with a total of 64 seats

Advanced examination against the real condition of the passenger accommodation decks, there main shows 214 seats and upper deck mounted 112 passenger seat with a total of 326 seats. Access for passengers to the vessel from the port is provided through the deck at the bow platform at the stern of the ship. The main deck accommodation room has 2 main access doors are available on either side of the bow with a width 77 cm and a single door access back to the kitchen and toilet area with approximately the same width.

Below is an overview of the evacuation line on the ship KMP. Zahro Express which already exist and which have been designed by the manufacturer of the ships


Figure 4.4 Ship Evacuation Route of KM Zahro Express

Due to a fire accident KM Zahro Express match reports from Basarnas. There are 24 died and 197 people survived. In accordance with the number of victims was found dead, as many as 20 passengers died found

are on the main deck accommodation spaces while the other 4 were found outside the ship.

Table 4.1 Victims Information [15]

Victims	died	Survivors	Amount
Passengers	24	192	216
Crews	-	5	5
Total Amount	24	197	221

Fires also resulted in severe damage on construction, from the bow section of the deck to the stern of the building destroyed by fire on board, space navigation, engine room and equipment was also destroyed by fire.

Figure 4.5 KM Zahro Express Identification [18]

4.2 Time Calculation of Evacuation

Calculation of evacuation time of the KM Zahro Express refers to the rules of the IMO MSC/Circ. 1 1238 2007 which aims to :

- Demonstrate the design of evacuation path, assambly point and nearest point with the safety equipment that is flexible for certain possibilities.

Calculation of time evacuation of the KM Zahro Express using the IMO MSC.1/Circ.1238 Simplyfied method. More simplyfied method operates on mathematical calculations and analysis of the flow of movement of passengers in any room or a certain place. This method is more suitable when used to evaluate the process of evacuation ships with a relatively small ship. Because almost all the evacuation routes must be evaluated for each parts. Therefore it takes a long time to evaluate a relatively large-sized ships and had some of the evacuation.

4.2.1 Evacuation Modeling

In this modeling using calculation methods simplyfied. The calculation by the method has some characteristics simplyfied, namely:

• Each person represented as agent.
• The ability of each agent has parameters, the speed of walking.
• Displacement of each of the agents was recorded.
• Each individual in the population has a variation of parameters.
• Each agent has the same percentage of the median in determining selection chose the evacuation.

4.2.1.1 Assumptions

Certainly requires a variety of assumptions to make modeling became more real or approaching the situation and conditions in the field. The following assumptions are used in the advanced methods of evacuation modeling.

• all passengers and crew will begin evacuation at the same time and will not hinder each other
• initial walking speed depends on the density of persons, assuming that the flow is only in the direction of the escape route, and that there is no overtaking
• people can move unhindered
• counterflow is accounted for by a counterflow correction factor
• simplifications are accounted for in a correction factor and a safety factor

4.2.1.2 Performance Standard

IMO MSC.1/Circ.1238 determines that the standard evacuation time calculation methods simplify as follows:

$$1.25\ R + T + 2/3\ (E + L) < n \ .... (4.1)$$
$$E + L < 30' \ .... (4.2)$$

where: T = Travel Time
E = Embarkation Time
L = Launching Time
n = Maximum time in the process of evacuation < 60'

Performance standard combined with SOLAS regulation III/21.14 as follows :
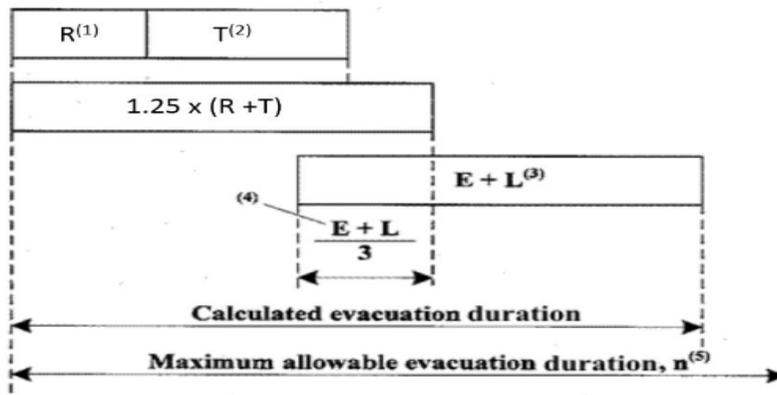
Figure 4.6 Performance Standart
Source : IMO MSC.1/Circ.1533

(1) 10' in case 1 and case 3, 5' in case 2 and case 4
(2) calculated as in appendix 1 to these Guidelines
(3) maximum 30' in compliance with SOLAS regulation III/21.1.4
(4) overlap time = 1/3 (E+L)
(5) values of n (min)

4.2.1.3 Identification of Passenger Density

Passenger density in certain areas are identified by passengers or crew with a density exceeding 4 p/m2 for a significant period of time. This level of passenger density will probably affect of evacuation simulation process overall. If density lasts for 10% of the total time of evacuation, it impacted significantly.

4.2.1.4 Parameters

IMO MSC.1/Circ. 1238 categorizes some parameters to facilitate simulation in modeling:

1. Category Geometrical
   The primary discussion about the layout and placement of the evacuation route on the ship. The layout and placement of the evacuation route from the existing conditions in KMP. Zahro Express.

2. Category Population
   This describes of the population in terms of age, gender, physical attributes and response durations. The population is identical for all

scenarios with the exception of the response duration and passenger initial locations.

Characteristics of the walking speed of passengers based on gender and age range that is modeled in the uniform distribution of appropriate IMO MSC. Circ./1533, 2016. For walking speed passengers on the stairs go up or down is determined by the software itself, with the formula:

$$V\,ft = \frac{k}{1,4}$$ .... (4.3)

The value of K correspond with the height of the stairs. As shown in the table 4.2,

Table 4.2 Value Convertion of K

Height of Stairs (Inch)	Width of Stairs (Inch)	K
7,5	10	1
7	11	1,08
6,5	12	1,16
6	13	1,23

Source : Technical Reference Pathfinder 2016

3. Category Environmental
   Describe of Static and dynamic conditions of the ship. These parameters will influence the moving speed of persons.

4. Category Procedural
   Assessment of the fourth case, the crew is assumed to follow the process of evacuation operations of embarkation point without exception.

4.3 Creating of Modeling & Simulation

A simulation model can represent the actual of affairs. This simulation model aims to calculate the traveling time on the process of evacuation. The model is created based on the General Arrangement of the KMP. Zahro Express.
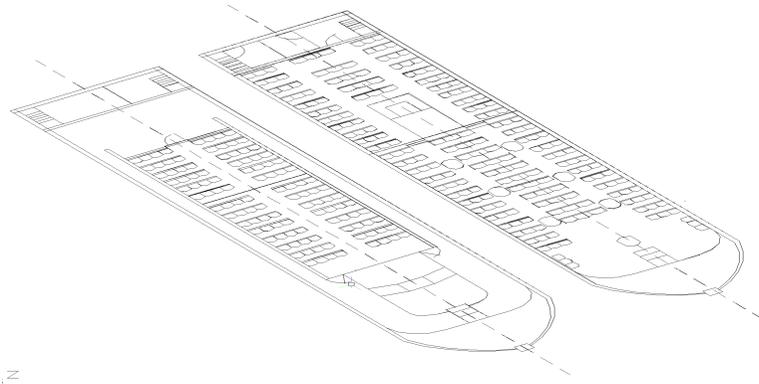
Figure 4.7 Redraw General Arrangement KM Zahro Express

Every room is bounded on all sides by walls. Only one room can occupy the space given, so if one room stacked with another, the overlap will be reduced from the old room and given to a new one. Each room is also equipped with access doors so that passengers can get out of the room toward the evacuation point.
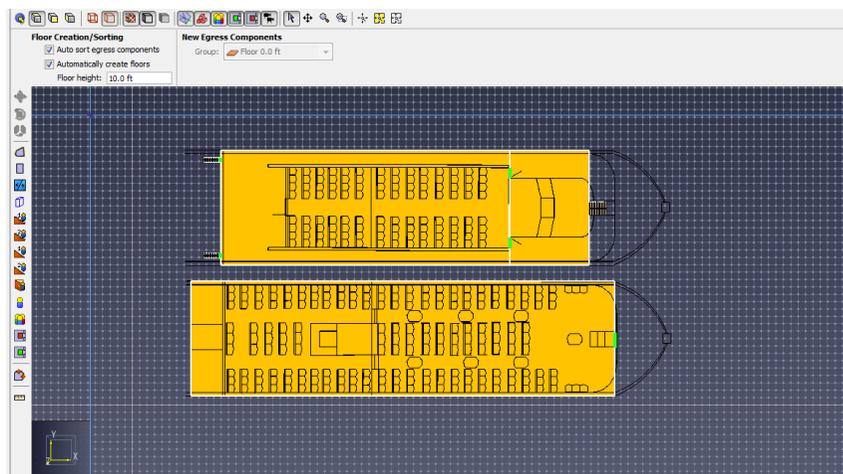

Figure 4.8 Creating layout KM Zahro Express

Stairs combining between deck consists of 2 types of staircase, half-landing and straight, the stairs half-landing on deck dominated by passengers, while the stairs straight dominant by crew. The size of stairs is different, according to the volume of people who access the stairs.
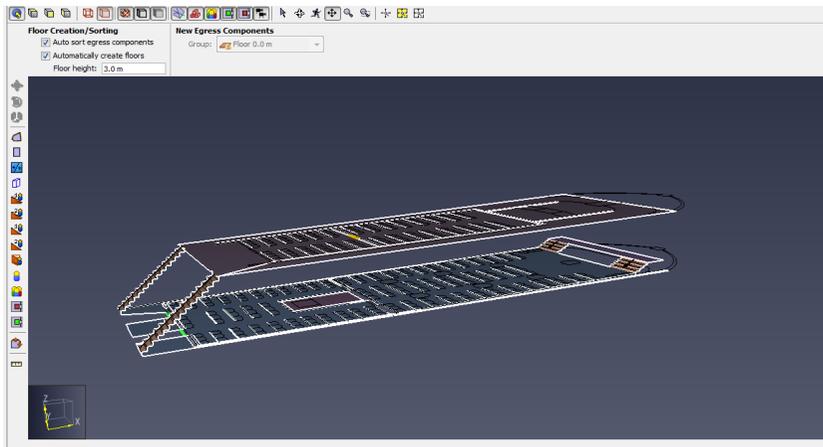
Figure 4.9 Creating stairs KM Zahro Express

After the layout completed, then the next step is to add the agent representing passengers and crew. Agent to be added has the characteristics of each. Height and width of shoulders assuming uniform distribution, altitude agent ranging between 1.58 – 1.71 meters for men and 1.47 – 1.6 metres for women, according to the statistics of the average height of people of Southeast Asia. While width of shoulder ranging between 34 – 48 centimeter for both men and women.
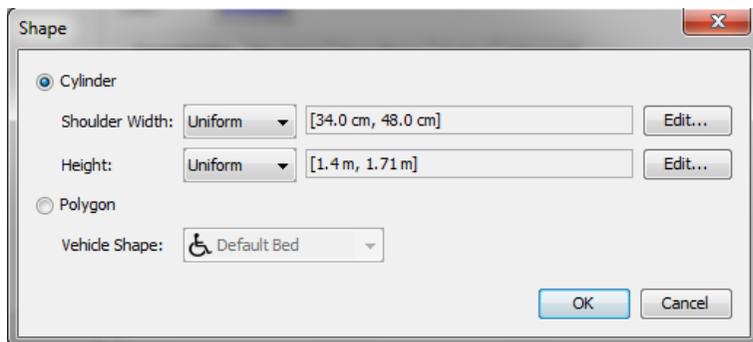
Figure 4.10 Insert Size of Shoulder Width

Placement of agents that represent crew and have specifications of passenger gender and age range, for crew to follow the standard IMO MSC.1/Circ.1238 and refers to data from the KM Zahro Express
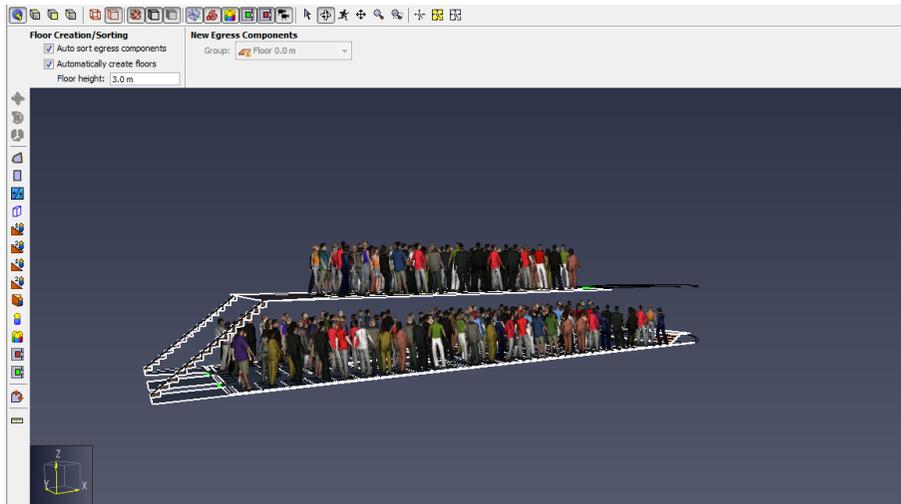
Figure 4.11 Creating Final Model

The image above is a picture of the final evacuation modeling standard in the case of evacuation. The model is ready to be run by producing traveling time.

After the model is complete and ready for running the simulation process can then immediately on the run. In this simulation process, the most important parameter is the behaviour of agents in the process of evacuation. There are two systems modeling simulation on the Pathfinder software, steering modes and SFPE mode.

Steering mode system attempt to imitation the behaviour and movements of agents. This system depend on the interaction of agents and evasion against the occurrence of collisions between agents.

SFPE system as explained on the SFPE Handbook of Fire Protection Engineering (Nelson and Mowrer, 2002) that controls the flow rate and the queue at the door. evacuation system specified is on the SFPE mode, because congestion arranged so that it does not exceed the initial assumption is 4 p/m2 for a significant period of time.

After the simulation parameters specified, followed by a simulated evacuation process. Then automatically will appear a dialog box processes simulation of evacuation.
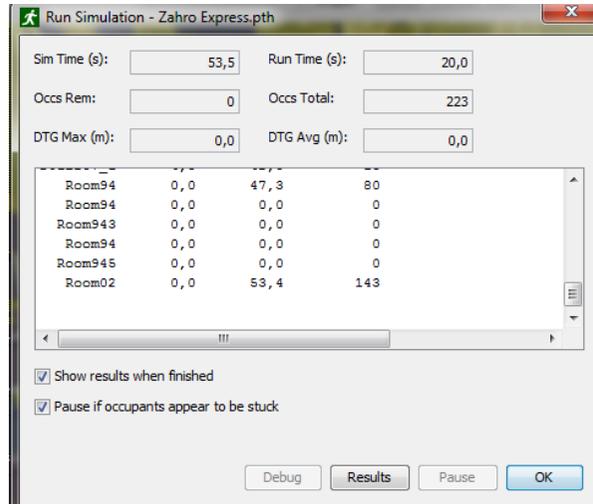
Figure 4.12 Dialog Box of Simulation

After the dialog box is running and all the agents evacuated, then the process will stop and it will automatically displayed a video simulation that generates time (traveling time) of evacuation.


Figure 4.13 Process of Simulation

In cases has different results according to the characteristics cases. In any case created a modeling simulation results are displayed into a graphs.
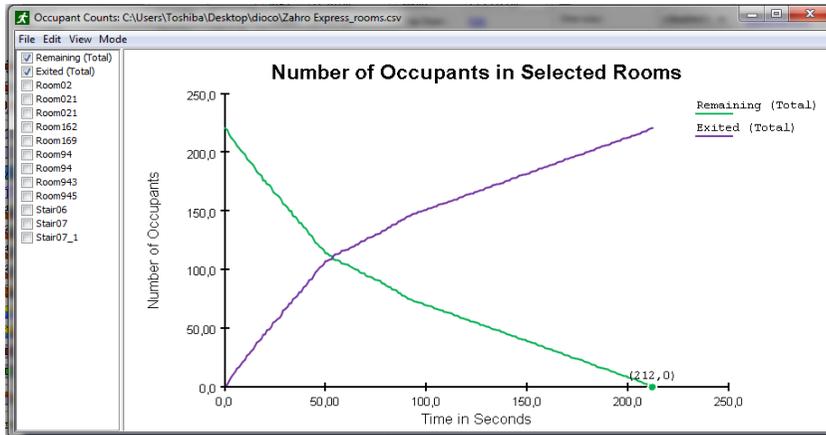
Figure 4.14 Result of Simulation Case

On the graph can be analyzed that the ship KM Zahro Express takes at least 212,0 seconds (travel time) for passengers and crew out of the ship. In this case, the simulation was conducted on the time of day in accordance with the incident.

4.3.1 Result of Evacuation Time Calculation

After getting the value of traveling time, then the next step is to enter the value of traveling time that has been obtained to the standards of performance.

$$1.25 \ R + T + b \ (E + L) < n$$
$$(E+L) \leq 30'$$

Process simulation of evacuation (traveling time), for this case takes 3,533 minutes (including time delay). Evacuation time calculation as follows:

$$evacuation \ time = 1.25 \ (5) + \ 3,533 + \frac{2 \ (30)}{3} \ minute$$
$$evacuation \ time = 29,783 \ minute$$

4.4 Fire Simulation Modeling

Fire evacuation modeling is modelled to calculate the time of evacuation in case of fire ships. Fire modeling is modelled with an added source of fire and smoke in accordance with material to burn. The burning sources can interfere with the movement of passengers and crew in carrying out the evacuation process.

The creating of fire simulation model uses Autocad software, Pathfinder software and Pyrosim software with process as follows:

Table 4.3 The process of creating a fire simulation model

Software	Autocad	Pathfinder	Pyrosim
Function	Create ship design on each deck of the ship	Create the evacuation modeling	Create the fire modeling
Description	Model based on the General Plan of the ship KMP. Zahroo Express	Produce a traveling time is later processed into the total process of evacuation time	Create fire modeling from layouts drawn on Autocad

4.4.1 Creating Fire Simulation Modeling

Creating fire simulation model is started by import a file into autocad to software pyrosim with dimensions of the actual ship and the only room that can be occupied by passengers or crew.
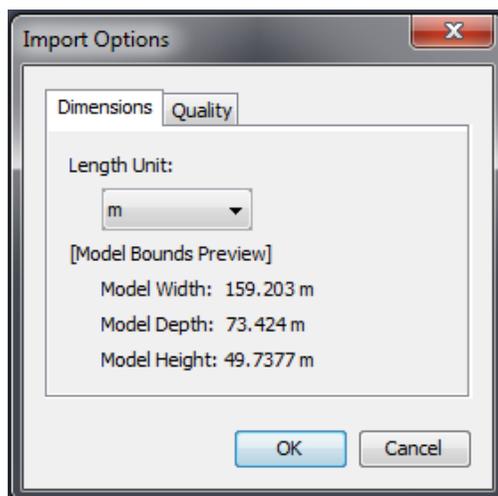
Figure 4.15 Importing Pictures From Autocad

Import 2D images in accordance with the deck on the ship general arrangement. Next create an image 2D to 3D so it becomes thick walls with specified. Thick material and the type of customized approaches with real conditions.
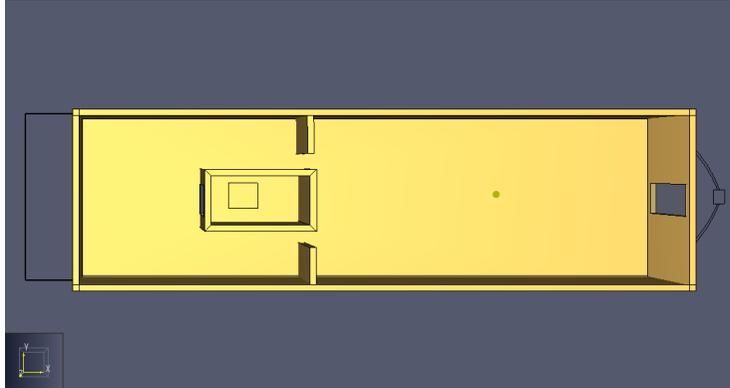
Figure 4.16 Create holes for the Access stairs and Doors

This hole is used for an access point of fire and smoke from one room to another room. The hole can be either a door or stairs connecting each deck. This hole is determined in such a way appropriate scale are on the General plan.
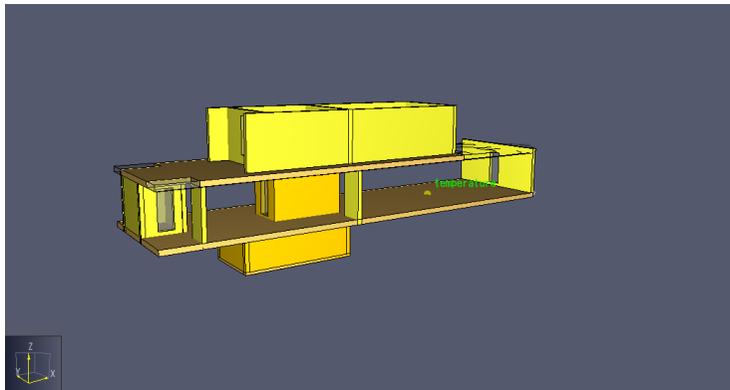
Figure 4.17 Creating Fire Simulation Model Layout

On the fire simulation model is contained materials used on ships (floor, external wall, internal wall, and upholstery). Each type of material has a composition of different materials. Details of the composition of the material is meant to resemble the existing materials on the ship. In addition to sort based on each flash point material fit its characteristics which may allow in the material come into burned by the flame. the classification of this type of material is as follows:

Table 4.4 Materials on Fire Simulation Model

Material	Floor	External Wall	Internall Wall	Upholstory
Description	The material used as the floor	The material used on the external walls of the ship	The material used on the internal walls of the ship parts in separating room	Furniture in the Ship
Composition	Mentu Wood	Mentu Wood and Fiber Glass	Mentu Wood and Fiber Glass	Metru Wood and Steel

Once all the material is already adjusted to the reality, the ship model added source of fire to simulate the occurrence of fires. The source of the fire placed on the position of fire begins, the position of a fire that occurred in the engine room or accurately sourced in the place of the laying of the accu and generator.

This modeling simulated assuming the burning material is located on the Engine Room with the kind of wood material. This material has burned and Heat Release Rate Per Area (HRRPA) of 50 kW/m2 with the width of the area burned was of 2.4 m2. The value of this HRRPA obtained from test results Laboraturium

The source of the fire to burn the material added by adding a vent on the location of the source of the fire. Then determine the dimensions according to your needs and provide a profile of the shape functions as a source of fire (burner). After determining the area of the source of the fire, and the value of HRRPA, then specify the source of the fire reaction to fire simulation while it lasted. Using wood reaction, details the composition as follows.

- Carbon atoms 45.0

- Hydrogen Atoms 6.2

- Oxygen Atoms 40.0

- Nitrogen Atoms 0.3
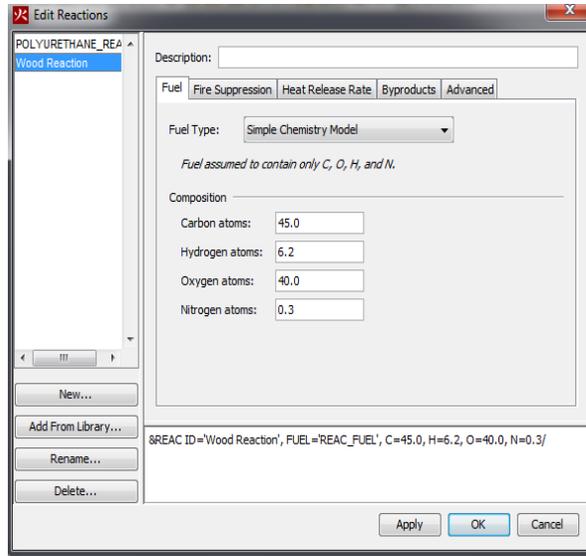
Figure 4.18 The Reaction Generated By The Source Of The Fire

Creation of Mesh on modeling fire serves to limit the fire affected areas in this model. On this restricted mesh modeling is a ship full of open and who are at the top of the ship. Open and functioning for the discharge of smoke or fire resulting in fire modelling so that the smoke from the fires don't get stuck on the limitations of the specified mesh.
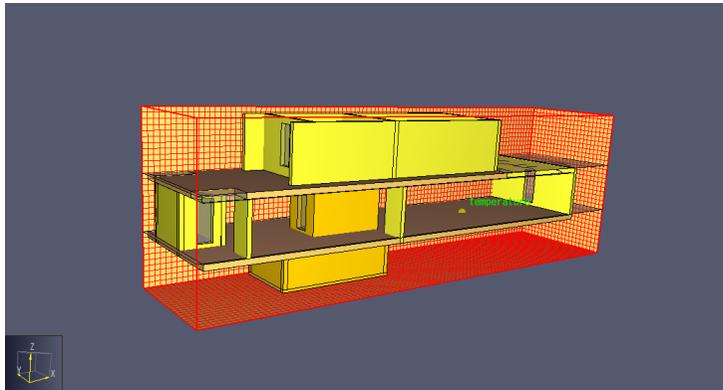
Figure 4.19 Creating a Mesh

Set process simulation modeling of fire in accordance with the desired conditions. The required parameters in the simulation is run time restrictions in running a simulation of a fire. Time used 1800 seconds. This time refers to the process of traveling time cases previously which takes no more than 1800 seconds.

To be able to integrated with evacuation modelling software on Pathfinder, then modeling fire must produce data in the form of a planar graph that can be read by software pathfinder. Modeling fire regulated so it can be read by software with a 3D Plot set up pathfinder Data. A 3D plot of the resulting Data must be expanded feet according to the specifications of pathfinder.

There are several ways to simulate the FDS (Fire Dynamic Simulation), by Application Under also called Under OS and Under DOS.

Simulation Under OS run with an app maker fire modeling software (Pyrosim). The downside of this OS Under simulation requires extra computer performance. The advantages of simulation Under this OS is more tactical in the process of running it, there is a parameter estimation of the time required and run simulations that are easy.

Simulation Under DOS to other options in the run process simulation of a fire. The simulation runs are relatively shorter than the simulations Under the OS. This is due to the process of the FDS (Fire Dynamic Simulation) runs on its own at the command prompt. But this simulation process difficult to run because it must understand in advance in operating command prompt (McGrattan. 2016).
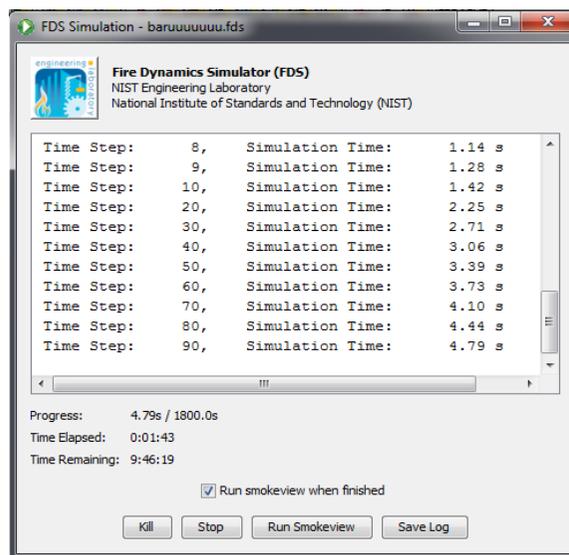
Figure 4.20 Dialog Box of Fire Simulation

4.4.2 Result of Fire Simulation Modeling

Results from simulations of fires is a graphic animations of the simulation, in addition also produces graphs of parameter that is already installed. Animated graphics also produce planar graphs that have been installed (slices). These slices will also be used as an object which combined to ease the evacuation simulation based on the results of a simulation of a fire that has been done.
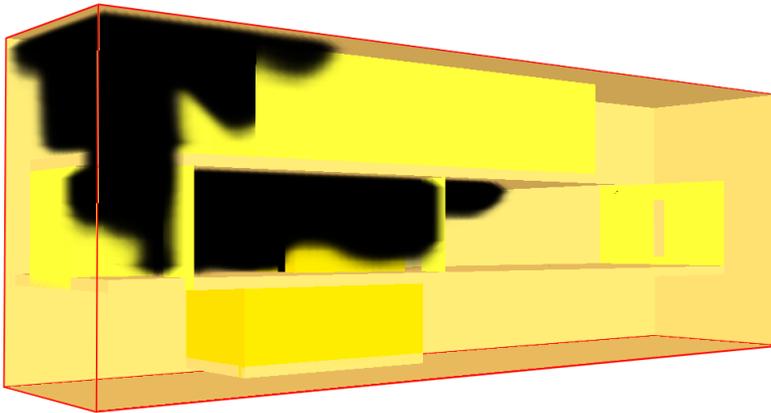
Figure 4.21 Result of Fire Simulation Modeling

In Figure 4.21 which is a result of the fire modelling shows that the spread of the smoke that comes from the engine room may spread to the rest of the deck. The smoke spread can be analyzed with device movement and slice.

Other results that can be used to identify environmental is a graph from the results of installation the device. This is very important because of the graph can be seen the temperature specific heat, as well as a percentage of the amount of smoke that how around the device installed. The following example chart generated from a device that has been installed.
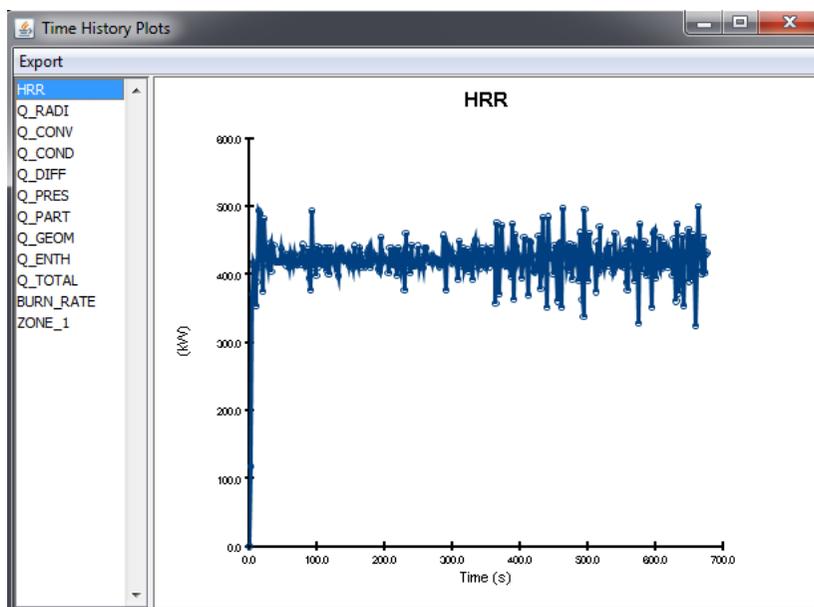
Figure 4.22 Result of Graph

From the graph above, can the analysis time and the amount of smoke on deck. It can be seen that in the 1800 minutes smoke levels produced in the relatively high place so disturbing in the evacuation process.

The analysis has been done conclude some points as follows:

- Process simulation is done for 1800 seconds do not produce a large fire, only produces smoke that allows agents to carry out performance disrupts the process of evacuation simulation
- The results of this simulation produces smoke that reaches throughout the body of the ship because of the location of the access stairs connecting anter deck is at near the source of the fire.

4.4.3 Analysis of Fire Simulation Modeling

Modelling of fire have resulted can be integrated with external evacuation modeling. It can be easier to analyze the impact that resulted in a change of the evacuation time on a variation of such cases.

The occurrence of gradations on walking speed each agent can be affected by smoke and temperature. White smoke is highly irritating to the eye produced by burning wood cribs, black smoke is less irritant produced

by burning kerosene. To limit the visible sign of a run, the following relationship can be presented in Cs. Walking speed is constant, but for the visibility of the Agency declined. Visibility or ability seen in smoke irritate dropped sharply on the smoke density exceeds a certain level. In smoke irritate with thick concentration, the eyes can not open for a long time and couldn't see the words on the signs of the evacuation. Even in this case, when the signs are so simple or familiar with the passengers or crew to be understood at a glance, the effect of irritating fumes may not cause problems to identify. Irritant smoke reduces visibility of the Agency, especially when there is the possibility for panic.

Time Evacuation

	0	5	10	15	20	25	30
Occupants	0	76	125	154	176	198	221

Time of Evacuation (Minute)
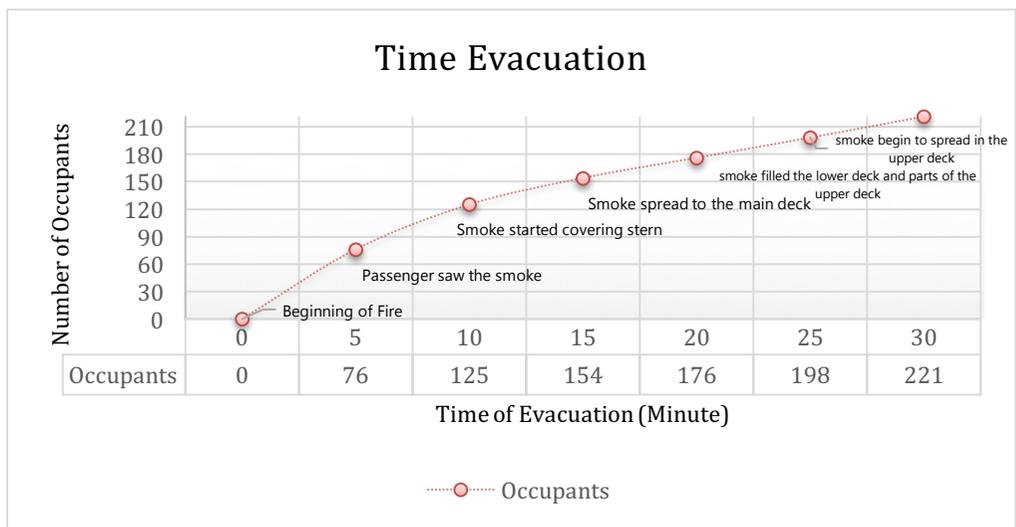
········O········ Occupants

Figure 4.23 Relation between Evacuation Time and Fire Simulation

This chart shows number of occupants that can evacuated in the beginning of smoke caused by fire. In the beginning of fire, none of passenger notice the fire.

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CHAPTER 5
CONCLUSION AND SUGGESTION

5.1 Conclusion

Based on the analysis and simulation has been done with the standard at IMO, then the conclusions of this thesis are:

1. Characteristics of the ship's passengers and crew the associated walking speed in each case is different. Walking speed reduction occurs when accidents or fires that affect the length of the evacuation process.

2. The evacuation process simulation at normal condition and fire condition can use simulation based on Agent Based Modeling Simulation (ABMS) with the relevant condition corresponds to the case that actually happened. With the output time, ABMS are able to represent the total evacuation time theoretically. All the simulations performed meet the standarts International Maritime Organization (IMO), however there are several factor that can affect the evacuation process, a physical and mental readiness of the passengers in the evacuation proxess on conditions of fire or danger that requires all passengers abandon the ship.

3. Evacuation simulation calculation result in normal condition is 29.783 minutes, the simulation is done during the day and according to the actual conditions, in these simulation there were 216 passengers and 5 crews all can be evacuated.

4. On the process simulation of fire, during the 1800 seconds do not produce a large fire, but smoke produced can interfere with the performanceof the agency to carry out the evacuation process. So the evacuation process become too long. Beside the condition of ship to many goods results in the evacuation process in interrupted

5. There were 24 passengers (20 People died cause fire and 4 People were found in the sea) who died on the case, according to the autor's analysis of the factor affecting passengers died because of the panic and not

ready to accept the situation of emergency, In addition there are also items belonging which affect the evacuation line

5.2 Suggestion

After Analyzing the calculation time of the evacuation, the author give suggestion for the next research are :

1. Create a new evacuation route and easily understand by all passengers and crew
2. Simulate and calculate the time of evacuation if the vessel in conditions of full

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ATTACHMENT 1

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Regression formulation for mean travel speed values

Gender	Age (Years)	Speed (m/s)
Female	2 - 8.3	$0.06 * \text{age} + 0.5$
	8.3 - 13.3	$0.04 * \text{age} + 0.6$
	13.3 - 22.25	$0.02 * \text{age} + 0.94$
	22.25 - 37.5	$-0.018 * \text{age} + 1.78$
	37.5 - 70	$-0.01 * \text{age} + 1.45$
Male	2 - 5	$0.16 * \text{age} + 0.3$
	5 – 12.5	$0.06 * \text{age} + 0.8$
	12.5 - 18.8	$0.008 * \text{age} + 1.45$
	18.8 - 39.2	$-0.01 * \text{age} + 1.78$
	39.2 - 70	$-0.009 * \text{age} + 1.75$

Walking speed on flat terrain

Population Group - Passengers	Walking speed on flat terrain (e.g., corridors)	
	Minimum (m/s)	Maximum (m/s)
Females younger than 30 years	0.93	1.55
Females 30-50 years old	0.71	1.19
Females older than 50 years	0.56	0.94
Females older than 50, mobility impaired (1)	0.43	0.71
Females older than 50, mobility impaired (2)	0.37	0.61
Males younger than 30 years	1.11	1.85
Males 30-50 years old	0.97	1.62
Males older than 50 years	0.84	1.4
Males older than 50, mobility impaired (1)	0.64	1.06
Males older than 50, mobility impaired (2)	0.55	0.91
Population groups – crew	Walking speed on flat terrain (e.g., corridors)	
	Minimum (m/s)	Maximum (m/s)
Crew females	0.93	1.55
Crew males	1.11	1.85

Walking speed on flat terrain
(In Fire Condition)

Population Group - Passengers	Walking speed on flat terrain (In Fire Condition) (e.g., corridors)	
	Minimum (m/s)	Maximum (m/s)
Females younger than 30 years	0.75	92
Females 30-50 years old	0.45	95.2
Females older than 50 years	0.57	0.75
Females older than 50, mobility impaired (1)	0.34	5.98
Females older than 50, mobility impaired (2)	0.3	0.49
Males younger than 30 years	0.89	1.48
Males 30-50 years old	0.65	1.29
Males older than 50 years	0.53	1.12
Males older than 50, mobility impaired (1)	0.54	0.46
Males older than 50, mobility impaired (2)	0.44	0.91
Population groups – crew	Walking speed on flat terrain (In Fire Condition) (e.g., corridors)	
	Minimum (m/s)	Maximum (m/s)
Crew females	0.93	1,93
Crew males	1.11	1.48

Walking speed on stairs

Population Group - Passengers	Walking speed on stairs (m/s)			
	Stairs (Down)		Stairs (Up)	
	Minimum (m/s)	Maximum (m/s)	Minimum (m/s)	Maximum (m/s)
Females younger than 30 years	0.56	0.94	0.47	0.79
Females 30-50 years old	0.49	0.81	0.44	0.74
Females older than 50 years	0.45	0.75	0.37	0.61
Females older than 50, mobility impaired (1)	0.34	0.56	0.28	0.46
Females older than 50, mobility impaired (2)	0.29	0.49	0.23	0.39
Males younger than 30 years	0.76	1.26	0.5	0.84
Males 30-50 years old	0.64	1.07	0.47	0.79
Males older than 50 years	0.5	0.84	0.38	0.64
Males older than 50, mobility impaired (1)	0.38	0.64	0.29	0.49
Males older than 50, mobility impaired (2)	0.33	0.55	0.25	0.41
Population groups – crew	Walking speed on stairs (m/s)			
	Stairs (Down)		Stairs (Up)	
	Minimum (m/s)	Maximum (m/s)	Minimum (m/s)	Maximum (m/s)
Crew females	0.56	0.94	0.47	0.79
Crew males	0.76	1.26	0.5	0.84

Walking speeds as a function of age and gender
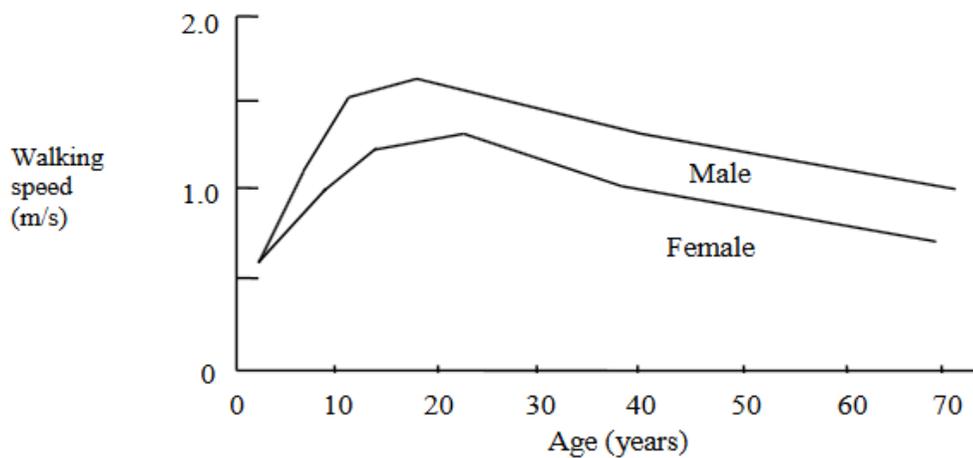
Table of Recommended values for clearances

Escape route element	Clearance (m)
Stairways	0.15
Handrails	0.5
Public space fixed seats	0
Walls	0.2
Doors	0.15

The characteristics of each variable of condition and facilities table

Type of Facility	Condition	Density D (p/m2)	Speed of person S (m/s)	Specific Flow Fs (p/(ms))
Stairs (down)	Low	< 1.9	1	0.54
	Optimum	1.9 to 2.7	0.5	0.94
	Moderate	2.7 to 3.2	0.28	0.77
	Crush	> 3.2	0.13	0.42
Stairs (up)	Low	< 1.9	0.8	0.43
	Optimum	1.9 to 2.7	0.4	0.75
	Moderate	2.7 to 3.2	0.22	0.62
	Crush	> 3.2	0.1	0.32
Corridors, doorways	Low	< 1.9	1.4	0.76
	Optimum	1.9 to 2.7	0.7	1.3
	Moderate	2.7 to 3.2	0.39	1.1
	Crush	> 3.2	0.18	0.55

ATTACHMENT 2

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B.L
OUTBOARD PROFILE

C.L
DECK 2

C.L
DECK 2

"KMP ZAHRO EXPRESS"

KAMAR MESIN

W/H

KAMAR MESIN

PAPAN HUBUNG BAGI UTAMA

TANGKI AIR TAWAR

MESIN INDUK

KIPAS PEMBUANGAN UDARA (KIRI)

JALUR BAHAN BAKAR

GENERATOR

MESIN PEMBANGKIT GENERATOR

TANGKI BAHAN BAKAR

GEARBOX

KIPAS PEMBUANGAN UDARA (KANAN)

AKI

KIPAS PEMASUKAN UDARA
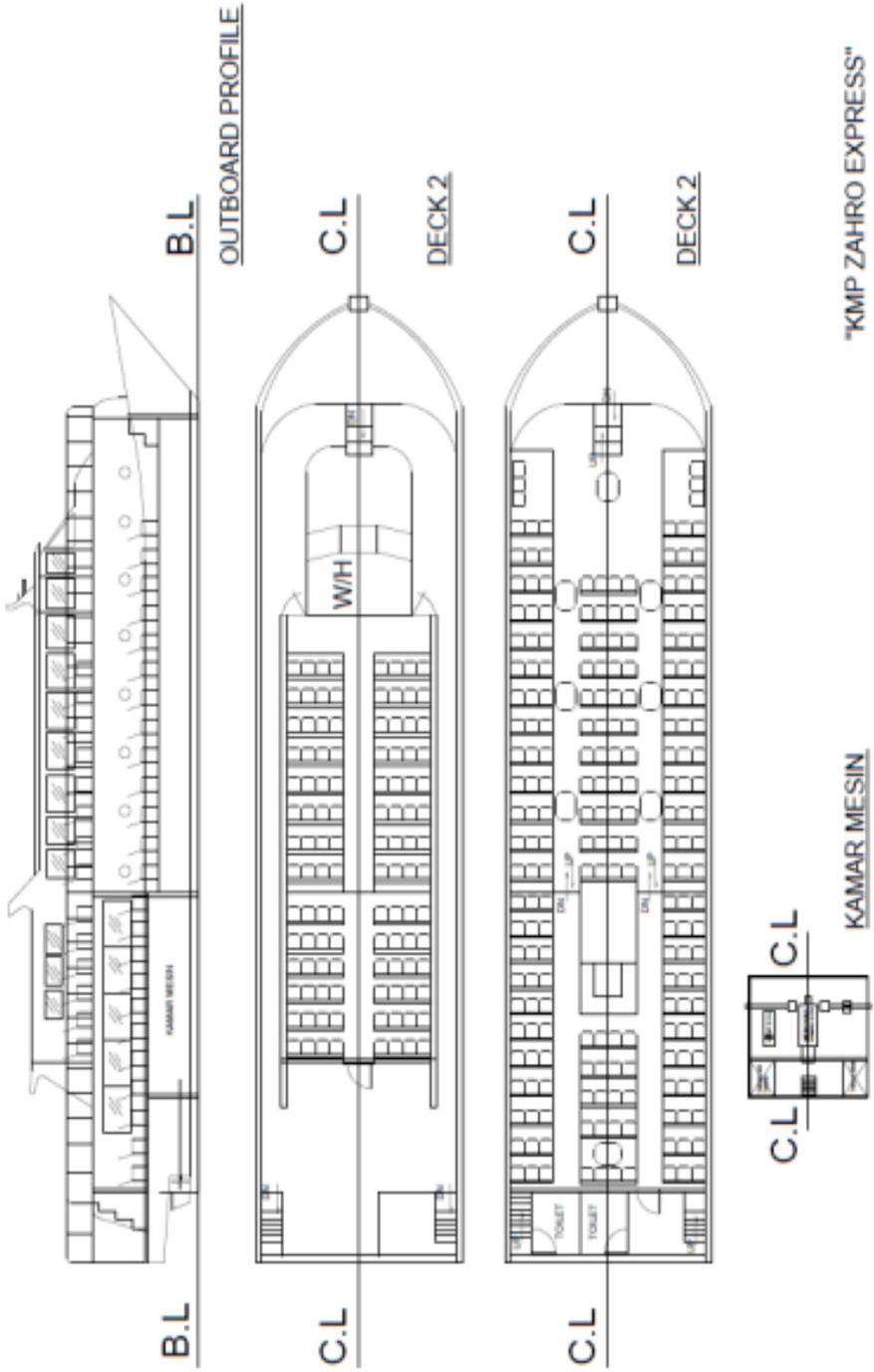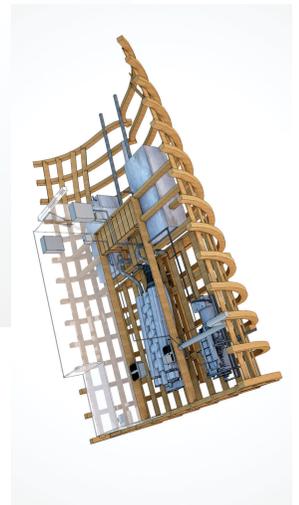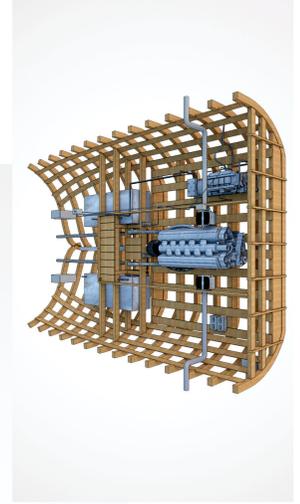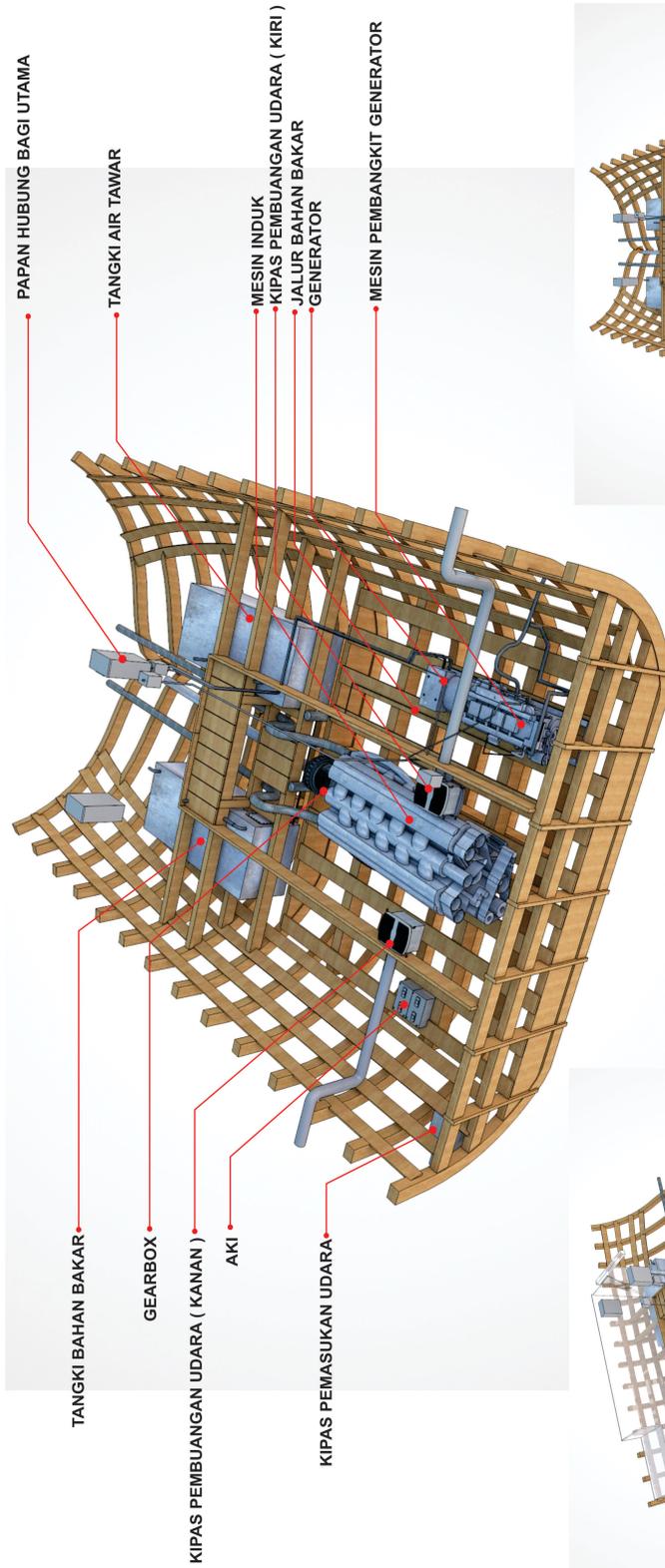
ATTACHMENT 3

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SURAT KETERANGAN PERNYATAAN TUKANG

Yang bertanda tangan dibawah ini saya :

Nama : Muslim

Alamat : Pulau Harapan RT 004/01 Kel. P.Harapan Kep. Seribu Utara

Pekerjaan: Wiraswasta

Bahwa benar saya telah mengerjakan pembangunan kapal motor KM. ZAHRO EXPRESS dengan keterangan ukuran sebagai berikut :

Peletakan Lunas tanggal 12 April 2013

Panjang : 21,00 M (Panjang lunas)

Lebar : 6,00 M

Dalam : 1,20 M

Peluncuran kapal pada tanggal 24 Juni 2013

Kapal motor tersebut milik MUTIA PRIMA YODI dikerjakan pembangunannya di Pulau Harapan Kep.Seribu Utara

Demikian surat keterangan pernyataan ini saya buat dengan sebenar-benarnya dan untuk digunakan sebagaimana keperlunya

Mengetahui: Jakarta, 24 Juni 2013

Pihak Kelurahan   Yang menyatakan

ARDANSI, S.SOS
1965 0378 19861 2100

Muslim

Mengetahui :
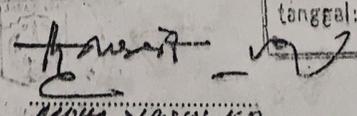
CAMAT

Telah didaftar di Tanjung Priok.
tanggal : 08 JAN 2014

MOHD. YASIN KP.
Nip. 1978 0513 1998 010001.

Shipbuilding contract letter of KMP. Zahro Express between the maker and the local Government used as ship's certificate
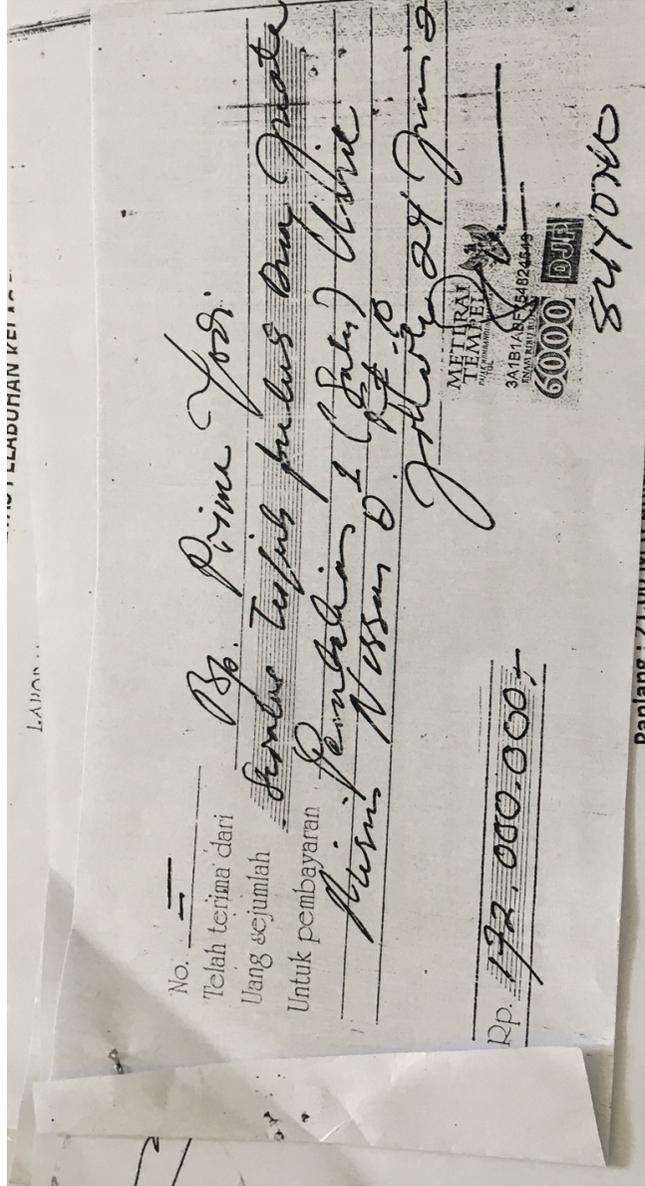
Receipt Purchasing of KM Zahro Express

KEMENTERIAN PERHUBUNGAN
DIREKTORAT JENDERAL PERHUBUNGAN LAUT
KANTOR KESYAHBANDARAN DAN OTORITAS PELABUHAN KELAS III SUNDA KELAPA

LAPORAN PEMERIKSAAN TEKNIS KAPAL

Nama Kapal : KMP. ZAHRO EXSPRESS
Jenis Kapal : kapal penumpang
Isi Kotor : GT. 106 .... RT
Pemilik : Murio prima yodi Di
Pemeriksaan di : muara angke
Kapal berada di : Di atas air
Meliputi bagian-bagian : konstruksi Dan permesinan
Jenis Pemeriksaan : teknis
Surat Pemilik : Nomor ..../........ Tgl ....
Nota DITKAPPEL : Nomor ..../........ Tgl ....
Dock terakhir : ....
Jenis Dock : ....
Tahun Pembuatan : TH. 2013 di kepulauan seribu
Kecepatan rata-rata : 6 mil/Jam/pada 1800 RPM
Kekuatan alat pendorong : 500 PK pada 1800 RPM
Kapasitas Tangki bahan Bakar : 1,5 TON
Kapasitas tangki air tawar : 1,5 Ton
Pemakaian bahan bakar : a. Di laut 80 ltr /Jam
                        b. Di Pelabuhan 30 ltr /Jam
Jumlah Palka/tangki : ....
Jumlah batang pemuat : —
Daya Angkat : a. ....
             b. ....
             c. ....
Klasifikasi : ....
Sertifikat Class : • Garis Muat : ..../......... s/d .... Endoors ....
                  • Lambung : ..../......... s/d .... Endoors ....
                  • Mesin : .... s/d .... Endoors ....
                  : .... s/d .... Endoors ....
Sertifikat MARPOL : ..../......... s/d .... Endoors ....
Sertifikat PMK/Co2 System : .... s/d .... Endoors ....
Nomor Sertifikat

PAS BESAR

REPUBLIK INDONESIA

Diterbitkan berdasarkan ketentuan Pasal 59
Permenhub Nomor PM 13 Tahun 2012

Yang bertanda tangan di bawah ini .... KANTOR KESYAHBANDARAN PELABUHAN SUNDA KELAPA

menyatakan bahwa : KAPAL MOTOR PENUMPANG

NAMA KAPAL	TANDA PANGGILAN	TEMPAT PENDAFTARAN	TANDA PENDAFTARAN
ZAHRO EXPRESS	-	TG. PRIOK	2014 Ba No.3745/L

UKURAN·P X L X D (M)	TONASE KOTOR (GT)	TONASE BERSIH (NT)	TAHUN PEMBANGUNAN
24.18 X 6.00 X 1.64	106	32	2013

PENGGERAK UTAMA	MEREK TK/KW	BAHAN UTAMA KAPAL	JUMLAH GELADAK	JUMLAH BALING-BALING
MESIN	NISSAN - 500 HP	KAYU	1 (SATU)	1 (SATU)

Milik ...... MUTIA PRIMA YODI .... berkedudukan di .... JAKARTA BARAT
memenuhi syarat sebagai Kapal Indonesia, sesuai dengan ketentuan peraturan
perundang-undangan, oleh karena itu berhak berlayar dengan mengibarkan bendera
Indonesia sebagai bendera kebangsaan kapal.

Kepada seluruh pejabat yang berwenang dan pejabat-pejabat Republik Indonesia maupun
mereka yang bersangkutan berkewajiban supaya memperlakukan nakhoda kapal
dan muatannya sesuai dengan ketentuan peraturan perundang-undangan Republik Indonesia
dan perjanjian-perjanjian dengan negara-negara lain.

Diterbitkan di : SUNDA KELAPA
Pada tanggal : 27 MARET 2014

Didaftarkan dalam
Register Pas Besar di : KSOP SUNDA KELAPA
No. Urut : 32
No. Halaman : 32
Buku Register : III

An. MENTERI PERHUBUNGAN
KEPALA KANTOR KESYAHBANDARAN DAN
OTORITAS PELABUHAN SUNDA KELAPA

Capt./FERRY AKBAR, MM
PEMBINA Tk.I (III/d)
NIP. 19660207 200312 1 001

TANDA SELAR : GT. 106 No.6960/Bc

The letter of KM Zahro Express
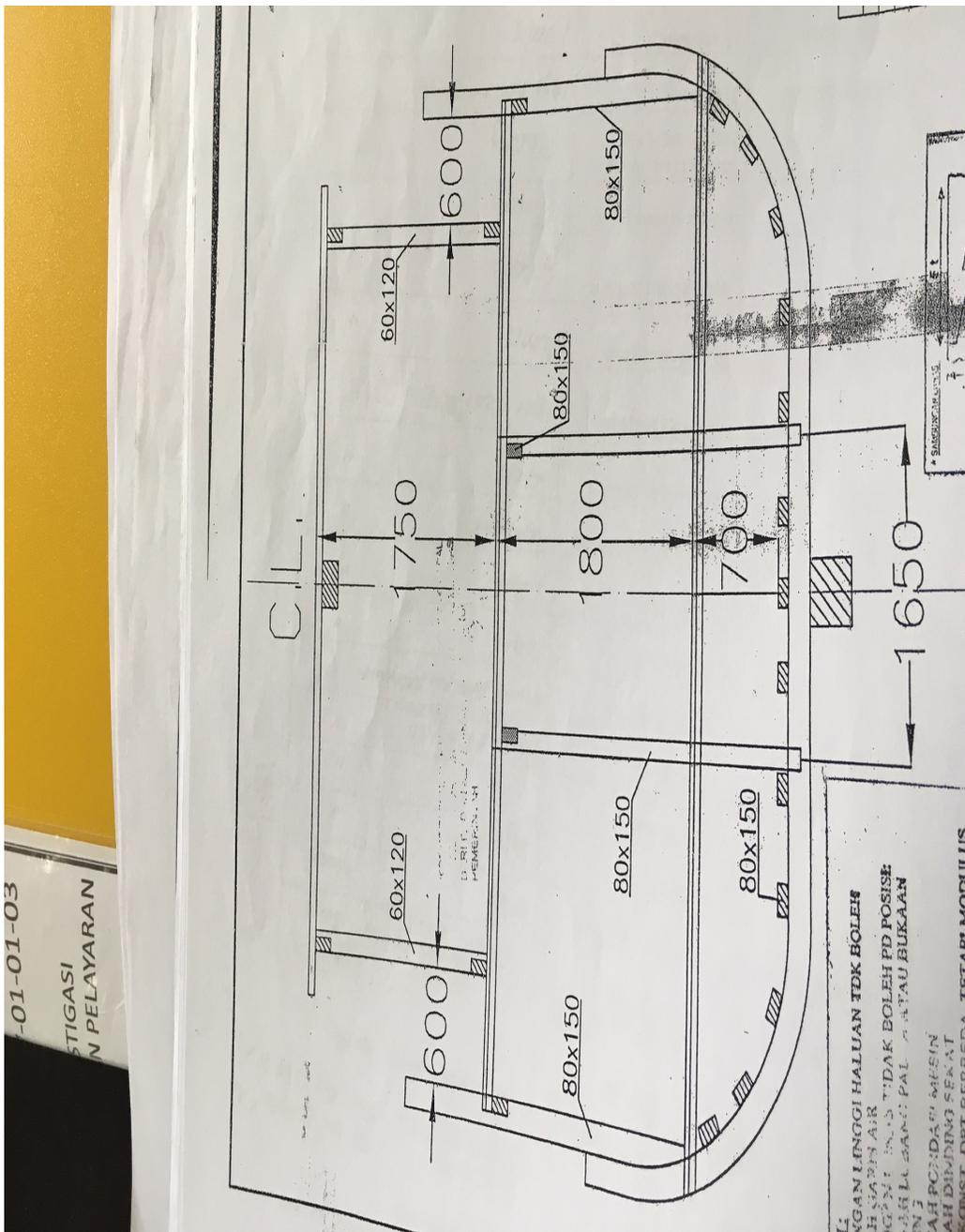
The Design Of The Ship KMP. Zahro Express looks back at a specific section that helps the author to make it easier to analyze

SURAT UKUR DALAM NEGERI SEMENTARA

No. .... 6960/Bc ...

Nama kapal : .

ZAHRO EXPRESS .

Eks ....

Pelabuhan Pendaftaran	Jenis Kapal	Tanda Panggilan	Digerakkan oleh Mesin atau Layar	Bahan
	KAPAL PENUMPANG .		MESIN .	KAYU .
Tempat dan tanggal peletakan lunas	Nama dan alamat Pembangun			Nomor Galangan
PULAU HARAPAN KEP SERIBU - 2013	MUSLIM Pulau Harapan - Kepulauan Seribu			-
Keterangan Alat Penggerak	Jumlah baling-baling	Jumlah cerobong asap	Jumlah geladak	Jumlah tiang
.	1 (SATU)	-	1 (SATU) .	-

UKURAN - UKURAN POKOK

PANJANG	: adalah jarak mendatar antara titik temu sisi luar kulit lambung dengan linggi haluan dan linggi buritan pada ketinggian geladak atas atau pada bagian sebelah atas dari rimbat tetap.	24.18	meter
LEBAR	: adalah jarak mendatar antara kedua sisi luar kulit lambung pada bagian kapal yang terlebar, tidak termasuk pisang-pisang	6.00	meter
DALAM	: adalah jarak tegak lurus ditengah-tengah lebar pada bagian kapal yang terlebar dari sebelah bawah alur lunas sampai bagian bawah geladak atau sampai garis melintang kapal yang di tarik melalui kedua sisi atas rimbat tetap.	1.64	meter

TONASE KAPAL ADALAH

TONASE KOTOR : 106

TONASE BERSIH : 32

Dengan ini diterangkan bahwa tonase kapal ini telah ditentukan sesuai ketentuan-ketentuan dalam Peraturan Menteri Perhubungan No. KM. 6 Tahun 2005.

Berlaku sampai : 11 MARET 2014

Dikeluarkan di .... SUNDA KELAPA .... Tanggal .... 12 DESEMBER 2013 ....

AN. MENTERI PERHUBUNGAN

TANDA SELAR : GT.106 No.6960/Bc .

Dipasang pada : DIPASANG PADA DINDING . RUMAH KEMUDI MELINTANG SEBELAH LUAR .

KEPALA KANTOR KESYAHBANDARAN DAN OTORITAS PELABUHAN SUNDA KELAPA

Capt. FERRY AKBAR, MM PENATA Tk.I (III/d).

ATTACHMENT 4

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Occupants Path
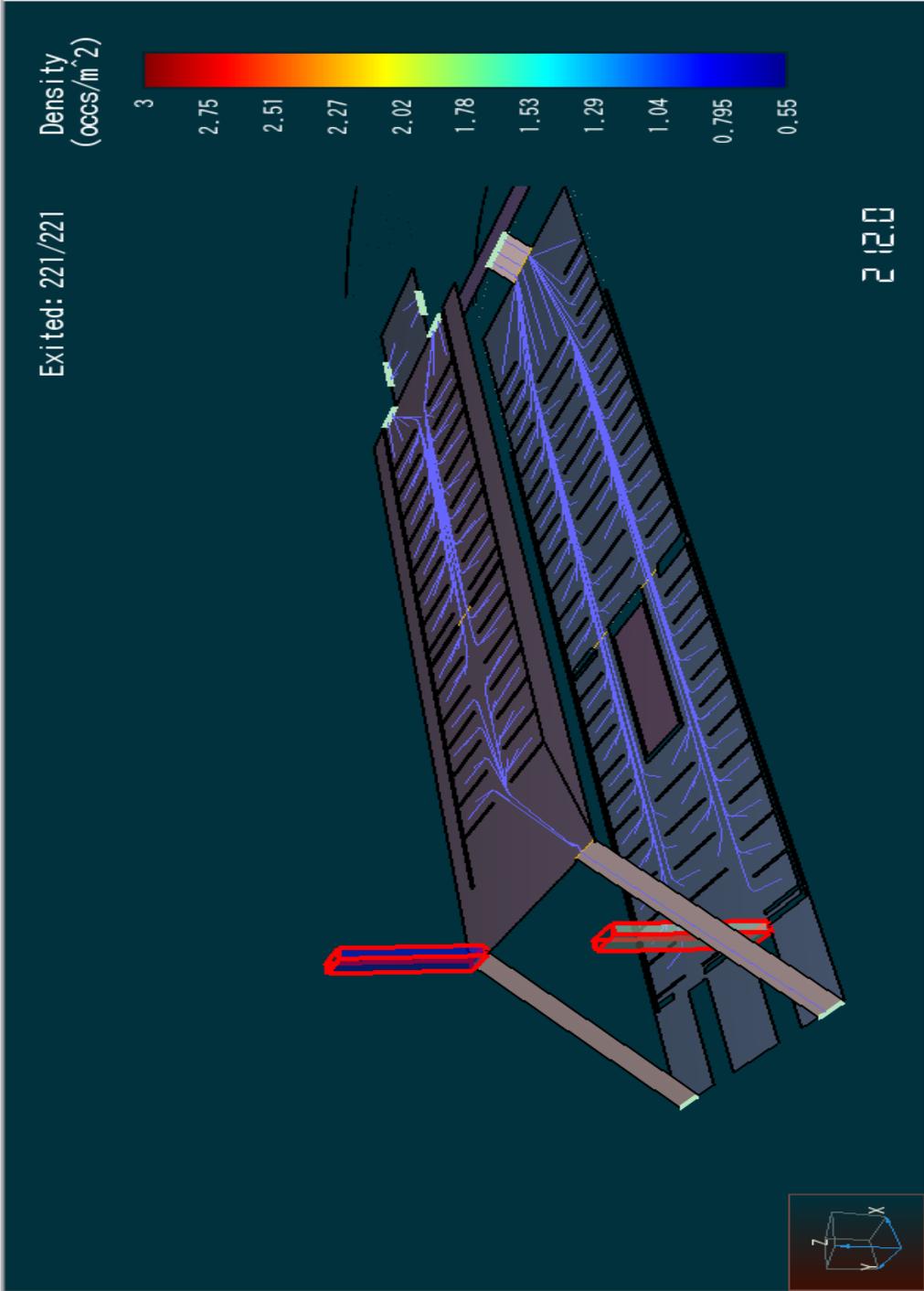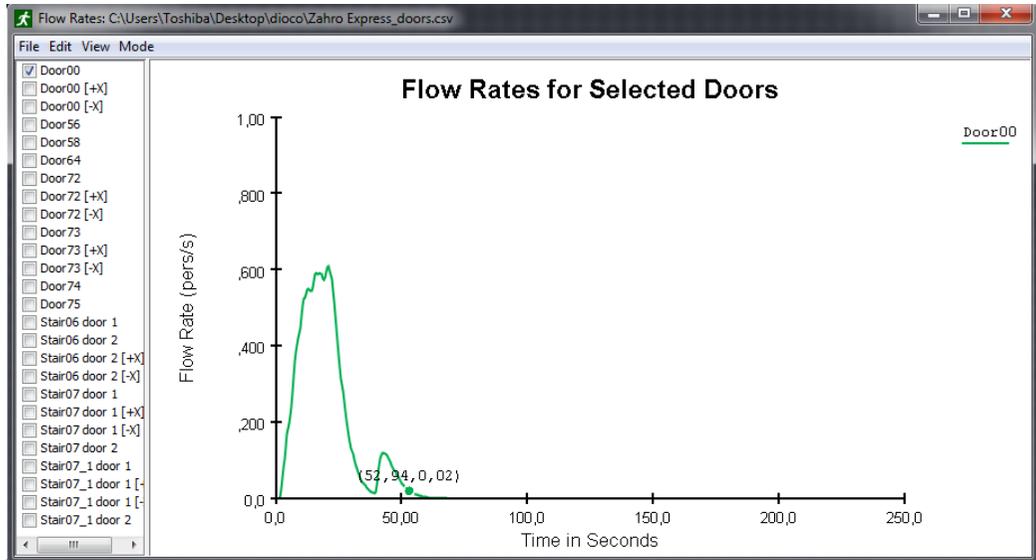
Flow Rate for Door 00
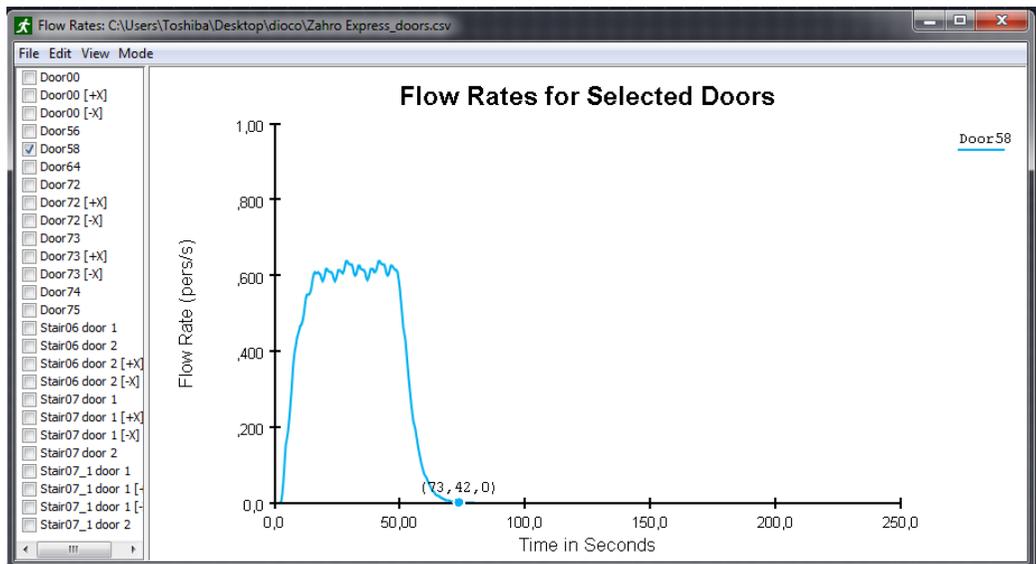
Flow Rate for Door 58
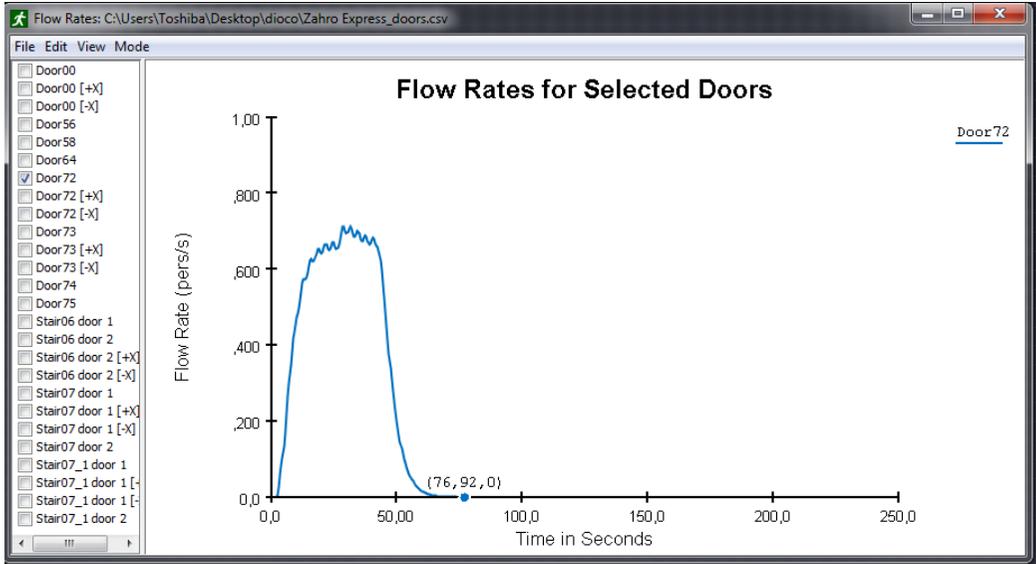
Flow Rate for Door 72
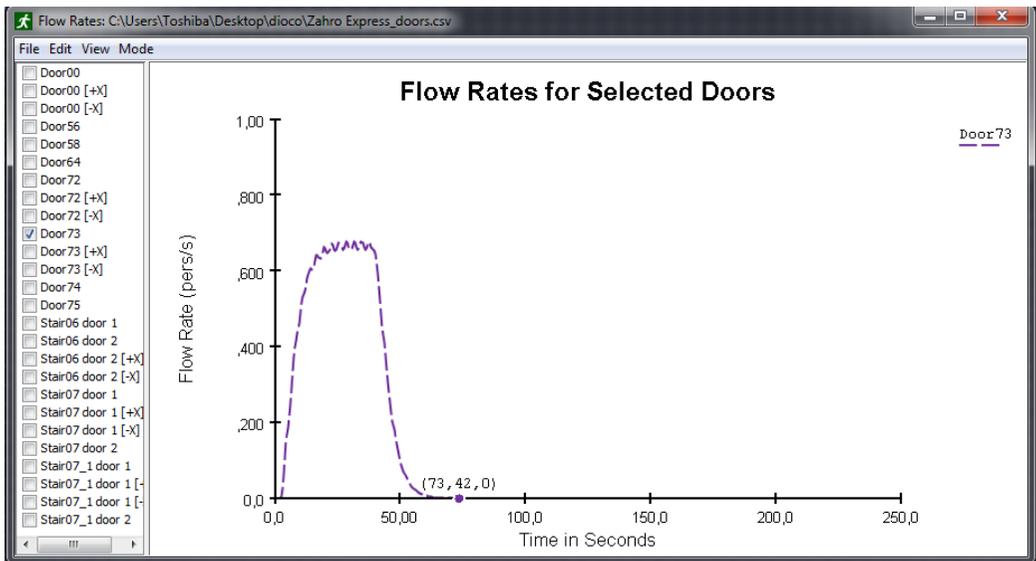
Flow Rate for Door 73
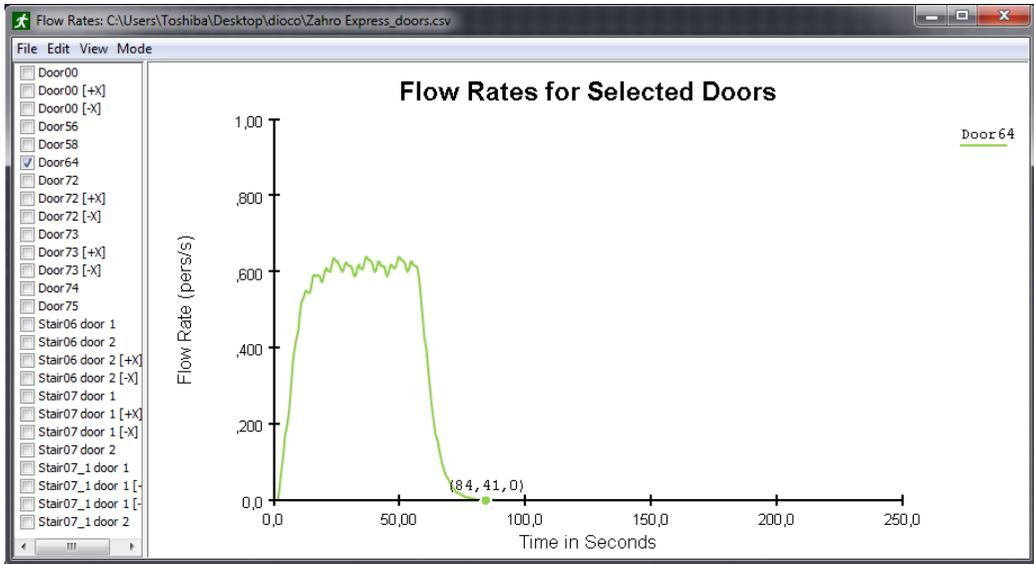
Flow Rate for Door 64
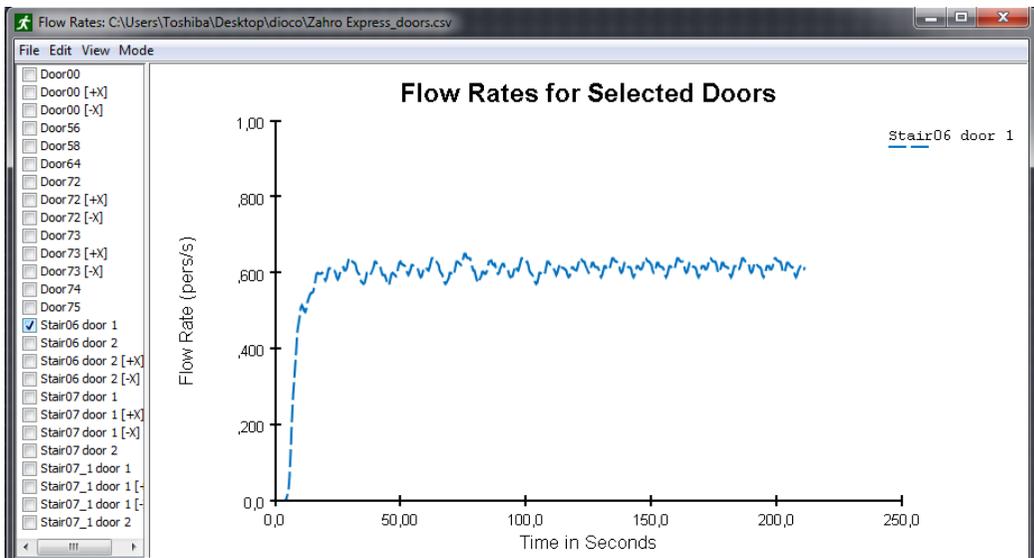
Flow Rate for Stair 06 Door 1
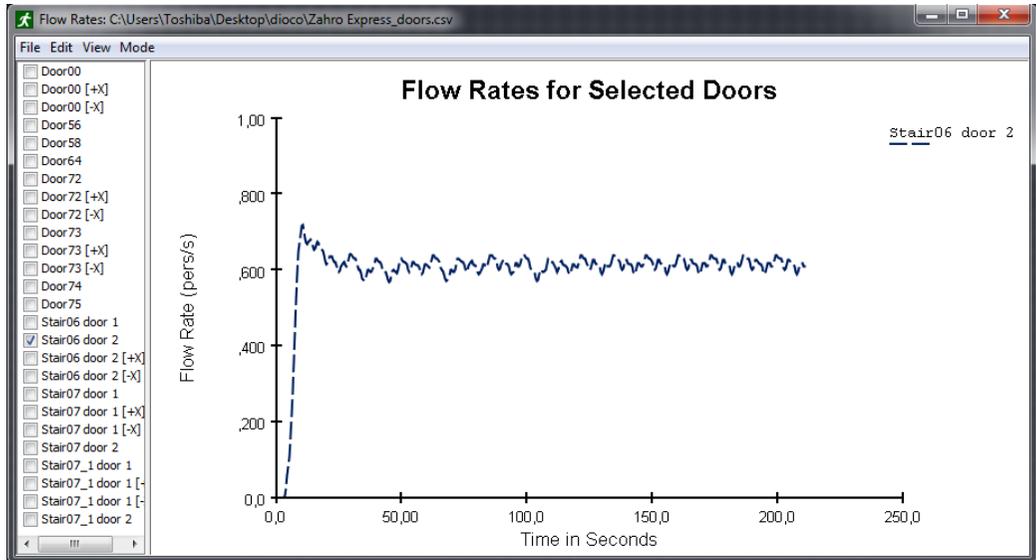
Flow Rate for Stair 06 Door 2
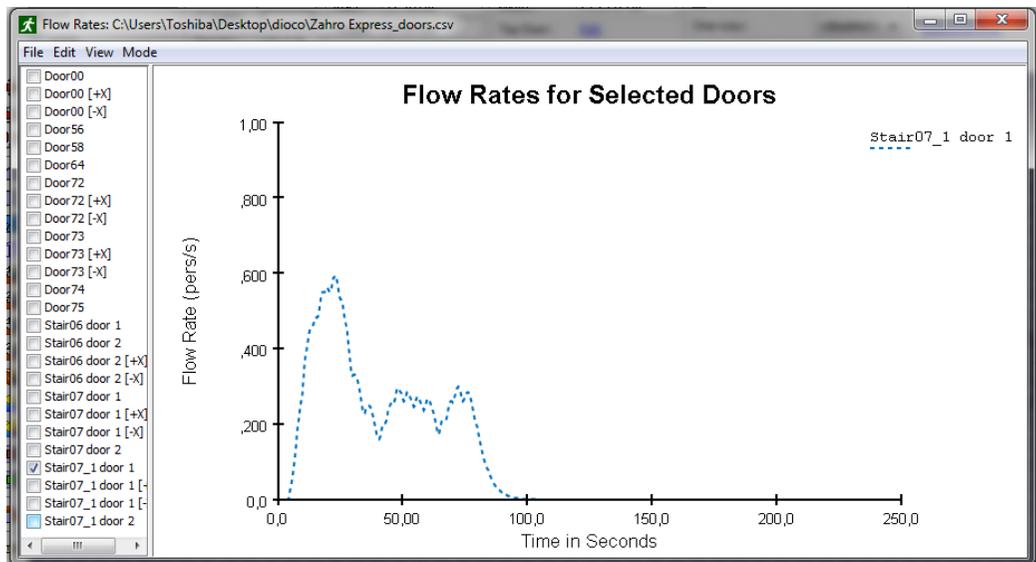
Flow Rate for Stair 07 Door 1
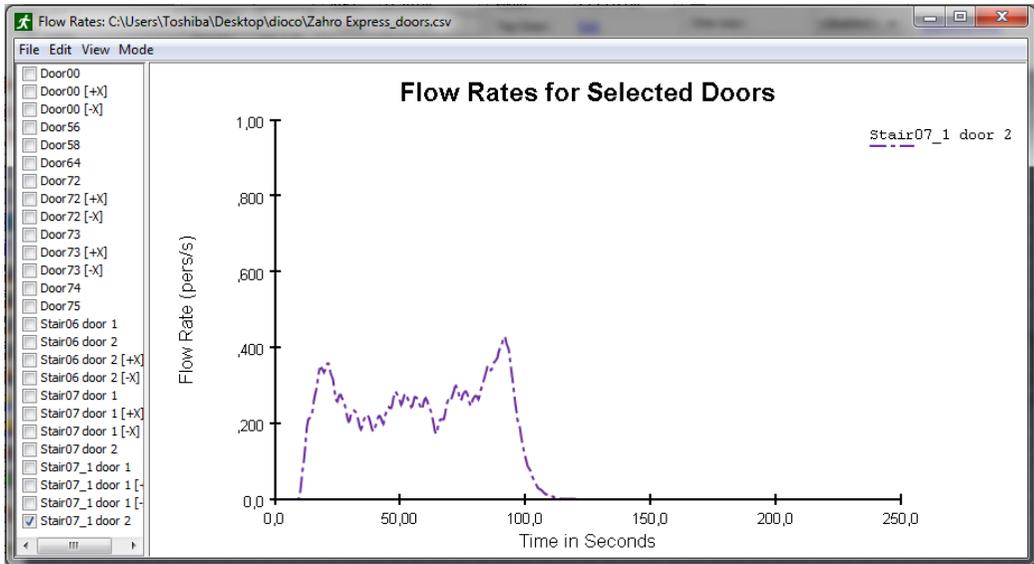
Flow Rate for Stair 07 Door 2

ATTACHMENT 5

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KEMENTERIAN RISET, TEKNOLOGI, DAN PENDIDIKAN TINGGI
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
LEMBAGA PENELITIAN DAN PENGABDIAN MASYARAKAT
Gedung LPPM, Kampus ITS Sukolilo - Surabaya 60111
Telp : 031 - 5953759, 5936940, Fax : 031 - 5955793, PABX : 1404, 1405
http://www.lppm.its.ac.id

LAPORAN HASIL PENGUJIAN

Nama Pemilik : Dioco Carlos Kristian

Alamat Pemilik : Teknik Sistem Perkapalan

Nama Contoh : **Kayu Mentru** Tanggal Terima : 25 Apr 2017
Deskripsi : Bentuk : Padat/~~Cair/Gas~~ Tanggal Pengujian : 03 Mei 2017
Contoh Volume : - Tanggal Selesai
  Kemasan : plastik Pengujian : 05 Mei 2017
Kode Contoh : **EI-232** Jumlah Contoh : 1

Menyatakan bahwa contoh tersebut di atas telah diuji di Laboratorium Energi & Lingkungan – LPPM ITS.

No.	Nama Contoh	Jenis Uji	Hasil	Satuan	Metode Pengujian
1	Kayu Mentru	kalori Meter	4.197	Cal/gr	Bomb Kalorimeter

Suhu : 23°C
Humidity : 71%
Analis : MBB

Catatan:
1. Hasil pengujian hanya berlaku dari sampel yang diuji.
2. Labotorium tidak bertanggung jawab atas kerugian pada pihak ke tiga.
3. Laporan hasil pengujian hanya diperbanyak secara utuh.

Manajer Puncak
Laboratorium Energi dan Lingkungan

Dr. Ir. Susianto, DEA
NIP. 19620820 198903 1 004

Manajer Teknis

Vita Yuliana, S.Si
NIPH. 914014001
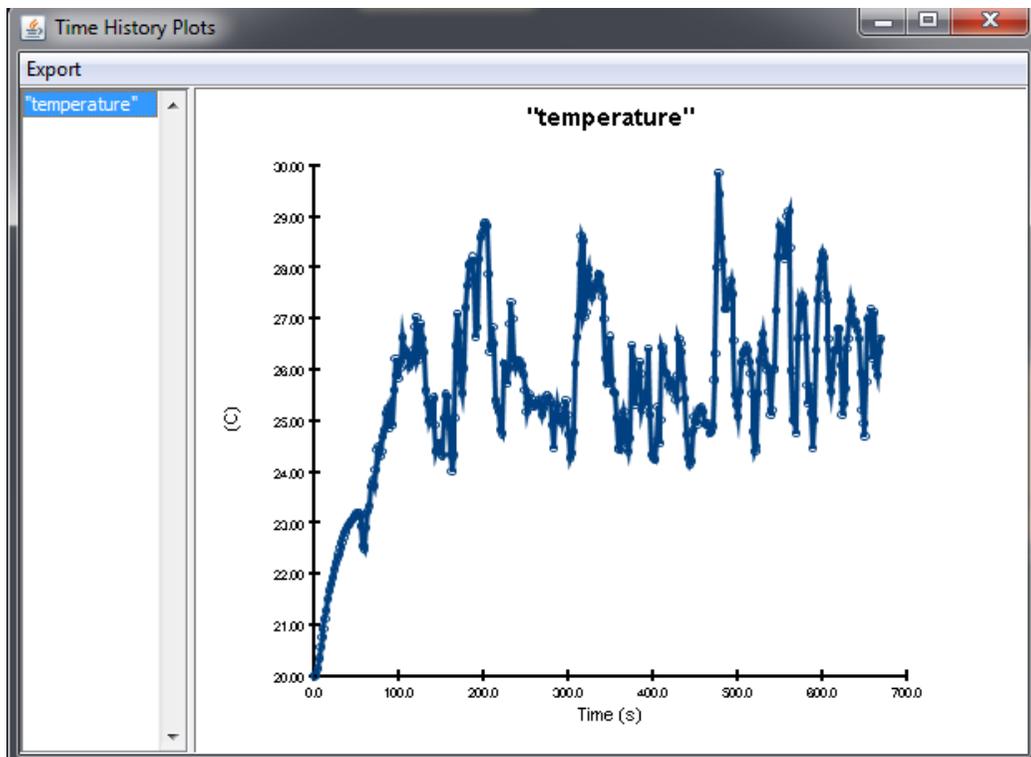
AUTHOR PROFILE

Author's name is Dioco Carlos Kristian Perdana was born in Surabaya, June 14th, 1995. The writer studied Elementary School at SDN Kaliasin III Surabaya in 2001, Junior High School at SMPN 6 Surabaya in 2007 and Senior High School at SMAN 4 Surabaya in 2010. Then the writer continue the education at Department of Marine Engineering Double Degree, Insitut Teknologi Sepuluh Nopember - Hochschule Wismar in 2013. During the lecture, the author became part of the Student Executive Board an the Faculty of Marine Technology, had been a staff in Human Resource and Development Department in 2015 to ever become Head of Human Resource and Development Department in 2016. On the Job Training experience has already done in PT. Bandar Abadi Shipyard (Batam, Riau Island) and PT. Pertamina Shipping Persero (Tanjung Priok, DKI Jakarta). In the 3 years of study, the author joined with the reliability, availability, maintenance, and safety laboratory (RAMS) and completed studies for 8 semesters.