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AIRCRAFT EVACUATION PROCEDURE USING DISCRETE EVENT SIMULATION

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ABSTRAK

Tesis ini adalah mengenai prosedur pemindahan pesawat menggunakn kaedah Discrete Event Simulation (DES). Proses pemindahan pesawat ini perlu di lakukan apabila berlakunya kecemasan seperti kerosakan enjin, kebakaran, dan asap. Pesawat perlu dikosongkan dalam tempoh 90 saat bagi mengurangkan risiko kehilangan nyawa. Hal ini kerana, kemungkinan bagi penumpang yang diselamatkan selepas tempoh 90 saat untuk selamat sangat tipis. Kebiasaannya, ujian proses pemindahan ini dilakukan secara manual. Namun, ujian yang dilakukan secara manual memerlukan kos yang tinggi dan mengambil masa yang lama. Pihak pesawat perlu mencari lebih dari 300 orang untuk dijadikan sebagai penumpang semasa latihan. Masa yang lama diperlukan untuk menerangkan kepada semua orang tentang prosedur dan tindakan yang perlu dilakukan. Krew-krew juga perlu melibatkan diri semasa ujian pemindahan pesawat. Hal ini melibatkan ramai pihak. Oleh itu, ujian pemindahan pesawat menggunakan simulasi ini diwujudkan. Tujuan kajian ini adalah untuk mengkaji samada ujian pemindahan pesawat secara simulasi lebih baik berbanding secara manual.

ABSTRACT

This thesis is about aircraft evacuation procedure using Discrete Event Simulation (DES) method. The evacuation process must be carried out in the event of an emergency such as engine failure, fire, and smoke. The aircraft must be emptied within 90 seconds to reduce the risk of loss of life. This is because, it is possible for passengers to be saved after 90 seconds to safely thin. Usually, the process of transfer process is done manually. However, manual tests require a high cost and take a long time. The aircraft management had to find more than 300 people to serve as passengers during training. Long time is needed to explain to everyone about the procedures and actions to take. The crews also need to engage during the evacuation. This involves many parties. Therefore, aircraft evacuation test using these simulations are created. The purpose of this study is to study whether the flight test is better than manual simulation.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Aircraft is a machine that gaining support from air to fly and it is one of the famous transport for all people around the world. The time required for travel from one place to another is shortest when using the aircraft compared to other transports, which is why the aircraft is passenger choice as it saves travel time. Every country has their own airline. In Malaysia, there are several famous major airlines. For example, AirAsia, Malaysia Airlines, and Firefly. Each of them has their own aircraft. Malaysia Airlines has Airbus A330-200, Airbus A330-300, Airbus A350-900, Airbus A380-800, Boeing 737-800 and Boeing 737 MAX. AirAsia has Airbus A320200, Airbus A320neo and Airbus A321neo while Firefly has ATR 42/72, Boeing 737 and Fokker F50/F60.

Evacuation are the action of transferring people from an area or threatened place as a security measure. It can occur at school, mall, airport, and also can happen in aircraft. Aircraft evacuation refers to emergency evacuation from an airplane or aircraft which can occur during on the ground, mid-flight, or in water. It is the urgent egress or escape of people away from an aircraft that have threat or hazard to property or lives. It is very important to ensure the safety of passengers because there are various risks that the passengers may encounter during the flight for example technical issue, threat or a hazard.

Each of evacuation process has their own procedure. For aircraft evacuation, it is included with locating and using the emergency exits, using slides and flotation device for water landings. Every aircraft manufacturers are required to demonstrate that the aircraft can be completely evacuated within 90 seconds. During evacuation simulation,

only half of the total emergency exits will be used. It is as a preparation because there is a possibility for failed evacuation devices or exits blocks due to structural damage and fire during the actual incident.

Is it by using discrete event simulation (DES) to model simulation for aircraft evacuation procedure is better than manual simulation? The purpose of this study is to determine that the simulation for aircraft evacuation using DES is more efficient. This study will focuses on modeling the evacuation procedure using discrete event simulation.

1.2 PROBLEM STATEMENT

Every new aircraft need to pass the evacuation procedures before the aircraft can be on sale. Simulation is a method to mimic the real scenario into a virtual scenario. In order to investigate the evacuation process on the new aircraft, discrete event simulation method will be used as it can model a realistic representation of a real scenario.

First problem statement is manual aircraft evacuation simulation will involve many parties during the evacuation test. Most of the existing evacuation use the manual process for the aircraft simulation. To ensure the evacuation test can be carried out as real events, the test should involve a large number of people to act as passengers. The evacuation test without passengers is still possible, but the evacuation test seems to be unreal. With passengers during evacuation, the crew can observe various possible possibilities that will slow down the evacuation process.

Second problem statement is passenger behavior during aircraft evacuation procedure. Fast movement by passengers during aircraft evacuation is very important as it is one of the factor that will determine the fate of other passengers and cabin crews. There are some passengers who are more concerned with their things than their own life. When an instruction to empty the aircraft was given, they were still able to pack their belongings without knowing they were in danger.

Third problem statement is discrete event simulation (DES) is less explore by people and also does not know what the advantages when using DES. It is a method of simulating the performance and behavior of a real life process. Most people are not exposed to DES. For aircraft evacuation procedure, DES rarely used because most evacuation procedure are involve with manual procedure.

Table 1.1 Summary of problem statement

No.	**Problem**	**Description**	**Effect**
1.	Manual aircraft evacuation simulation will involve many parties.	During manual simulation, aircraft manufacturers need to hire many people to act as passengers.	Difficult to handle and will involving high costs.
2.	Passenger behavior during aircraft evacuation procedure	There are some passengers who are more concerned with the things than their own lives.	Will slow down the evacuation process.
3.	Discrete event simulation (DES) is less explore by people	Most people do not know about the advantages of using DES for aircraft evacuation simulation.	DES rarely use for aircraft evacuation procedure.

1.3 OBJECTIVE

The goal of this research is to develop a simulation about aircraft evacuation procedure for Airbus A380 using discrete event simulation. In order to achieve the research goal, several objectives must be fulfilled. The objectives of the research are:

i. To study on the evacuation procedure for aircraft.
ii. To model the evacuation procedure using discrete event simulation.
iii. To validate the simulation model using sensitivity analysis method.

1.4 SCOPE

This research consists of 3 scopes covered. The scopes are:

i. Study on aircraft evacuation procedure for Airbus A380.
ii. To explore discrete event simulation to be used for aircraft evacuation.
iii. Use discrete event simulation to develop a model for evacuation procedure.

1.5 REPORT ORGANIZATION

This report consists of five chapters. Chapter 1 shall discuss on introduction to the research, it includes the problem statement, objectives, and scope of the project. In chapter 1, the definition of aircraft, type of aircraft, aircraft evacuation and discrete event simulation (DES) are briefly explained.

Chapter 2 shall discuss the reference and the literature review. This chapter will be focusing on reviewing other related works, and compare the content of each references.

Chapter 3 illustrates the methodology. This chapter will propose an overall approach to solve and enhance the existing problem. The flow of conducting the research will be presented in this chapter.

Chapter 4 discuss about the implementation of discrete event simulation (DES) for aircraft evacuation procedure using agent based simulation. Effectiveness of DES will also be discussed in this chapter.

Chapter 5 is about summarization. A summary about the research that already done. Finalization of the result and possible future improvement will be discussed.

CHAPTER 2

LITERARTURE REVIEW

2.1 INTRODUCTION

This chapter discussed about the literature review of the research. It not only just state the summary about the research but also consist a critical discussion, showing a detail understanding and contradiction of techniques, theories and methods.

A literature will describe about the existing problem or solution done by other parties, and detail about techniques/method/hardware or technologies that will be use in this research. It also will be focus on overall information of aircraft evacuation procedure, discrete event simulation and evacuation efficiency.

2.2 AIRCRAFT EVACUATION PROCEDURE

Aircraft Evacuation procedure is a process of emptying an aircraft when an emergency occurs. This evacuation can happen whether on land or water. It has procedure to make sure evacuation process run smoothly. Based on Title 48 Code of Federal Regulations (CFR) part 121.29, a new aircraft with a seating capacity of more than 44 passengers must conduct aircraft evacuation test of the full capacity and process need to complete within 90 seconds to qualify for a certificate (Federal Aviation Regulation, 2015). It is very important to follow the standard and ensure the efficiency evacuation procedure because failure to evacuate the aircraft within the prescribed time can cause injury or death of passengers and crew.

The aircraft evacuation system has three key elements that are exits and slides, efficient means of reaching the exits, and the crew and passengers who use them. Evacuation performance actually need enhanced cabin safety to prelude incapacitation from impact, smoke, heat, and toxic gases before egress can be achieved. Evacuation performance also depends on the design and operation of emergency equipment and flight attendant training ("RESEARCH AND TECHNOLOGIES FOR EVACUATION SYSTEMS," n.d.).

There are two examples of severe accidents investigated by the Safety Board in the last decade illustrate some of the safety issues pertaining to emergency evacuations. The first one is USAir Boeing 737 and a Skywest Metroliner collided on the runway at Los Angeles International Airport on February 1, 1991. The second accident is on November 19, 1996, United Express flight 5925, a Beechcraft 1900C, collided with a King Air at the airport in Quincy, Illinois (Hall, Hammerschmidt, Goglia, Black, & Carmody, 2000).

Evacuations have two main types, one of the type is planned evacuation. Meaning that cabin crew have sufficient time exists to inform and prepare the passengers for an emergency evacuation, and review the procedure. Cabin crew briefing the passengers with the step of evacuation, point the location of nearest emergency exit, and show safety instruction card. The emergency checklist also used in planned evacuation. It used to help the cabin crew to do the preparation for emergency, and has all the steps required to prepare the cabin. It also contains the step to be completed in order of priority. With the existence of emergency checklist, it provide support to cabin crew to help the complete all the important steps without forgetting anything. The result from cabin crew preparation and briefing cause the number of passengers injured during evacuation is with few to no injuries. There are a few operational standards for a planned evacuation such as planned evacuation briefing. During emergency situation, communication play very important role. The successful evacuation of the aircraft depends on the rate of

communication effectiveness between passenger, cabin crew and flight crew. For example, during emergency occur, maybe the flight crew use specific signal to inform the cabin crew such as a specific word or a series of alarm. Other operational standard is the cabin crew to passenger briefing. The flight crew are very busy in the cockpit during emergency, so the cabin crew will required to make the announcement to the passengers about emergency situation, cabin crew instructions, and the need to prepare the cabin. During evacuation briefing, cabin crew cannot walk up and down the aisle, and need to coordinate the demonstration with the announcement. During briefing also, cabin crew cannot talk because worried will distract the passenger's attention from the briefing.

The other type is unplanned evacuation means that the crew member have insufficient time to brief the passengers about the emergency evacuation. The operational standard for an unplanned evacuation is silent review. Silent review or 30 seconds review is a tool that cabin crew can use to prepare for unexpected events. Cabin crew should perform this review during takeoff and landing process. This review can help cabin crew to prepare and react rapidly when emergency happen because all the important elements needed for review the evacuation are in silent review. It contains several things such as location of exits, location of equipment, commands, and brace position. During takeoff or landing, cabin crew need to alert about any indication of a possible emergency such as, unusual aircraft attitude, unusual noises, fire, and smoke. Cabin crew play very important role during the emergency, because all information given by cabin crew will help the flight crew to make decision whether need to evacuate or not. There are some cases when there is disaster situation, like no communication from flight crew, smoke, uncontrollable fire, emergency ditching landing on water, and serious damage to some parts of the aircraft, the cabin crew need to make decision to initiate an evacuation. The delay of making decision will affect the evacuation process and can cause the number of injured or dead victims to increase. There are a few factors that can influence the successful of aircraft evacuation. An assertive cabin crew play very important role because they must strict, clear, loud, and short when give command. They also must ready to use some physical force when needed during evacuation process. Next factor is brace commands. It is the first and very important command given to passengers in an

unplanned evacuation. Brace is position passenger should do when hear the cabin crew shout “Brace! Brace! Brace!” There are two option for brace position. First is place feet flat on floor, heads down by lap, and put arms under knees. Second position is place feet on floor, cross writs and place on seat back in front, and rest foreheads on crossed hands. The other factor is assessing outside conditions. It is very import for cabin crew to check the outside conditions whether it safe or not before opening an exit.

2.2.1 AIRCRAFT EVACUATION ON LAND

Aircraft evacuation on land is the process of evacuate the aircraft on land when emergency occur. Although the emergency happen during flight, the aircraft need to landing immediately at nearby airports and make sure the aircraft has stopped completely to start the emergency evacuation. This evacuation happen for many reason that can bring threat to the passengers and cabin crew. For example, during aircraft on runway prepare to take off, one of the engine has problem and the warning system is activated. The aircraft stopped on the runway because there are smoke and flames on the left wing of the aircraft. Due to this problem, other remaining engine is shut down and evacuation process needs to be done.

2.2.2 AIRCRAFT EVACUATION ON WATER

Evacuation on water basically involve the same procedures with evacuation on land except for a few things. Passengers should know about the ditching procedure or water landing. Landing on water is very rare for commercial aircraft, but smaller aircraft tend to land more often because normally small aircraft have only one engine and have less redundant system. Actually, water landing is one of the most suitable and survivable emergency procedures that any pilot can perform because it is much safer than landing on trees or in a forest. Most of the latest aircraft have a control system to allow pilots to shut down all openings and air valves in the airplane to ensure they can float on the water.

The pilot also need to make sure the wings level is at secure level to prevent from being hit by wave that can cause the aircraft to break apart.

The most important thing for evacuation on water is life jacket. Cabin crew need to demonstrate how to wear the life jacket and make sure the passengers know how to wear it and, understand how and when to inflate it. Life jacket for the crew should be different color with passengers. The cabin crew also need to show the emergency exits and show the safety instructions card. There are a few things need to consider when preparing to evacuate on the water. Crew member need to determine the water level outside and inside the aircraft. Exit cannot be used if the water level is above the door sill, then the life raft can be detached and moved to another usable exit. The number of passengers use raft cannot exceed the limit of raft capacity. Assign crewmember to each raft to give command and guide passengers.

2.3 AIRCRAFT EVACUATION EFFICIENCY

Aircraft evacuation efficiency means the rate of evacuation effectiveness performed within prescribed time. It plays an important role in determining the fate of crew and passengers. There are a few factors that influence the evacuation efficiency.

First factor is people behavior. It is important factor that effect the emergency evacuation and related to nature of passenger. The behavior varies by age, gender, physical ability of an individual, body size. It is a factor that hard to understand and handle. Passenger thought and behavior may different depending on the background and their environment. Each person have their own psychological characteristics such as have ability to make the right decision during an emergency, have skill to understand emergency information immediately, and have various responses during emergency evacuation. There are some researches that already done to investigate the effect of selfish behavior and passenger panic level during emergency evacuation. This attitude can cause congestion on the exit of the aircraft, slowing down time for evacuate the aircraft, and

may cause failure of aircraft evacuation (Du, Zhang, & Yang, 2014). Another behavior is relations among passengers. This attitude means that travelling companions or family member will stick together during evacuation, and will create groups of passenger moving together. This can cause time to empty the aircraft slowly, and may endanger the lives of other passengers.

Another factor is passenger movement. It means that the movement of the passengers from start to end of the evacuation process, movement during in the cabin aisle, movement to the usable exits, and movement when using slide. The passenger should start moving immediately when the cabin crew announce to evacuate the aircraft. The passenger need to follow the emergency arrow to ease the movement. The movement may affect the evacuation process because passenger need to evacuate from the aircraft as soon as possible. One of the reason why passengers movement slow are due to their personal items. Passengers insist on not abandoning their items even though they were directed by the crew to leave the items. Another reason is the passengers are not fully prepared to face the emergency evacuation. Passengers have no knowledge and do not understand what the cabin crew brief to them before takeoff. This causes passengers not knowing what to do after receiving instructions to evacuate the aircraft. Cabin crew need to help the passengers to make sure the evacuation run smoothly and finish within 90 seconds to reduce the risk of injuries to passengers. Table 2.3.1 shows the movement speed according to passengers' type (Deng, 2016).

Table 2.3.1 Passenger movement speed

Passenger type	Speed (m/s)
Children	1.08
Female elderly	1.04
Male elderly	1.05
Elderly	1.04
Female adult	1.24
Male adult	1.30
Adult	1.27

Environmental also one of the factor that can affect evacuation process. Environmental factors consist a few things such as presence of smoke and toxic gases, the orientation of the aircraft, cabin maybe exposed to water, the increasing of cabin's temperature and, increasing in lighting level in the cabin (E. R. Galea, Blake, & Lawrence, 2001). Environmental also about weather on aircraft flight. Weather can affect the evacuation process. There are reports show that during evacuation, environmental factors can increase the chance for passengers' injury. The behavioral and cognitive impairment as a result of these factor made evacuation process more challenging and likely to be unsuccessful. There is a research that has been done to study the effects of non-toxic smoke on the evacuation process of aircraft (Aviation, 2001).

Configurational is one of the factors that give the huge effect for evacuation process. Configurational means the layout design for the aircraft that can influence the passengers' access to usable exits. It including exit location, type of exit, aisle width, bulkhead width, and the seating arrangement. For example, an accident happen in England involve Boeing 737, found that the alarm set-off and smoke during the emergency evacuation make the passengers panic, cause congestion and chaos during emergency evacuation. If the width of bulkheads leading to the front exit are so narrow, the passenger will stuck at the bulkhead and exit rows. This situation will slow down the evacuation process.

2.4 TYPE OF TECHNIQUE

A few techniques that can be used to ensure that the evacuation procedure run smoothly are artificial intelligence, virtual reality, and simulation. Artificial intelligence is an area of computer science that focus on development of intelligent machines that react and work like humans. It also able to perform tasks that normally required human intelligence, for example such as speech recognition, problem solving, visual perception, and translation between languages. This software can be used to demonstrate the aircraft evacuation process. It allows to implement important elements like seating configuration, exits, and slide. Another technique is virtual reality. Virtual reality is the computer generated simulation of a three dimensional image or environment. It can be use using special electronic equipment. Example of the equipment are helmet with a screen inside and also gloves fitted with sensors. Simulation one of the most technique use to simulate the evacuation process for aircraft.

2.5 SIMULATION MODEL

Simulation is an imitation of the real events or process. Using simulation, it have capabilities to allow understanding and analysis how the process happen. Simulation model can be used to test many events or procedures, for example such as simulation of passenger traffic in airport, simulation of road traffic and simulation for aircraft evacuation procedure. Aircraft evacuation procedure using simulation is to demonstrate the simulation and can determine the best procedure or step to make sure the evacuation process not more 90 seconds.

Simulation model is a better way to test aircraft evacuation procedure compare to manual test. There are possibility threat of injury to the volunteers involve in manual evacuation test. Between 1972 and 1991 a total of 37 volunteers sustained injuries ranging from cuts and bruise to broken bones (E. Galea, 2004).

To overcome all the effects of manual evacuation test, simulation models have been develop recently to simulate the evacuation process instead of evacuating manual evacuation test. The simulation model not only will reduce cost and avoid potential risk in manual evacuation test, but also provide insight about new aircraft and how the result of the test before the aircraft is physically build (Liu, Wang, Huang, Li, & Yang, 2014).

In aircraft evacuation certification test, Federal Aviation Administration (FAA) law prohibits the use of disabled people, children, smoke, and fire for the safety reason. So the tests are done in not real situation. Human behavior under real emergencies can be very different from those in certification test. During real evacuation, passenger will not as calm as during certification test because they are in real danger (Sharma, Singh, & Prakash, 2008).

There are a few common type of simulation technique used such as discrete event simulation (DES), agent based simulation (ABS), and system dynamic simulation (SDS). However, many DES used for modeling evacuation procedure because it is faster and also provide more accurate approximation of a system's behavior.

2.6 CURRENT IMPLEMENTATION OF DISCRETE EVENT SIMULATION IN AIRCRAFT EVACUATION PROCEDURE

Discrete event simulation (DES) is actually a process of codifying or simulating the behavior and operation of a system or real-life process. DES is rarely used in creating a simulation model for aircraft evacuation procedure. However there are still have a few implementation of DES. The research use DES to construct a model to investigate the

evacuation process for commercial aircraft by considering the passenger's path from the seat to the exits, and the slide-down processes in the evacuation (Deng, 2016).

CHAPTER 3

.

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss about the methodology that will be used for the success of this research. Methodology is a system of method, theoretical analysis of the methods used in a particular area of study. Methodology that been decided to use for this research is the research-based methodology. Research methodology is the process involve to collect the data and information for establishing a new facts or conclusions. The iterative method has been choose as the core structure for this research instead of use the traditional method.

3.2 METHODOLOGY

Figure 3.2.1 shows the research methodology that used in this research with the iterative methodology.

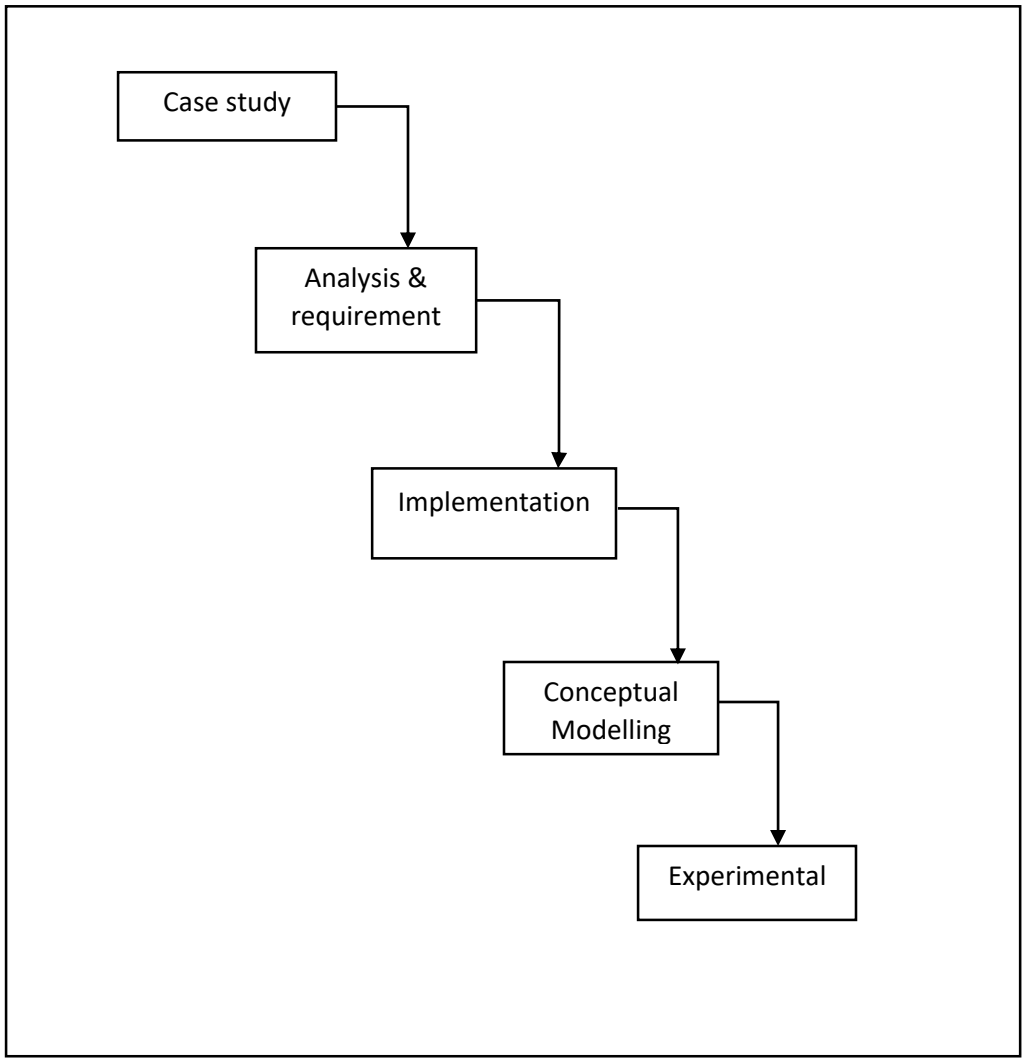


Figure 3.2.1 Purposed methodology

3.3 PHASE 1: CASE STUDY

Aircraft Evacuation Procedure using Discrete Event Simulation (DES) is a simulation modeling for aircraft evacuation during emergency occurred. This simulation modelling can provides the better display of evacuation and can determine the best procedure for an aircraft to improve the process, passenger movement, configurational and efficiency. Is it by using discrete event simulation to model simulation for aircraft evacuation procedure is better than manual simulation? This is the research question that led to this research.

3.3.1 DEFINE OBJECTIVE

Goal for this research is to develop a simulation about aircraft evacuation procedure for Airbus A380 using discrete event simulation. There are several objectives that need to fulfil to achieve the research goal. First objective is to study on the evacuation procedure for aircraft. Every new aircraft need to get the certificate to allow the aircraft to operate. To get the certificate from Federal Aviation Administration (FAA), aircraft need to do evacuation test and must finish the evacuation process in 90 seconds.

The second objective for this research is to model the evacuation procedure using discrete event simulation. From this objective, there are a few factors that can increase the evacuation procedure efficiency which are aircraft configurational, people behavior and passenger movement. Using simulation method, the evacuation procedure can be improved and more people life can be saved.

The third objective is to validate the simulation model using sensitivity analysis method. The sensitivity analysis gives information on how the exclusive parameter values

will influences model results and allow the users to speculate the degree of validity of a simulation model in absolute term.

3.4 PHASE 2: ANALYSIS

In this phase, the other research paper has been refer to be used as a reference material or literature review for this research. It show that there a few important requirements that can increase the effectiveness of aircraft evacuation procedure which are people behavior, passenger movement, environmental and configurational. This data will be used in the simulation to make sure the efficiency of aircraft evacuation procedure.

3.4.1 DATA COLLECTION

People behavior. It is a responses of groups of peoples or individuals to external or internal stimulation. Every people have different physical action and different emotion state. The behavior of people different within a range with some behavior are unusual, some being common, some beyond acceptable limits ad some acceptable. Herding or flocking always happen during emergency situation. Herding happen when people feel panic and very nervous. So they will lose the ability to think rationally and hard to decide on their own. This will causes people will follow the others assuming that they will exit safely and this will make more flocks of people start to form. There are a few factors that influence the people behavior which are genetics, experience, faith, and social norms. During emergency situations, it can cause extreme amounts of emotional and physical stress. How people respond when facing an emergency situation will determine the outcome of that situation. It is very important to know how to deal with this stress because the impact can be reduced. The most important thing is that it can increase the chances of survival. Table 3.4.1.1 shows the common reactions of people when facing the emergency situation.

Table 3.4.1.1 Common Reactions to Disaster

Response	Explanation
Anxiety	Anxiety and panic are a result when there is a fear of what will happen. When feeling panic, you must realize quickly that you are the person who causes the feeling of panic in itself to emerge, and then take action to reduce the level of your anxiety. Make a plan of action because it is the top way to relieve a troubled mind.
Depression	In an emergency situation, depression can be a killer because people almost impossible to make rational decisions during that time. People by this response need to keep the mind focus on positive thoughts. Congratulate self even for a small victory because it is very important to keep positive mind at all times.
Hyperactivity	During emergency situation, some people will feel become easily agitated. This will cause them to be easily distracted and make actions that will endanger their lives.
Anger	Anger is a familiar response to an emergency situation. This response can lead you to make unreasonable decisions. However, sometimes anger can give you strength and alertness when dealing with danger.
Guilt	It is a very common feeling for survivors to feel. They feeling guilty because they

	can survive, but cannot help the other victims. Sometimes, they blame themselves for that situation.

Passenger movement. Movement is an act of moving from one place to another place. The passenger movement during emergency is very important because it able to influence the result of the situation. During aircraft evacuation, the movement of passengers are really important. When cabin crew announce to evacuate from the aircraft, the passengers need to move as fast as possible and follow the right way. The movement of human are different based on age, gender, and situation. Table 3.4.1.2 shows the speed of human movement.

Table 3.4.1.2 Speed of Human Movement

Classification		Speed (m/s)
Under 15	male	1.02
	female	1.09
15-50	male	1.45
	female	1.23
50-70	male	1.19
	female	1.04
Over 70	male	0.99
	female	0.89
Infant and mother		0.88

Configurational. It is one of the main factor that can effect aircraft evacuation process. Configurational means the arrangement of every parts in a things. For this research, it is about the arrangement of the aircraft. Configurational of aircraft consist of size of aircraft, seat arrangements, location of the usable exits and others.

Airbus A380. It is an aircraft that have a double deck, four engine jet airliner, and wide body. It is the world's largest passenger airliner and manufactured by famous European manufacturer Airbus. This aircraft consists upper deck and lower deck. A380 has only 35% more seats than Boeing 747 but has 49% more floor area. The length for aircraft is 73 Meters and for cabin length is 50.68 Meters. The total for the seats are 494, which are 136 seats for upper deck and 358 seats for main deck. Figure 3.4.1.1 below shows the layout for Airbus A380.

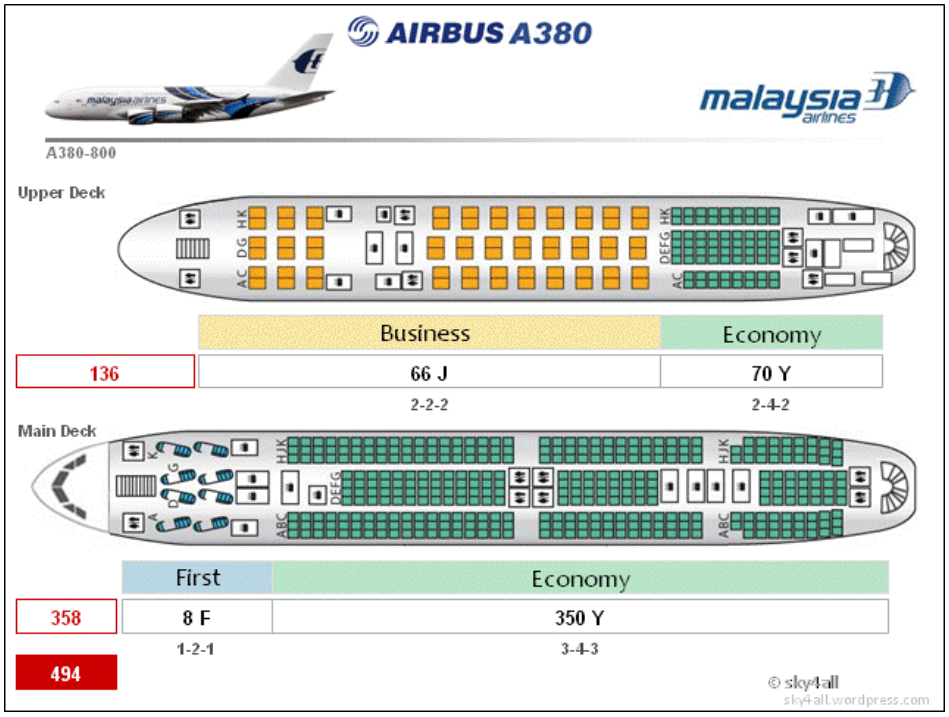


Figure 3.4.1.1 Airbus A380 layout

The configuration of aircraft for this simulation will use Airbus main deck consist first class and economy class. First class has 8 seats and for economy class has 350 seats. Each of first class seat is an open suites with 180 degree recline and width 26.1 while economy seat is a standard seat with 6 inch recline and width 18. There are 10 emergency exits located at main deck. Seat with pink color are bad seat because located at the last row of the main deck and will have limited recline. There may be a limit storage space because it usually use for crew equipment or luggage. Figure 3.4.1.2 shows main deck configuration Airbus A380.

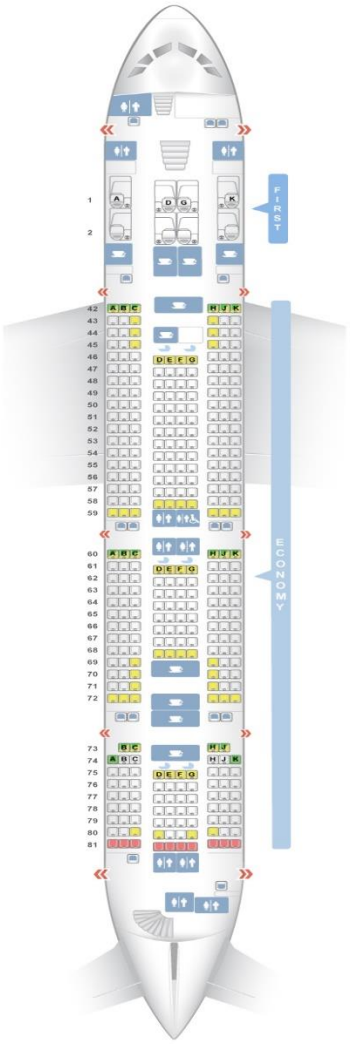


Figure 3.4.1.2 Main Deck Configuration

Upper deck for Airbus A380 66 business seats and 70 economy seats. Each of business seats is flat bed seats with 180 degree recline. Upper deck has 6 emergency exits that can be used during emergency situation. The seats labeled with yellow color are be aware seat because this seats are located at the last row of the business class cabin. The noise from economy class cabin may be bothersome. Figure 3.4.1.3 shows the upper deck configurational.

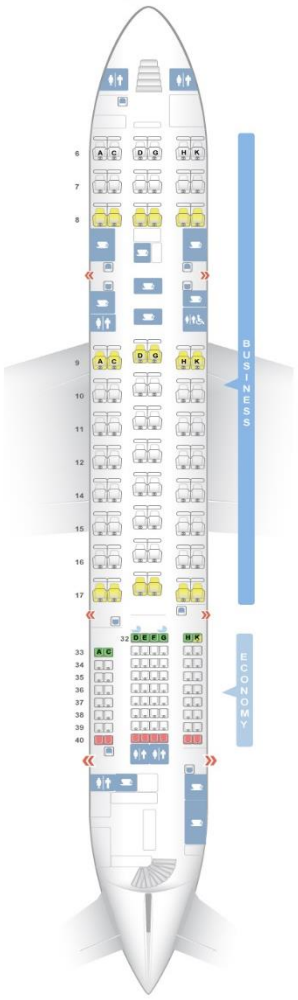


Figure 3.4.1.3 Upper Deck Configurational

Seat pitch for economy class is normally 31-32 inches and the seat width is 18 inches. Seat pitch mean the distance between the back of the seats in the row in front of

it and the back of the seat in a row. Figure 3.4.1.4 shows the cross section for economy class seating.

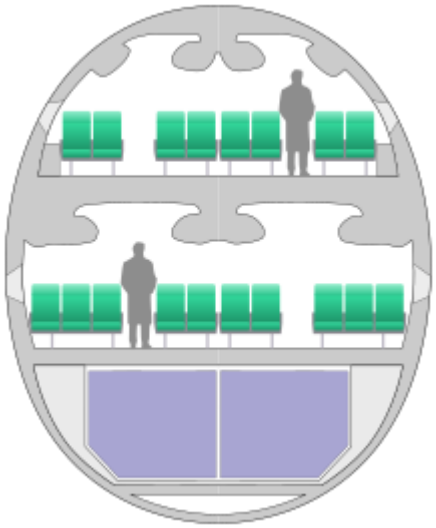


Figure 3.4.1.4 Cross Section Economy Class Seating

3.5 PHASE 3: IMPLEMENTATION

All the information gather previously will be analyzed and translate to the simulation modelling using Discrete Event Simulation (DES). It is a method of simulating the performance and behavior of a process, system, or facility. DES is usually being use in stress testing, health-care services, evaluating potential financial investments, and others. During literature review, it can be concluded that research using the DES method is rarely used especially in aviation. This has led to this research to see the benefits of doing the aircraft evacuation process by using a simulation with DES method compared to manual evacuation test. Figure 3.5.1 below shows the flowchart of aircraft evacuation procedure.

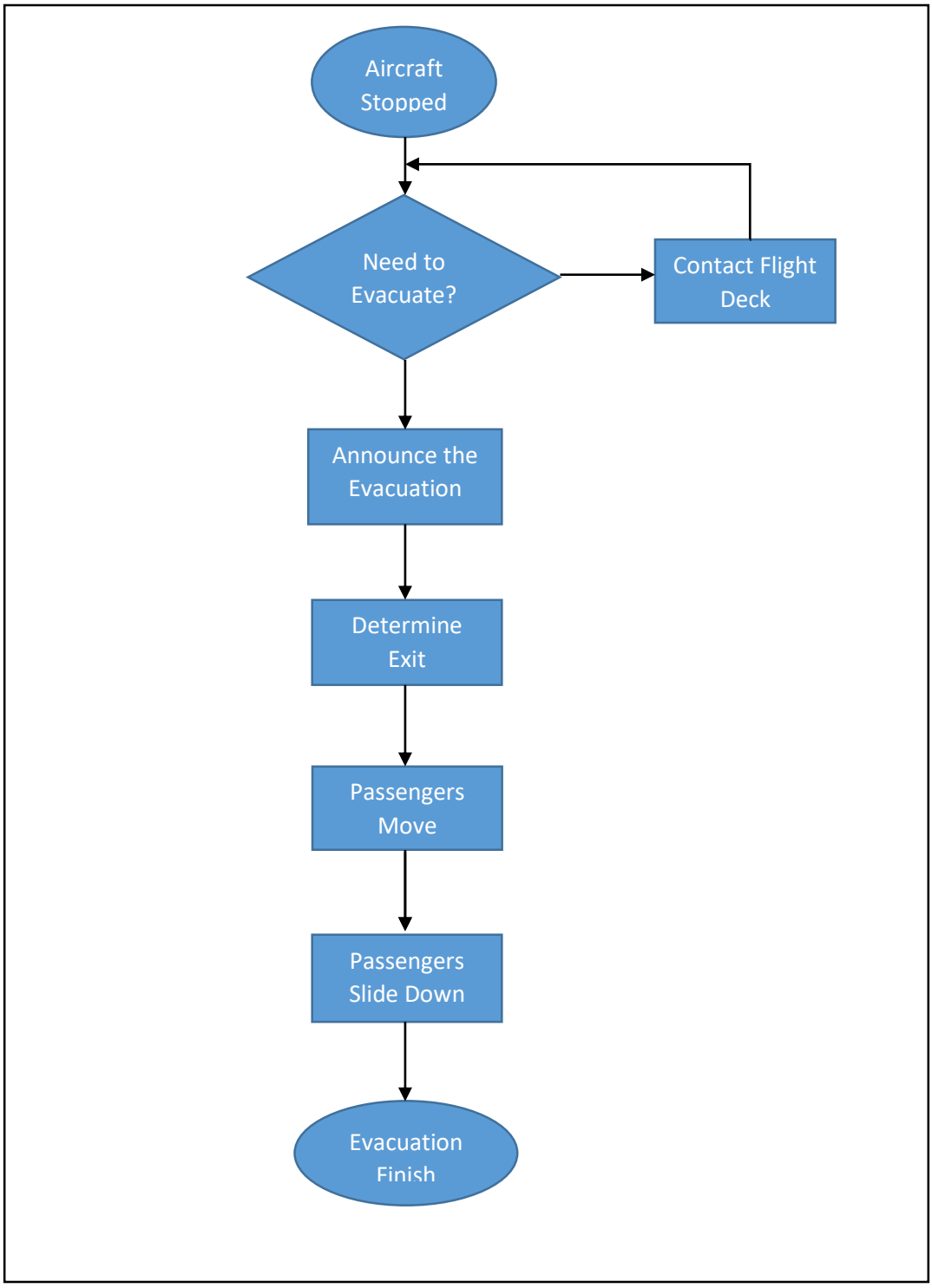


Figure 3.5.1 Flowchart of Aircraft Evacuation Procedure

3.5.1 STEPS IN AIRCRAFT EVACUATION PROCEDURE

Air Asia Airbus A380 is in on the way from KLIA to London, but suddenly the aircraft made an emergency landing on other airport. When the aircraft in the fully stop state, all the passengers release safety belt. Cabin crew need to make quick decision whether need to do evacuation process or not. If no evacuation signal received, and no indication of danger or signal received to not evacuate, the cabin crew need to contact the flight deck immediately. The cabin crew need to follow the PIC's instruction. If PIC instruct to evacuate, all crew member and passengers need to follow the procedure.

After aircraft landing and stop moving, if cabin crew receive evacuation signal and indication of danger, the cabin crew decide that evacuation process need to do immediately. The cabin crew announce the evacuation and ask the passengers to follow the instructions given and leave all the belongings which can interfere with the evacuation process. In the event of an emergency, the passengers are always concerned about the belongings as compared to their own lives. The impact of some passengers with that behavior may also results in the death of others passengers because of delay in evacuation process.

Determine Exit. In aircraft evacuation test, only half of the total emergency exits will be used. This is because during real event, there are probability that some of the exits blocked due to structural damage or fire. This is a preparatory step to face the real situation. During evacuation happen, it really important to determine the exit because it can affect the duration of evacuation process. The cabin crew will determine the usable and closest exit with the passengers.

Passengers move. After the usable exit decided, the cabin crew help to guide the passengers move from their seats to the exit. There are only one capacity to access the aisle from each group, means only one passenger that can get through the seat by aisle to the aisle and then evacuate. Based on the passengers' seat configuration, only the passenger seat by the aisle that can access the aisle directly. Passengers that seat at the

middle and by the window seat need to wait until the seat by the aisle become empty. This will formed a queue of passengers to get access to the aisle. At the aisle, the passenger can move to the usable exit.

Passengers slide down. It is widely implemented in evacuation simulation process to simulate passengers entering the aisle, moving through the aisle, and entering the usable exit. When the passenger at the usable exit, they need to sliding down on the slides. The simulation will end when the all the passengers evacuated successfully.

3.5.2 CONCEPTUAL MODELLING

Conceptual modelling is a way of representing of a system, made a concept that will help people to understand or simulate a subject of the model. Figure 3.5.2.1 shows the example of conceptual modelling for aircraft evacuation on land while figure 3.5.2.2 shows the example of conceptual modelling for aircraft evacuation on water

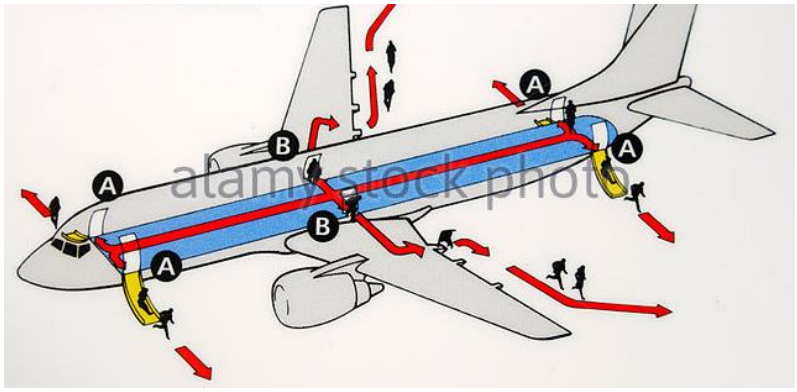


Figure 3.5.2.1 Conceptual Model for Evacuation on Land

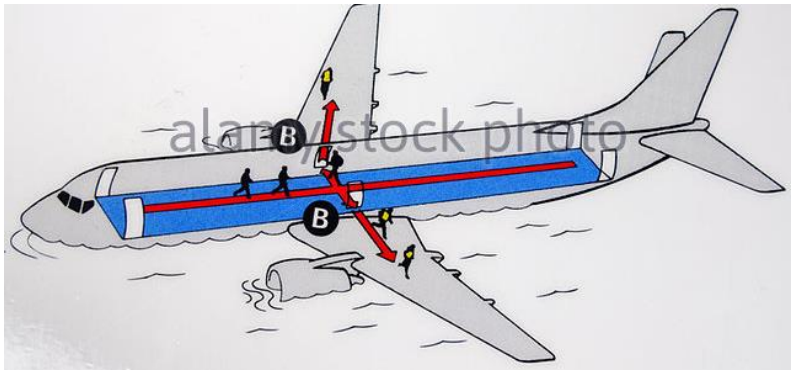


Figure 3.5.2.2 Conceptual Model for Evacuation on Water

3.5.3 EXPERIMENTS

Experiment 1: Number of Evacuation Exits

Experiment 1 will review about the effect of number of evacuation exit during evacuation procedure. In the simulation, the number of exits can be reduce and add easily using Anylogic tools.

3.6 HARDWARE AND SOFTWARE

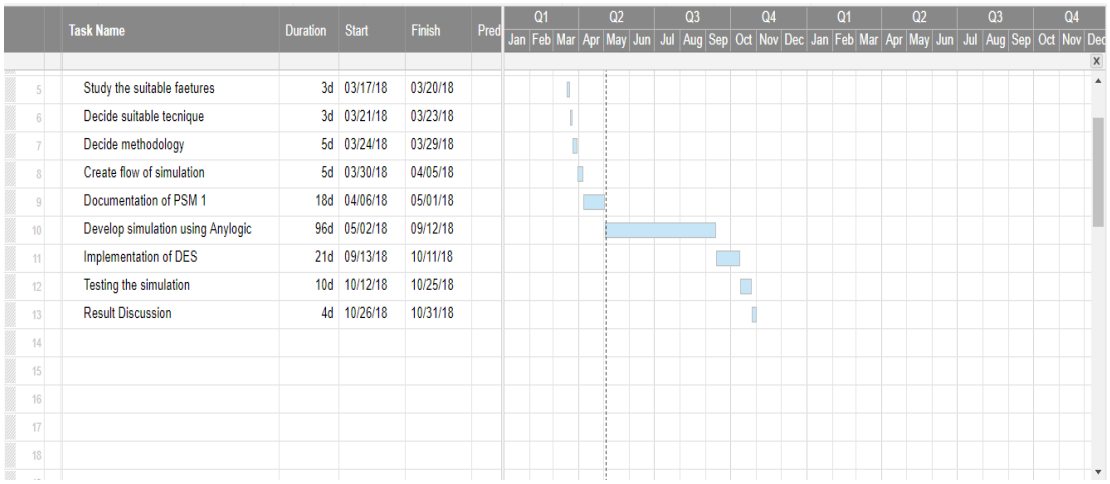
In this research, the software and hardware that used during PSM are defined based on requirement during the development of this research. Hardware is very important device that needed to operate and work with the PSM project. The devices that used in this research are laptop, printer, and smartphone. Software that used in this PSM are Microsoft Office Word and Microsoft Project. Table 3.6.1 shows the list of hardware and software used in PSM.

Table 3.6.1 Hardware and Software Used in PSM.

Hardware	**Purpose**
Laptop	• Use as a tool to work with PSM project.

	• To do the research through search engine. • To do the research documentation.
Printer	• Use to print all document related to PSM.
Smartphone	• Contact with Supervisor.
Software	**Purpose**
Anylogic	• To create the simulation for aircraft evacuation procedure.
Microsoft Office Word	• Make the PSM documentation.
Microsoft Project	• To create the Gantt chart.

3.7 GANTT CHART



	Task Name	Duration	Start	Finish	Pred
5	Study the suitable faetures	3d	03/17/18	03/20/18	
6	Decide suitable tecnique	3d	03/21/18	03/23/18	
7	Decide methodology	5d	03/24/18	03/29/18	
8	Create flow of simulation	5d	03/30/18	04/05/18	
9	Documentation of PSM 1	18d	04/06/18	05/01/18	
10	Develop simulation using Anylogic	96d	05/02/18	09/12/18	
11	Implementation of DES	21d	09/13/18	10/11/18	
12	Testing the simulation	10d	10/12/18	10/25/18	
13	Result Discussion	4d	10/26/18	10/31/18	
14					
15					
16					
17					
18					

Figure 3.7.1 Gantt chart

CHAPTER 4

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IMPLEMENTATION AND DISCUSSION

4.1 INTRODUCTION

This chapter shows the implementation of DES using recommended guidelines. It presents a case study which explores the modelling of aircraft evacuation procedure. Thus, the scenario 1, 2, and 3 were discussed and carried in this chapter to explore the performance of DES in modelling the evacuation procedure. This chapter begins with the description of the case study and continue to describe about the development of conceptual modelling based on the scenarios involve. Three sets of conduct experiment related to evacuation are described and discussed. Lastly, the results that obtained through the experimentation are presented.

4.2 IMPLEMENTATION OF SIMULATION MODELS

Airbus A380 is one of the commercial aircraft that belongs to Malaysia Airlines (MAS). DES has been used to provide a simulation model of aircraft evacuation procedure. Every aircraft need to pass the emergency evacuation demonstrations to get the certification from FAA as a permission to start the operation. Most of the evacuation simulation demonstration had done by manually. Manual demonstration has many constraint. For example, in some localities have child labor laws, thus sometimes there is a possibility that children with ages between 3 and 11 cannot participate in evacuation demonstrations. So the demonstration cannot be done based on real situation because absolutely there are many children on the aircraft during actual flight. The situation very different with the presence of children. In upper deck, there is 6 emergency exits provided while main deck has 10 emergency exits. During emergency evacuation demonstrations,

the total number of exits and slide that will be opened and deployed will less than 50 percent.

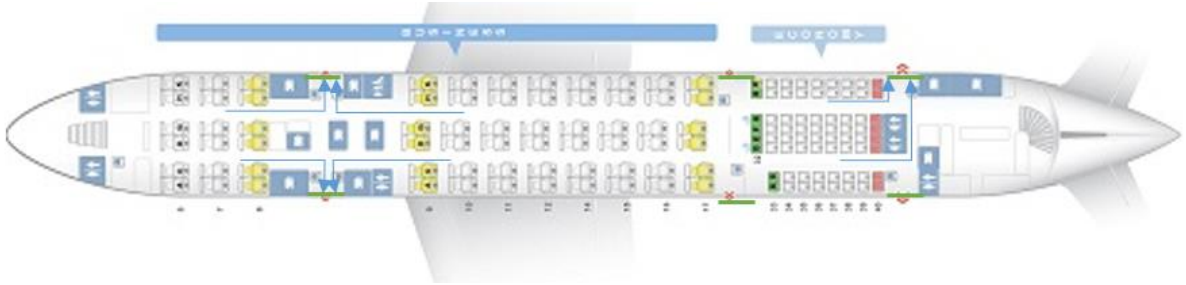

Figure 4.1: Model 1 for real configurational of Airbus A380 (Scenario 1)

To know about the aircraft evacuation procedure, the research about the configuration of aircraft, number of seats, number of emergency exits, number of slide row, and data collection was conducted. Figure 4.1 illustrates the operation of passenger flow when emergency evacuation occurs and blue arrow representing the flow of passenger movement. The operation in the evacuation of passenger flow system starts when the emergency alarm rings. Passenger move in the row to the nearest usable emergency exit. The passenger need to evacuate from the aircraft within 90 seconds using usable emergency exits and slides to be safe. Basically, the number of emergency exit for Airbus A380 is 6 exit for upper deck and 10 exit for main deck. This model only focus on upper deck configuration which have 6 emergency exit. The total time for evacuation is recorded.

Figure 4.2: Model 2 for proposed model configurational of Airbus A380 (Scenario 2)

Figure 4.2 illustrates the operation of passenger flow when emergency evacuation happen and green arrow representing the flow of passenger movement. The operation of emergency evacuation starts when emergency alarm rings. Passenger need to move in the row to the nearest usable exit. All the passenger and crew need to evacuate successfully within 90 seconds. This model increase the number of emergency exit to 8 exit. The total time for evacuation is recorded.

4.3 EXPERIMENTATION

4.3.1 Model Implementation, Verification, and Validation (Scenario 1)

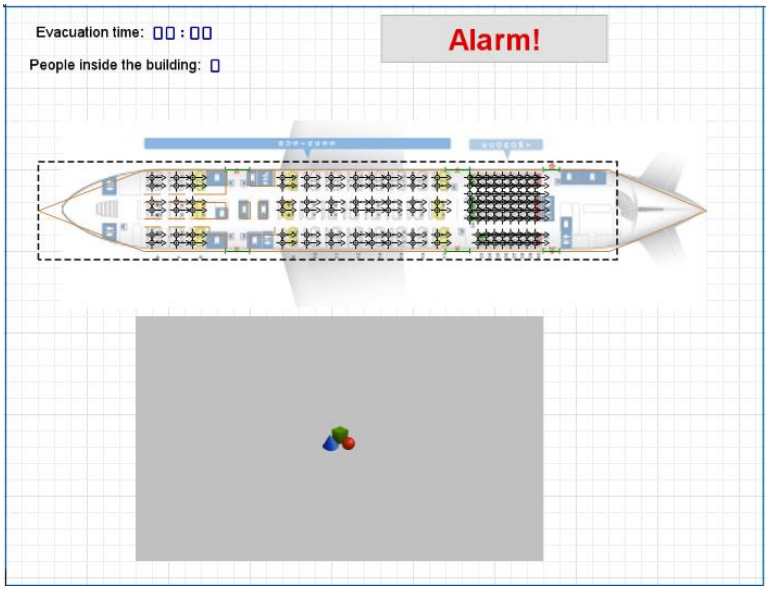

Figure 4.3: Conceptual model 1 for real configurational of Airbus A380 (Scenario 1)

The development of DES model begins with developing the basic configurational of the actual model for Airbus A380. The operation start when passenger enter the aircraft and go to their sit. The evacuation process flow begins when the emergency alarm rings. The passenger need to evacuate using nearest emergency exit in the row. If the nearest exit is blocked or cannot be used, the passenger need to go to the next nearest usable emergency exit. Then, the passenger will successfully evacuate from the aircraft. The conceptual model 1 for actual environment was shown in figure 4.3.

Simulation model consist of passenger, and number of usable emergency exit. The evacuation flow for this simulation begins when the emergency alarm ring. The simulation model use same model input parameter values as described as follows:

1. Passenger

   Based on data collection of the number of passenger in the real system illustrated, the number of passenger for the simulation model is defined. In the

simulation model, the total passenger for upper deck is 136. There are 136 seats available for passenger are distributed based on the class shown in Table 4.1. The configuration of seats pattern as in the Table 4.1 is used because it corresponding the real data collected.

Table 4.1 Passenger seat configuration (Scenario 1)

Type of Class	**Number of Seat**
Business	66
Economy	70

2. Emergency exit

For the emergency exit, there are 6 exit that used when emergency situation occurred in upper deck. During the simulation, only less than half of the emergency are opened. This is because during the real emergency evacuation, not all the emergency exit can be used. Some of the exit are blocked or have obstacle. Situation and number of emergency exit are show in Table 4.2.

Table 4.2 Number of emergency exit used in simulation (Scenario 1)

Situation	**Number of Emergency Exit**
Normal	6
Emergency	3

Before conducting the validation experiments, the first step is to decide the experimental condition such as the run length for the simulation model, total time needed to make sure all passenger enter the aircraft, and the number of passenger involve. Simulation models begin the evacuation process when the emergency alarm ring. The simulation is terminated once the passenger successfully evacuated from the aircraft.

Next, the simulation model are run for 15 times, and the speed of passenger movement, number of usable emergency exit, and evacuation time as shown in Table 4.3.

Table 4.3 Cumulative average for model 1 (Scenario 1)

Parameters	**Cumulative average**
Speed of passenger movement	1.25 m/s
Number of usable emergency exit	3
Evacuation time	87 seconds

Table 4.3 shown that the parameters for the model 1 which are speed of passenger movement is at 1.25 m/s for the cumulative average of aircraft evacuation. The number of usable emergency exit is 3, and the evacuation time is 87 seconds.

4.3.2 Model Implementation, Verification, and Validation (Scenario 2)

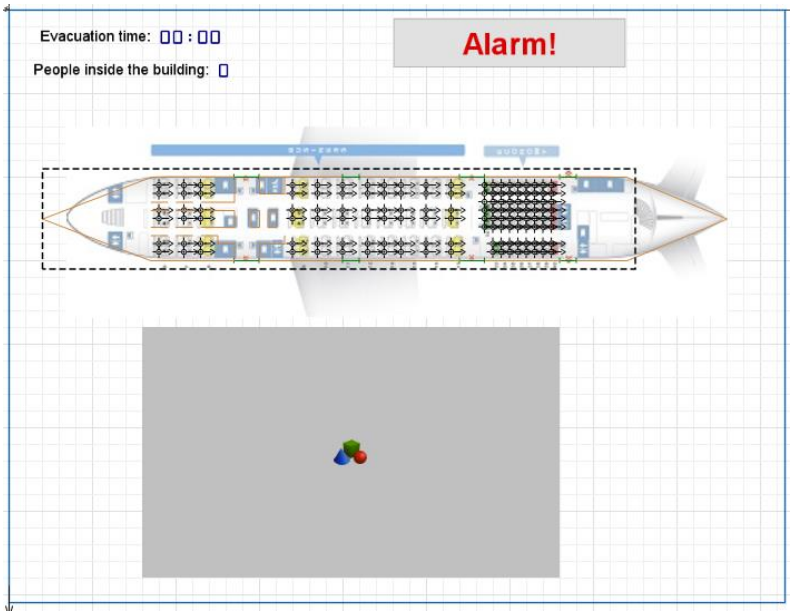

Figure 4.4: Conceptual model 2 for proposed model configurational of Airbus A380 (Scenario 2)

The development of DES model begins with developing the basic configurational of the actual model for Airbus A380. The operation start when passenger enter the aircraft and go to their sit. The evacuation process flow begins when the emergency alarm rings. The passenger need to evacuate using nearest emergency exit in the row. If the nearest exit is blocked or cannot be used, the passenger need to go to the next nearest usable emergency exit. Then, the passenger will successfully evacuate from the aircraft. The conceptual model 1 for actual environment was shown in figure 4.4.

Simulation model consist of passenger, and number of usable emergency exit. The evacuation flow for this simulation begins when the emergency alarm ring. The simulation model use same model input parameter values as described as follows:

1. Passenger

   Based on data collection of the number of passenger in the real system illustrated, the number of passenger for the simulation model is defined. In the

simulation model, the total passenger for upper deck is 136. There are 136 seats available for passenger are distributed based on the class shown in Table 4.4. The configuration of seats pattern as in the Table 4.4 is used because it corresponding the real data collected.

Table 4.4 Passenger seat configuration (Scenario 2)

Type of Class	**Number of Seat**
Business	66
Economy	70

2. Emergency exit

For the emergency exit, there are 8 exit used when emergency situation occurred in upper deck. During the simulation, only less than half of the emergency exit are open. This is because during the real emergency evacuation, not all the emergency exit can be used. Some of the exit are blocked or have obstacle. Situation and number of emergency exit are show in Table 4.5.

Table 4.5 Number of emergency exit used in simulation (Scenario 2)

Situation	**Number of Emergency Exit**
Normal	8
Emergency	4

Before conducting the validation experiments, the first step is to decide the experimental condition such as the run length for the simulation model, total time needed to make sure all passenger enter the aircraft, and the number of passenger involve. Simulation models begin the evacuation process when the emergency alarm ring. The simulation terminated once the passenger successfully evacuated from the aircraft.

Next, the simulation model are run for 15 times, and the speed of passenger movement, number of usable emergency exit, and evacuation time as shown in Table 4.6

Table 4.6 Cumulative average for model 2 (Scenario 2)

Parameters	**Cumulative average**
Speed of passenger movement	1.25 m/s
Number of usable emergency exit	4
Evacuation time	75 seconds

Table 4.6 shown that the parameters for the model 1 which are speed of passenger movement is at 1.25 m/s for the cumulative average of aircraft evacuation. The number of usable emergency exit is 4, and the evacuation time is 75 seconds.

4.4 VERIFICATION AND VALIDATION

The verification and validation process is done concurrently with the development of the basic simulation model for Discrete Event Simulation (DES). Simulation results from simulation models had been compared with the real system output in terms of evacuation time. Below are figure 4.5 that shown the results of the parameters such as speed of passenger movement, number of usable emergency exit, and evacuation time after 15 replications.

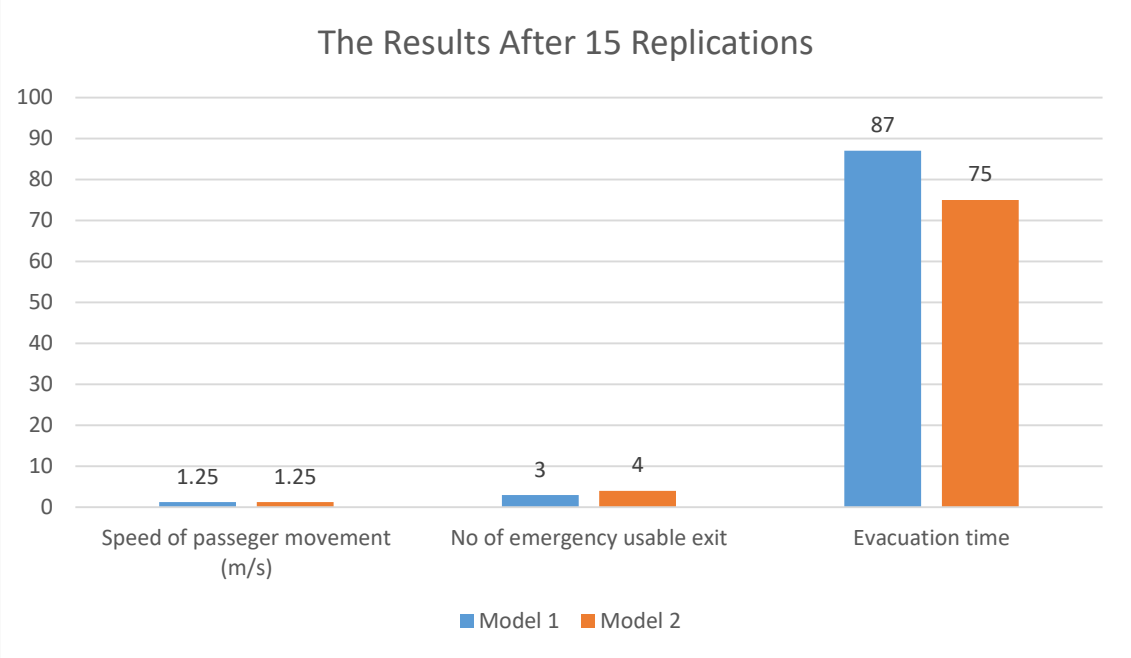

Figure 4.5: The results after 15 replications

The data for Model 1, and 2 were shown in the figure 4.5. This data is from the replication of the simulation for 15 times. S2 had shown the minimum result of evacuation time which is better than S1, the actual aircraft configurational by 75 seconds. The number of usable emergency exit for S2 is higher than the actual model which is 4 exit. Next, the speed of passenger movement is same for both model.

The purpose of the sensitivity analysis validation is to examine the sensitivity of the simulation results when the number of exit for Airbus A380 had been changed. The

idea behind sensitivity analysis validation is to investigate this validation effected the DES model's performance measures.

For example, when number of exit for aircraft increase, the time to complete the evacuation process become shorter. This can save many more life during real aircraft emergency evacuation procedure.

4.5 DISCUSSION AND CHAPTER SUMMARY

The validation process reveals that the DES simulation model is a good representation of the real system. In the sensitivity analysis validation, simulation shows a close correspondence in the median of number of usable emergency exit and evacuation time. This prove that the simulation models of this study are sufficiently accurate for predicting the performance of the real system.

CHAPTER 5

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CONCLUSION

5.1 INTRODUCTION

This chapter describe and elaborate about the conclusion of the finding from previous chapters and about the answer of the research question stated earlier chapter 1. This chapter also will recap of the study, contribution of study, limitation, some suggestion future work for this research, and the conclusion of the study.

5.2 RECAP OF STUDY

The main problem will be understood through research question because it also determine the research's main focus. This research investigation consists of research question which is it by using Discrete Event Simulation (DES) to model simulation for aircraft evacuation procedure is better than manual simulation? The point of this study is to research about the effectiveness of using DES simulation for testing the aircraft evacuation procedure compare to manual aircraft evacuation. To achieve this goal, the three research objectives are analyzed according to the evidence that found in scenario 1, and 2. The objectives for this research are to study on the evacuation procedure for aircraft, to model the evacuation procedure using discrete event simulation, and to validate the simulation model using sensitivity analysis method.

5.3 CONTRIBUTION OF STUDY

The comparison of modelling aircraft configuration is a key contribution to simulation and research. This very important because the knowledge about the

comparison is very valuable for the simulation user. It is very important for understanding the capability of DES in modelling the different scenario of aircraft evacuation procedure. The study that carried out in the present research shows that the overall, it is worth for modelling the aircraft evacuation procedure because it provides many useful information. Using the simulation, we can try to simulate something that cannot be done during the manual simulation test. This vision is important because it shows the weakness and the benefits of the simulation models related to the problem that have been investigate. The knowledge that have been collect throughout this study is very valuable not only to the user of simulation, but also useful to the literature in comparing DES for aircraft evacuation simulation modelling.

5.4 LIMITATIONS

The comparison is limited to the research study in modelling aircraft evacuation procedure using DES. This type of simulation only suitable to get the understanding about evacuation procedure that are based on queues and processes. Because of the limitation of time frame of the present research, only two scenario are developed for this study. Apart from time limits and scope, the simulation software that involve in this study also have some of the limitation. The process flow need to study and understand before can start create the simulation. The software have many symbol and each symbol has its own meaning and the model can up to 150 entitles only.

5.5 FUTURE RESEARCH

As a further study from this research, it remains to be observe on how this software can adapt to multi-objective optimization problems. Other than that, this simulation technique also can be used in some engineering application such as manufacturing, biological, mechanical, or chemical. This also includes the ideas for improving the cogency of the comparison result from the modelling result. Thus, the future researches are:

1. Investigation about the performance of DES in more complex system and large sample.
2. Investigate the effectiveness of DES technique and combine DES with other techniques in future case study.
3. Conduct simulation model for other difficult investigations and improve the validity of results.
4. Add more comparison measure in the simulation.

5.6 CONCLUSION

Airbus A380 is an aircraft that have a double deck, four engine jet airliner, and wide body. It is the world's largest passenger airliner and manufactured by famous European manufacturer which is Airbus. Based on Title 48 Code of Federal Regulations (CFR) part 121.29, every new aircraft need to conduct the emergency evacuation test and need to successfully complete the evacuation within 90 seconds as a condition to qualify to get certificate from Federal Aviation Regulation (FAA). Normally, the evacuation test had been done manually. Manual evacuation test need a lot of work, huge expenses, and involve many people. The participation from volunteer are needed to fulfill the passenger seat. Due to this constraints, aircraft evacuation procedure using discrete event simulation is studied. Simulation is an approach that could be used in order to handle the problem. The research is highlight for the sensitivity of the output is, by changes in one input. Two scenarios for aircraft configurational for the evacuation are scenario 1 which is for real Airbus A380 configurational (Model 1), and scenario 2 which are for new model that had been suggested (Model 2). Anylogic is a simulation tool that widely used for modelling and simulation of DES system. This research had been used the Anylogic to model the aircraft evacuation procedure for all scenarios. The result of this research can help the manufacturer to produce the better aircraft that can reduce the incidents. Both experiments are focus with comparing the results of simulation when modelling the aircraft evacuation. The results show that the proposed modelling approach can be used as a basic for the future analysis.

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