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M.Sc. THESIS

2020

A MODEL ON RISK ANALYSIS METHODS IN SHIP HANDLING DURING PORT MANOEUVRES

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PİRİ REİS UNIVERSITY

SEPTEMBER 2020

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DURING PORT MANOEUVRES

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M.S., Maritime Transportation and Management Engineering, Piri Reis University, 2020

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Maritime Transportation Management Engineering
Piri Reis University
SEPTEMBER 2020

Ferdi ÇINAR, M.Sc. student of Piri Reis University Maritime Transportation Management Engineering student ID: 178013001, successfully defended the thesis entitled **"A MODEL ON RISK ANALYSIS METHODS IN SHIP HANDLING DURING PORT MANOEUVRES"** which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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ACKNOWLEDGEMENTS

This thesis would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

Foremost, I would like to express my sincere gratitude to my advisor Assist. Prof. Dr. Murat Selçuk Solmaz and Assist. Prof. Dr. Emre Çakmak for the continuous support of my master study and research, for their patience, motivation, encouragement, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis.

I would like to thank my colleagues who gave their full support without hesitation and my dear lecturers for their contribution to the simulation studies. Additionally, I would lıke to thank Ahmet Fırat Usta for his support during the thesis process and contributions in simulation studies.

To my family, who is always with me and encouraged me throughout my life.

Finally, I would like to thank my caring, loving, and supportive darling Nilay Mermer and her sweet cat Jülide.

ABSTRACT

A MODEL ON RISK ANALYSIS METHODS IN SHIP HANDLING DURING PORT MANOEUVRES

Ports are the connection points between the sea and the land in the maritime industry, have an important role in world trade. Ports host many ships each day. The characteristics of the ships that can manoeuvre within the port limits are determined depending on the technical structure of the ports and the environmental conditions of the ports' location. The characteristics of the ships such as their type, length, width, draft, and tonnage are important factors that determine the port's limitations. If these restrictions are not followed, it is inevitable for marine accidents to happen within the port area, which can lead to severe consequences such as deaths and injuries, material damage, environmental pollution, and even disasters.

Risk analysis studies are carried out in order to prevent possible accidents at the ports and to determine the perils that may occur. When the studies in this field are examined, it is determined that different risk analysis methods are utilized. By using these analysis methods, the dangers sourced from ship manoeuvring that may occur within the port limits are tried to be analyzed.

While the coastal structures such as port or pier, dock, dolphin located in the port built in Turkey are at the project stage, a modeling report on ship manoeuvres is requested by the Turkish Ministry of Transport and Infrastructure. In this report, it is requested to evaluate the ship manoeuvres with a risk analysis method by using ship bridge simulator systems. With this modeling report prepared, it is determined which ships are suitable for manoeuvring the coastal structure planned to build under various environmental conditions. The modeling report is prepared only by ministry-authorized institutions. When these reports prepared by the institutions are examined, it is seen that each institution apply different risk analysis methods.

The purpose of this study is to create a risk analysis model to be used in the prepared modeling reports and to determine with this modeling report which ships are suitable for manoeuvring in a port and under which environmental conditions ship can manoeuvre. Fine-Kinney and Fuzzy Fine-Kinney methods were chosen as the main risk analysis methodology for this study, which have not been used in the related literature.

In the study, a full mission ship's bridge simulator was used in created scenarios by taking various environmental conditions into account and coming alongside manoeuvres were carried out by masters with a pre-determined ship on a pier at a port in Istanbul. After the end of each manoeuvre, surveys were filled out and assessments were made by masters that are considered as experts in maritime domain. According to results obtained from the risk analysis methods applied in the study, it was determined which ships with which characteristics are suitable for manoeuvring and under which environmental conditions.

In addition, both risk analysis methods applied were compared at the end of the study and it was seen that consistent results were obtained from both methods. It was determined that both analysis methods are applicable, but the Fuzzy Fine-Kinney method gives more precise results than the Fine-Kinney method. It is expected from both methods to contribute to future studies in this area. In addition, as a result of this study, a risk analysis model is created for institutions to benefit in their modeling reports.

Keywords: Ship Manoeuvres, Risk Analysis, Fine-Kinney, Fuzzy Fine-Kinney

ÖZET

LİMAN MANEVRALARI SÜRESİNCE GEMİ KULLANIMINDA RİSK ANALİZ YÖNTEMLERİ ÜZERİNE BİR MODEL

Denizcilik endüstrisinde, deniz ile kara arasında bir bağlantı noktası olan limanlar dünya ticaretinde önemli bir role sahiptir. Limanlar her gün birçok gemiye ev sahipliği yapmaktadır. Limanın teknik yapısına ve limanın bulunduğu konumun çevresel koşullarına bağlı olarak, liman sınırları içerisinde manevra yapabilecek geminin özellikleri belirlenir. Geminin tipi, boyu, genişliği, su çekimi ve tonajı gibi özellikleri liman sınırlandırmalarını belirleyen önemli faktörlerdir. Bu sınırlandırmalara uyulmadığı takdirde, liman alanı içersinde bir deniz kazasının olması kaçınılmazdır. Meydana gelen deniz kazaları birçok ölüm ve yaralanmaya, maddi zarara, çevresel kirliliğe hatta çevresel felaketlere yol açabilir.

Limanlarda meydana gelebilecek olası kazaları önlemek ve oluşabilecek tehlikeleri belirlemek amacıyla risk analiz çalışmaları yapılmaktadır. Bu alanda yapılan çalışmalar incelendiğinde farklı risk analiz yöntemlerinin kullanıldığı fark edilmiştir. Kullanılan bu analiz yöntemleri ile liman sınırları içersinde yapılan gemi manevralarının oluşturabileceği tehlikeler analiz edilmeye çalışılmıştır.

Ülkemizde inşa edilen liman veya liman bünyesinde yer alan iskele, rıhtım, dolphin gibi kıyı yapıları proje aşamasında iken, Ulaştırma ve Altyapı Bakanlığı tarafından gemi manevraları üzerine bir modelleme raporu hazırlanması istenmektedir. Bu raporda köprüüstü simülatör sistemleri kullanılarak yapılan gemi manevralarının bir risk analiz yöntemi ile değerlendirilmesi istenmektedir. Hazırlanan bu modelleme raporu ile inşa edilen kıyı yapısının farklı çevresel koşularda hangi gemilerin manevra yapmasına uygun olduğu tespit edilmektedir. Modelleme raporu sadece bakanlık tarafından yetki verilen enstitüler tarafından hazırlanmaktadır. Enstitüler tarafından hazırlanan bu raporlar incelendiğinde, her enstitünün birbirinden farklı risk analiz yöntemleri uyguladığı görülmektedir.

Bu çalışmanın amacı, hazırlanan modelleme raporlarında kullanılmak üzere bir risk analiz modeli oluşturmak ve oluşturulan bu model ile bir limana hangi gemilerin, hangi çevresel koşullarda manevra yapmasının uygun olduğunu tespit etmektir. Çalışmada daha önce bu alanda yapılan çalışmalarda kullanılmayan Fine-Kinney ve Fuzzy Fine-Kinney yöntemi, risk analiz yöntemi olarak kullanılmıştır.

Yapılan çalışmada tam donanımlı köprüüstü simülatörü kullanılmıştır. Farklı çevresel koşullar dikkate alınarak, simülasyonda belirlenen bir gemi ile İstanbul'da bulunan bir limana ait iskeleye kaptanlar tarafından aborda olma manevraları gerçekleştirilmiştir. Yapılan her manevranın sonunda uzmanlar tarafından anketler doldurularak değerlendirmeler yapılmıştır. Çalışmada uygulanan risk analiz yöntemlerinden elde edilen sonuçlar neticesinde, iskeleye hangi özellikteki gemilerin, hangi çevresel koşullarda manevra yapmasının uygun olduğu belirlenmiştir.

Çalışmanın sonunda, uygulanan her iki risk analiz yöntemi kıyaslanmış ve her iki yöntemden de tutarlı sonuçların elde edildiği görülmüştür. Yapılan değerlendirmeler sonucu her iki yönteminde uygulanabilir olduğu, fakat Fuzzy Fine-Kinney yönteminin Fine-Kinney yöntemine göre daha hassas sonuçlar verdiği anlaşılmıştır. Uygulanan her iki metodun da ileride bu alanda yapılacak çalışmalara katkı sağlaması beklenmektedir. Ayrıca bu çalışma ile enstitülerin modelleme raporlarında kullanılabileceği bir risk analiz modeli oluşturulmuştur.

Anahtar Kelimeler: Gemi Manevraları, Risk Analizi, Fine-Kinney, Fuzzy Fine-Kinney

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LIST OF SYMBOLS

Symbol	Description
m^3	Cubic meter
°C	Degree celcius
σ	Function width
μ	Fuzzy set
$\int$	Integral
$\cap$	Intersection of two sets
$\in$	Is an element of
$\sum$	Summation
$\cup$	Union of two sets

LIST OF ABBREVIATIONS

Abbreviation	**Description**
AHP	Analytic Hierarchy Process
AIS	Automatic Identification System
ALRS	Admiralty List of Radio Signals
BBN	Bayesian Belief Networks
BNWAS	Bridge Navigational Watch Alarm System
BORA	Barrier and Operational Risk Analysis
C	Consequence
COLREG	Convention on the International Regulations for Preventing Collisions
CPA	Closest Point of Approach
ECDIS	Electronic Chart Display and Information System
ES Model	Environmental Stress Model
ETA	Event Tree Analysis
ETA	Estimated Time of Arrival
F	Frequency
F-AHP	Fuzzy-Analytic Hierarchy Process
F-FTA	Fuzzy-Fault Tree Analysis
FHA	Functional Hazard Assessment
FIS	Fuzzy Inference System
FMEA	Failure Modes and Effects Analysis
FSA	Formal Safety Assessment
FTA	Fault Tree Analysis
GPS	Global Positioning System
HAZID	Hazard Identification
HAZOP	Hazard and Operability Studies
HCA	Hazard Checklist Analysis
HEART	Human Error Assessment Reduction Technique
HF	High Frequency
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities

ICS	International Chamber of Shipping
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite System
ISM	International Safety Management
ISO	International Organization for Standardization
IWRAP	IALA Waterway Risk Assessment Program
LOA	Length Overall
MAIB	Marine Accident Investigation Branch
MF	Medium Frequency
MWE	Might Well Be Expected
N	North
NAVTEX	Navigational Telex
NE	Northeast
NOAA	National Oceanic and Atmospheric Administration
NP	Nautical Publication
OOW	Officer of the Watch
P	Probability
PARK Model	Potential Assessment of Risk Model
PBT	Pilot Boarding Time
PHA	Preliminary Hazard Analysis
PRA	Preliminary Risk Analysis
R	Risk
RADAR	Radio Detection And Ranging
RO-RO	Roll on - Roll off
SOLAS	International Convention for the Safety of Life at Sea
SRS	Ship Routing System
SW	Southwest
SWIFT	Structural What-If Technique Analysis
SWL	Safe Working Load
TTC	Time to Collision
VDR	Voyage Data Recorder
VHF	Very High Frequency

VTS	Vessel Traffic Service
W	West

1. INTRODUCTION

A ship can face many dangers during the navigation. These dangers increase as the ship approaches from the open sea to the shore. During navigation in limited waters, increasing traffic density, narrowing of the manoeuvre area, and existing shallow water as we approach towards the shore are the most important factors in increasing the risk. These factors cause restrictions on ship manoeuvres (Hu et al., 2017).The fact that ships usually navigate in the port areas cause them to face these dangers frequently. If necessary precautions are not taken, marine accidents such as collision, contact, and grounding may occur. These accidents lead to human injuries and loss of life, economic losses, and environmental damages.

The difficulties faced by a ship navigating in the port area vary depending on the ship's characteristics, the port's structure, environmental conditions and human factor. The technical characteristics of the ship that manoeuvre in a port area, such as its length, width, draft, tonnage, etc. must be suitable for the manoeuvre area. By considering the structure and technical features of the port, there should be restrictions on ships that will manoeuvre the port area. This is important for ship and port safety. While determining these restrictions, environmental conditions that affect the ship manoeuvre should be taken into consideration. It is important to determine these restrictions at stages such as port construction, wharf/dock expansion, construction works that will change the port structure. This situation prevents possible accidents in the port area.

Ship bridge simulators are generally used to determine the suitability of a port or a structure such as a pier, dock, etc. to determine suitability for ship manoeuvres. By using ship bridge simulators, the ships available in the simulation system are manoeuvred by experts in the designated area. Manoeuvres are evaluated with a risk analysis method by experts. With these studies, It is determined which ships can safely berth to a specified port or a structure of the port under different environmental conditions.

In Turkey, the suitability for ship manoeuvres of a port or of the structures will be built in the port area is checked by the "Ministry of Transport and Infrastructure". "The Communique on the Evaluation of Shore Facility Construction Demands" in the Official Gazette No. 27170 dated 15.03.2009 was laid out by the Ministry (Official Gazette, 2009a)**.** In this communique, it was asked to prepare a modeling report before the construction of the above mentioned coastal facilities. The modeling report is prepared only by ministry-authorized institutions. With this modeling report, it is determined which ships are suitable for manoeuvring to a coastal facility under various environmental condition. In the modeling report, ship manoeuvres are requested to be carried out in the simulation environment and evaluated by a risk analysis method. However, there is no information about the desired risk analysis method. For this reason, it is seen that different risk analysis methods are used in modeling reports prepared by authorized institutions. The proper selection of the applied risk analysis method is very important for obtaining consistent results.

In the study, it was aimed to create a model to be used in modeling reports and to identify a proper risk analysis method that can be used in this model. At the end of the study, a model has been created for using modeling reports. Moreover, studies on port maneuvers in the literature have been examined and their advantages and disadvantages have been determined. In the study, these disadvantages were eliminated by using Fine-Kinney and Fuzzy Fine-Kinney methods. At the end of the study, the results obtained from both methods were compared and evaluated.

In the application part of the study, a pier in a port is situated in the İstanbul area was modeled in the simulation system. Scenarios have been prepared considering the environmental conditions of the port area. Coming alongside manoeuvres were carried out on the pier by the experts. In the study, human errors and problems that may arise from ships which are explained in chapter three were not taken into consideration. Besides, marine traffic occurring by navigating ships was not included in the risk scope, considering that the control of the ship traffic will be provided by the port authority. After each simulation application, the risk analysis of the manoeuvres performed by the experts was made. The data obtained at the end of the study were evaluated using two risk analysis methods and were ascertained in what conditions the port was risky. As a result, it has been understood which ships are suitable for manoeuvring at the pier and in which environmental conditions ships can manoeuvre. With this study, a model has been created to be used in modeling reports and the risk analysis method to be used in this model has been determined.

The study consists of nine chapters in total. In chapter 2, the processes related to ship handling were mentioned in the manoeuvres that took place during the port period. In this chapter port period was analyzed in four categories; preparations made prior to entering port limits, the pilot embarking the ship, navigation with the pilot, and going alongside manoeuvres.

In the third chapter of the study, the factors affecting the ship manoeuvres during port navigation are explained. These factors are divided into four main topics. These were examined as ship-related factors, the port area related factors, external factors, and human-related factors. Also, the factors mentioned in these main titles were categorized by dividing subheading.

In chapter four, the terms used in the terminology of risk analysis studies were explained. Then, risk analysis studies in the maritime field were clarified. After this, literature reviews on ship manoeuvres in the port area were done. Finally, studies on this topic were evaluated.

The fifth chapter consists of two main titles. In the first part, information was given about the simulation systems used in the maritime field. In the second part of the chapter, the process of the simulation study was applied in the thesis was explained in detail.

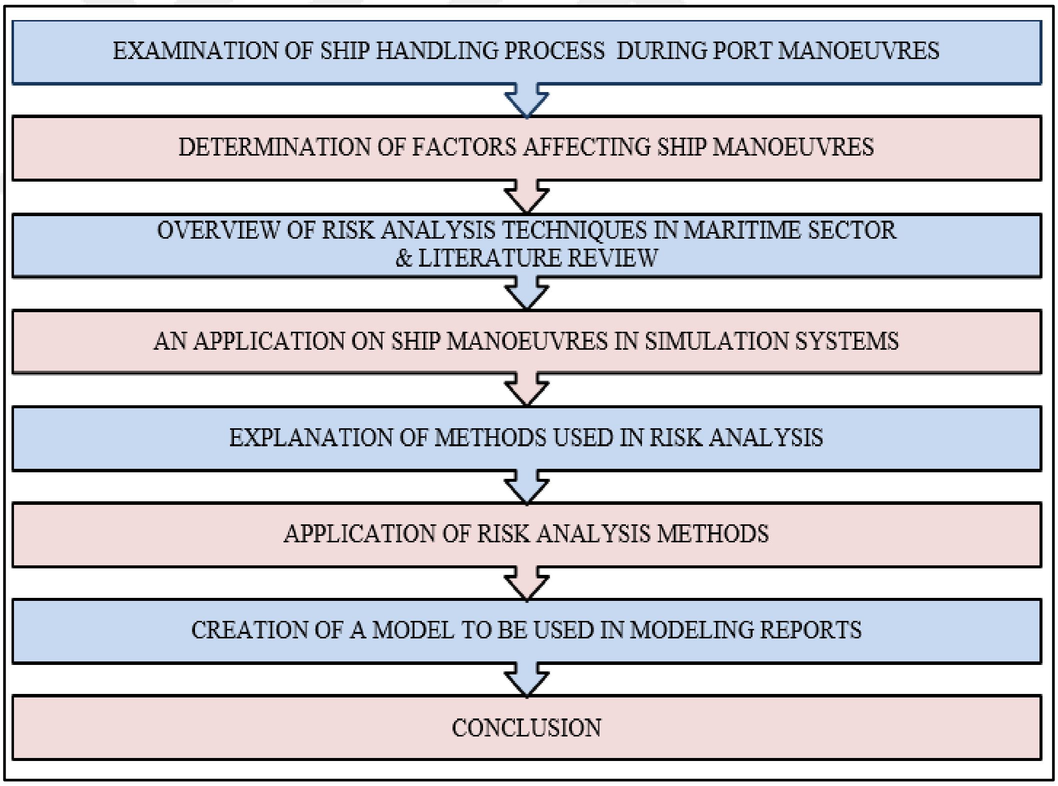
In the sixth chapter, Fine-Kinney and Fuzzy Logic methods, which are used as risk analysis methods, are mentioned in the study. In this chapter, information about the history and general structure of both methods applied were given.

In the seventh chapter of the study, details on the application of risk analysis methods described in the sixth chapter were given. Findings obtained as a result of the risk analysis were described in this chapter. Also, the results of both risk analysis methods were compared.

In the eighth chapter, the model that occurred to be used in the modeling reports of the study is mentioned. Each step of the model consisting of 6 steps is described.

In the ninth chapter, which is the conclusion chapter of the study, the contributions of the study were touched on. Also, information was given about the studies planned in a similar field in the future. The flow chart of the study is shown in Table 1.1.

Table 1.1. Flow chart of the study



2. SHIP HANDLING DURING PORT MANOEUVRES

With the development of marine technologies, it is seen that the structural changes such as size and the tonnage of ships are increasing. These structural changes on ships increase the difficulties in manoeuvres done in restricted areas. Naturally, the developments in the maritime area (tug assistance, contributions of electronic devices, the significance placed on communication, etc.) ease the manoeuvres done in such difficult areas considerably. Even though these developments contribute to easing the manoeuvres, the fact that the decrease in number of personnel working on ships with increased size and tonnage also decrease the safety margin to a minimum and thus creates a safety risk should not be overlooked. In the case of countermeasures against these risks not being taken, marine accidents may take place. These accidents may cause casualties, damages on the ship, and marine pollution.

When maritime terminology is considered, manoeuvring is moving a ship back and forth, turning it and stopping it with the use of its engine, rudder, and other auxiliary systems. Ships often need to make more manoeuvre more in areas such as narrow canals/straits, traffic separation schemes, port limits, and areas close to shore since these areas are restricted when it comes to navigation.

A ship’s manoeuvre changes depending on the ship’s characteristics and the environmental conditions. Especially bad weather conditions and navigational equipment faults or malfunctions on the ship prolong maneuvre time, and increase the risk of accident. When maritime accidents are analyzed, it is seen that many accidents such as collision and grounding take place during the manoeuvring of a ship. It shows that the manoeuvres carried out by the ship pose a significant risk in maritime accidents.

Mooring or departure manoeuvres to and from ports are one of the situations that this risk is often present. The risk can be eliminated by the precautions taken and preparations made by the ship’s personnel prior to the manoeuvre. The requirements set by the International Maritime Organization (IMO), company safety policies and guides lead the way for these precautions and preparations.

The precautions taken and preparations made by the ship's personnel prior to port entry play an important role that navigation within port limits is completed safely. The port period was analyzed in four categories, namely; preparations made prior to entering port limits, the pilot embarking the ship, navigation with the pilot and going alongside manoeuvres.

2.1. Preparations Made Prior to Entering Port Limits

Preparations made prior to entering port limits help the navigation within port limits is done effectively. Firstly, the ship needs information about the port it is headed . The ship's master usually collects information on topics such as anchorage areas, berthing place, reporting information, pilot boarding time, port characteristics and recommended routes by communicating with agents or port authorities. In addition, the nautical publications onboard the ship (Admiralty Sailing Directions, Guide to Port Entry, ALRS Volume 6 - NP/286 Pilot Services, Vessel Traffic Services and Port Operations) can be viewed to collect information about the port to be navigated in. The ship's personnel, with the direction of the ship's master, prepares the directions issued by the port authorities before arrival at the port and the necessary documents. With the completion of the necessary procedures, there are no more restraints on the ship for port entrance.

The master, within time periods set by the port authority, updates and reports the ship's estimated time of arrival (ETA) to the port. ETA is the expected time for a ship to arrive at a destination. The port authority makes the necessary preparations according to the ETA.

The updates to the navigation plan made by the responsible officer during navigation should be checked and approved by the master. The navigation plan should be made "berth to berth" and any changes to the ETA should be reported to the port authorities.

The master holds a meeting with the bridge team prior to port arrival. Firstly, in this meeting, the ship's personnel are informed about the port area, environmental conditions, and the navigation plan. The personnel is also informed about the risks encountered during the navigation period, the necessary precautions to be taken, and points of importance that need attention.

The master should make a plan on how to manoeuvre before starting the manoeuvre. In this plan; wind, currents, tide, the ship's trim, draught, freeboard, the situation of the equipment on deck and navigational equipment to be used during the manoeuvre, external support (tugs, port personnel, mooring boats, etc.) should be accounted for. In the meeting, critical points of navigation should be discussed and necessary precautions should be taken. If needed, the topic should be discussed with the bridge team and the best way to proceed with the manoeuvre should be decided. The manoeuvring team should be informed about the kind of manoeuvre to be made and what is there to pay extra attention to (the position of the tugs, which side is to be boarded from, how the anchor will be used etc.). Alternative plans should be thought of in case of any setbacks.

Both the deck and the engine departments should proceed within the decisions made for the safety of the ship, the environment, and their personnel. The crew should behave carefully and in a controlled manner while performing the given duties. When it is considered that a lot of the accidents and the casualties on a ship happen during manoeuvring, they should not forget that the priority is the safety of themselves and those around them.

The master informs the personnel about their positions and duties during manoeuvring. The officer of the watch informs all personnel prior to the beginning of the manoeuvre and the master gives the order to start the preparations. Usually, the third officer and for steering one able seaman are stationed on the bridge with the master. The chief officer, the bosun, and two or three able seamen are stationed on the forward station, and the second officer is stationed on the aft station with two able seamen. The station of the officers or the personnel may change according to the master's directions. The engine personnel is stationed at the engine control room and make the necessary preparations for manoeuvring.

Prior to port entry, the deck personnel stationed at the forward and aft stations check the deck equipment to see if they work properly. The ship's lines are prepared according to which side is to be boarded from. The tugs, which are an important contributor to the manoeuvre, are followed and if any lines are to be given or taken to or from the tugs, the necessary equipment is prepared. Often, according to the difficulty of the manoeuvre within the port, taking one or two tugs is made obligatory by the local authorities. Tugs have an important effect on completing a manoeuvre safely with minimum risk.

2.2. The Pilot Embarking the Ship

Pilotage is a service controlled by the local authorities and provided by pilots with adequate knowledge and experience on the concerned area to help navigate narrow waterways such as straits, gulfs, port entrance and departures and for the protection of human life, property and the environment (Official Gazette, 2020).

A pilot is someone who knows the characteristics of the area they work at (port, canal etc.) well, who is educated in navigating a ship in shallow waters and heavy traffic, and on top of that someone who provides the communication between the ship and external elements (tugs, mooring boats, shore mooring workers) (Ungereanu, 2015).

The importance of the use of pilots has been officially recognized in the "Assembly Resolution A.159 (ES.IV)" by IMO in 1968. According to this resolution, states must regulate the pilotage services which they can prove are more effective than other precautions and must identify the ships and ship classes that pilotage services are mandatory for (IMO, 1968). With this resolution, IMO made it mandatory for ships to take pilots in high risk areas in regards to navigation.

A pilotage plan should be made for the navigation with the pilot. In this plan; the ship’s proximity to navigational dangers, recommended routes within the pilotage areas, communication information, pilotage procedures, the situations, rules and restrictions to know about the area, reports to be made and communication procedures and information about the planned berthing/anchorage should be present (International Chamber of Shipping [ICS], 2016).

The responsible officer of the watch prepares the ship for navigation with the checks they make prior to the navigation with the pilot. They make these checks with the help of the check lists contained within the International Safety Management (ISM) System of the ship and log these checks in the deck log book. They carry out the tests for the main engine, rudder systems, thrusters, and other auxiliary equipment and make sure they are fit for manoeuvring. They check the bridge equipment such as the Electronic Chart Display and Information System (ECDIS), Radio Detection and Ranging (RADAR), Global Positioning System (GPS), Voyage Data Recorder (VDR), Very High Frequency (VHF), Course Recorder, Navigational Telex (NAVTEX), Automatic Identification System (AIS), etc.

If the ship’s wheel is in auto pilot mode it is to be set to manual mode and if a single steering pump is being used, the other steering pump is to be put to use as well. This ensures that the ship responds to steering faster. The helmsman tests the wheel after setting it to manual mode to see if the ship responds to the commands. Seamen who are good at steering are tasked as the helmsmen. The helmsman steers the ship in manual mode until the manoeuvre is over during berthing or when the ship leaves the port limits and reaches a safe area. Sometimes, when crossing a canal, steering times may be prolonged. In these kinds of situations, another helmsman continues the steering. The officer of the watch present on the bridge should keep an eye out on the rudder to make sure it responds to the commands issued.

It should not be forgotten to raise the flag of the country, when the territorial waters are entered. The pilot flag and any other flags deemed necessary by the authorities should be kept ready on the bridge.

A “pilot card” is prepared for the pilot to learn about the ship’s particulars and a “wheelhouse poster” should be hung at the bridge for the pilot to learn about the ship’s manoeuvre characteristics (IMO, 1987). The “pilot card” is prepared by the officer of the watch and is checked by the master. It is then checked and signed by the pilot embarking the ship. The pilot learns about the current situation, rudder, and manoeuvring equipment and engine particulars from this document which is prepared in accordance with the IMO standard format.

The “wheelhouse poster” should be hung somewhere on the bridge that is easy to notice. Information such as general information about the ship and it’s manoeuvring characteristics are present on this poster. It is an important document for the pilot to get to know the ship quickly.

When the ship is close to port limits, if all preparations necessary for port entry are done, the situation is reported to port authorities. For navigation with the pilot, the pilot station is contacted through radio to be notified the “pilot boarding time (PBT)”, in case of there being no pilot station, “port control” or VTS (Vessel Traffic Service) is contacted instead. Additionally, necessary preparations for the pilot are also notified through the contacted authority.

A “pilot station” is the position that a ship and a pilot boat meets for the pilot to embark or disembark the ship. This position is marked on nautical charts with a symbol. Besides, it is possible to find out additional information about the “pilot station” by checking pilotage books (ALRS Volume 6- NP/286 Pilot Services, Vessel Traffic Services, and Port Operations) The port authority, when choosing this position, should make sure that this position is safe, is at an appropriate distance away from the start of the pilotage and is far and environmentally appropriate enough for the master-pilot exchange to take place (IMO, 2003).

The master should conduct their manoeuvre in such a way and put their ship in such a position to ensure the safe embarkation of the pilot. The ship should proceed towards the port with a safe speed.

When the ship is proceeding towards the “pilot station”, some preparations are to be made to ensure the safe embarkation of the pilot. Information about the side of the ship that the pilot ladder should be lowered from and the height of the pilot ladder from the waterline should be confirmed with the pilot station. This distance depends on the freeboard of the pilot boat present. If the ship’s freeboard is higher than 9m, an “accommodation ladder” must be prepared in combination with the “pilot ladder” (IMO, 2012). Depending on the sea state, the pilot may embark on the ship from a pilot boat or a tug. The pilot ladder prepared by the ship’s personnel is checked by the responsible deck officer according to the standards set by IMO Resolution A.1045 (27) “Pilot Transfer Arrangements” (IMO, 2011). The deck officer should make sure the pilot can embark on the ship safely. When the pilot is embarking the ship, they should be helped and necessary reports should be made to the master through radio. The officer stationed at the pilot embarkation point escorts the pilot from the moment they embark on the ship. Pilots usually embark on a ship from the sea but it is sometimes seen in certain ports that they may join the ship with a helicopter.

The moment the pilot embarks the ship, the “pilot on board (H)” flag, which should have been prepared earlier, is raised. If the embarkation is at night, in addition to the navigation light, a white light on top of a red light is lit in a manner that they can be seen from any direction. Prior to this, it should not be forgotten to raise the flag of the country that the ship is navigating in the territorial waters of.

The engine personnel should be prepared and ready to intervene with any malfunctions that may arise during the manoeuvring process. For a safe manoeuvre, harmony between engine and deck personnel is very important.

2.3. Navigation with the Pilot

Port entry and departure manoeuvres are high risk situations. One of the main reasons that the risk is high is because the ship’s personnel is not familiar with the area to manoeuvre in. To minimize this risk, from this point onward, there is a guide that knows the area well onboard the ship.

The pilot embarking the ship being experienced with the area to manoeuvre in is a big advantage for a safe manoeuvring process. The pilot knows the environment well while the master and the crew know the ship and its equipment inside. This situation makes it necessary for the bridge team and the pilot to communicate effectively.

A pilot's foremost duty is to make sure the marine traffic flow within the pilotage area is conducted safely. With this, the pilot reduces the possibility of any dangers arising for the ship or the environment around it.

An area having a "compulsory pilotage" rule is one of the most important precautions for navigational safety. But this rule does not relieve the ship's personnel from their responsibilities. IMO Resolution A960 (23) Annex-2 Article-2 (Duties of Master, Bridge Officers, and Pilot) states that; the presence of a pilot onboard a ship does not relieve the master or the officer of the watch from their duties and responsibilities. Due to this, the master and the responsible officers of the watch should be aware of the situation before the pilotage starts and always be ready to carry out the responsibilities of their duties. To safely manage the ship, the master and the responsible officers should communicate well with the pilot. The master and the officers on the bridge should support the pilot and should not forget to monitor the instructions of the pilot to be able to step in if the need arises. (IMO, 2003)

Pilot, in addition to professionally commanding the ship, is responsible for communication with the local services (mooring boat, linesman, tugs, and port workers). With this, miscommunications between the ship and the local services are eliminated.

The master should make sure the pilot embarking the ship is physically and mentally capable of carrying out the manoeuvre. They should also make sure the pilot has the certificates laid out in IMO Resolution A.960 (23) Annex-1 and is medically fit for duty (IMO, 2003)**.** If the master concludes that the pilot embarking the ship does not have the necessary qualifications or the experience, they have the right to change the pilot as to not endanger the navigational safety. The pilot, on the other hand, may refuse to the ship if they deem the ship not fit for manoeuvre, or the ship may endanger navigational safety or the environment (IMO, 2003).

To ensure the navigation with the pilot proceeds without problems, a “master-pilot information exchange” should be carried out. In this exchange, the master and the bridge team should inform the pilot of the ship’s characteristics and the navigational equipment and the pilot should inform them of navigational conditions of the area they are experienced in and the rules set by the relevant authority. The pilot confirming the manoeuvring characteristics of the ship they embark as quickly as possible is important for safe navigation.

An increase in information shared will reduce the risks brought by the manoeuvre. The check lists such as the “pilot card”, “wheelhouse poster” etc. will help the pilot with an easy manoeuvre.

During the manoeuvre, if a common language is not spoken, the language spoken should be English and the language spoken should be fit for the standards set by the “IMO Standard Marine Communication Phrases” (IMO, 2003). In addition, if the persons to be contacted outside the ship (tugs, mooring boats, shore workers, etc.) do not know the common language, the pilot should share the necessary information in English with the bridge team.

In addition to a clear and effective “Master/Pilot information exchange”, the situations laid out by the Bridge Procedure Guide section 5.4. and mentioned below should be applied for navigational safety; (ICS, 2016)

- An up to date pilot card prepared by the responsible officer should be presented to the pilot and the pilot should sign and approve it.
- The pilotage plan should be analysed and situations in which the plan might be deviated from should be prepared for. The changes in duties of the bridge team should be done prior to the commencement of the pilotage.
- Information about the changing weather conditions, water depth, tide, and current in the local area should be shared and it should be made sure that the information is up to date.
- The marine traffic in the area should be analysed and areas with risk should be paid attention to.

- Information about the ship’s dimension and the ship’s manoeuvring characteristic should be shared with the help of the wheelhouse poster.
- A “manoeuvring booklet” should be kept ready on the bridge for use.
- The pilot should be made aware of the limitations that might effect the safe conduction of the navigation (crew limitation, navigational or machinery equipment, etc.).
- Port authorities should plan out the arrangements that might be needed during pilotage (tugs, mooring boats, mooring arrangements, and other external facilities). The master and the pilot should exchange information about the number of tugs to be used, where on the ship the tugs should be used, the position the tugs will commence pushing or pulling, etc. and this information should be shared with the ship’s personnel by the master.
- Thoughts on the contingency plan should be shared, the precautions to be taken in case of any emergencies and malfunctions, etc. should be decided on.
- The official language to be used during the pilotage should be decided on.

The continued communication between the bridge team and the pilot should be ensured even after the “Master/Pilot information exchange”. The pilot should respond appropriately to any questions asked and any information or advice given by the bridge team. In case of any malfunctions or inconveniences, the bridge team should be informed and in case of a change in the pilotage plan, the bridge team should be warned.

During the pilotage, all personnel tasked within the bridge team should carry out their duties with attention. The bridge team should ensure the navigational equipment works effectively and support the pilot in this matter should they need it. The bridge team should not forget the pilot is onboard as an advisor and should constantly monitor the pilot and any other member of the bridge team. Especially, the ship’s position should be checked often to see if there are any deviations from the navigation plan. If there are any deviations, the reason should be confirmed with the pilot in an appropriate manner. The officer of the watch present on the bridge and the master should ensure that instructions issued by the pilot are understood by the members of the bridge team. In any suspicious situation, the master should be informed promptly.

OOW (Officer of the watch) should assist the pilot regularly by informing them of the ship's speed and other variables. During navigation, "under keel clearance" should be checked regularly with the help of the echo sounder and the ship's position. The forward team should keep the anchor ready to be let go at any time.

One of the most important assistances to manoeuvring is tugboats. In addition to assisting the ship to manoeuvre towards the desired direction, they escort the ship to promptly intervene in case of any emergencies. During the manoeuvre, the tugs' lines are made fast by the ship's personnel in the positions decided by the pilot. With this, a fast and easy manoeuvre can be carried out by applying pull or push forces on desired points on the ship by the tugs. Instructions issued by the pilot are carried out by tug masters. Tugs are especially important in areas with restricted manoeuvring space.

2.4. Coming Alongside Manoeuvres

When approaching a pier, the master and the pilot decide on the lines to be given to shore. The master relays this decision to the forward and aft stations via radio. When the distance between the ship and the pier is appropriate, with the instruction of the officers tasked at the forward and aft stations, the "heaving line" is thrown by the able seamen towards an appropriate point on the pier and the responsible personnel on the pier catches the "heaving line". Afterwards, with the help of the heaving line, the necessary lines are given to shore and the ship is moored to the pier.

A lot of accidents can happen during line operations and this can lead to the loss of life or property (URL-1). It should be made sure that the commands issued by the master are understood clearly and any unsafe actions should be avoided. The responsible officer should make sure of the safety of the personnel and avoid any situations that may harm the ship or the environment while carrying out the instructions given by the master.

When all the lines are fasted and the ship is in the desired position, the manoeuvre is completed. With the completion of the manoeuvre, the tugs' lines are cast off with the master's command. The pilot starts preparing for disembarkation after making sure the ship is fast ashore safely. While pilots usually disembark the ship from the shore side, they may also disembark via the pilot ladder from the sea side. The deck officer accompanies the pilot while they disembark, and reports to the master afterwards.

3. FACTORS AFFECTING SHIP MANOEUVRES

According to Charles H. Cotter, a ship's manoeuvre is the art of overcoming the forces we can not control with the use of the forces that we can (Cotter, 1963). To perform this art well, a good captain and a strong bridge team supporting them are needed.

While forces such as the main engine, the rudder, the anchor, the thrusters, and the tugs are forces under human control, environmental factors such as wind, current, wave, and tide are defined forces out of control. In a manoeuvre performed by a ship, the purpose is to complete the manoeuvre safely and efficiently by overcoming the forces out of control with the use of the forces under control.

To be able to complete a manoeuvre safely and efficiently, a ship with adequate manoeuvring capabilities, a well-educated crew led by a master with the adequate knowledge and experience to carry out the manoeuvre and an adequate environment for the manoeuvre is needed (Figure 3.1.). It is unavoidable for an accident to happen in case of misfortune in these three conditions.

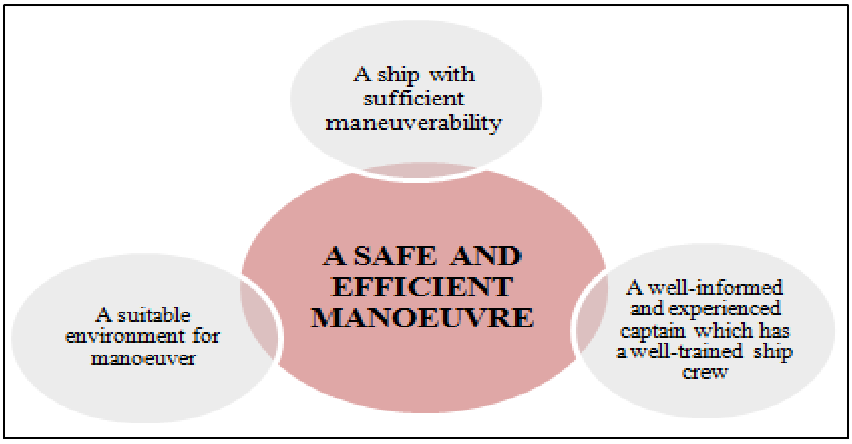


Figure 3.1. A safe and efficient manoeuvre

A manoeuvre done within port limits carries out much more risk than one done on the open seas. Compared to the open seas, the main reason for the growing risk in port manoeuvres is limits set by environmental factors. For a manoeuvre done within port limits to be considered successful, the ship should reach the point desired in a timely manner and without taking any damage. To be able to achieve this, the possible factors that may affect the manoeuvre should be well analysed.

In this chapter, factors that may affect a ship's manoeuvre until the time the ship comes alongside a dock, a dolphin, or a pier during a port manoeuvre were analysed under 4 categories, namely, ship-related factors, port area related factors, external factors, and human-related factors (Table 3.1.).

Table 3.1. Factors affecting ship manoeuvres

FACTORS AFFECTING SHIP MANOEUVRES

3.1. Ship Related Factors

- 3.1.1. Ship Design Related Factors
- 3.1.2. Ship Propulsion System Factors
- 3.1.3. Bridge Navigation Systems Factors
- 3.1.4. Other Related Factors
  - 3.1.4.1. Loading Condition Factors
  - 3.1.4.2. Ship Speed
  - 3.1.4.3. Ship Anchor

3.2. Port Area Related Factors

- 3.2.1. Width of Port Area
- 3.2.2. Width and Depth of Port Entrance
- 3.2.3 Depth of Port Area
- 3.2.4. Aids to Navigation in Port Area
- 3.2.5. Height Restriction
- 3.2.6. Berthing Area
- 3.2.7. Illuminations around Port Area
- 3.2.8. Traffic Condition

3.3. External Factors

- 3.3.1. Weather Condition
  - 3.3.1.1. Wind
  - 3.3.1.2. Visibility Condition
- 3.3.2. Sea State
  - 3.3.2.1. Wave
  - 3.3.2.2. Current
  - 3.3.2.3. Tide
- 3.3.3. Day / Night Vision
- 3.3.4. Tug Usage

3.4. Human Related Factors

In this study, no any classification related to human factor has been made.

3.1. Ship Related Factors

The characteristics that come to be during a ship’s construction define the limits of its manoeuvres. The ship related factors affecting manoeuvres were categorized as ship design related factors, ship propulsion system factors, bridge navigation system factors and other related factors.

Firstly, the effects of the measurements related to ship design such as the length, the width, the draft, and the tonnage on ship manoeuvres were mentioned. Subsequently, the important duties of parts of the ship propulsion system such as the main engine, the steering system, the propeller system, and the thrusters were mentioned. Later, the necessities of the aids to navigation within the bridge navigational system were explained. Lastly, in the other related factors section, topics such as adjusting the ship’s speed, the effects of the ship’s loading condition (ballast/laden) on the manoeuvre, and the use of the anchor were emphasized.

3.1.1. Ship Design Related Factors

When a ship’s dimensions are mentioned, the measurements of length, width, and draughts are considered. At the same time, these measurements are the factors defining the tonnage capacity of a ship being built. These measurements specify the area the ship can work in, the canals she can pass and the ports she can enter.

Different measurements are used according to the purpose of the discussion being had when the length of the ship is considered. Usually, when the length of the ship is being mentioned, length overall (LOA) is used. LOA is defined as the distance between the forward-most point and the aft-most point of the ship. It is the maximum length of the ship. As the length of the ship grows, differences in the ship’s manoeuvring characteristics occur. The force needed to stop or control a larger ship is considerably higher than that of a smaller one. In addition, it becomes more difficult for the ship to be able to turn and its stopping distance grows. It needs a larger manoeuvring area.

The ship's width is also called the "extreme breadth". It is the distance between the port and starboard extremes measured from the midship section of the ship (URL-2). Just as in the ship's length, the changes in ship's breadth also affect its manoeuvring capabilities. As the breadth of the ship increases, more force is needed for the manoeuvre, it becomes harder for the ship to turn and its stopping distance grows. A larger manoeuvring area is needed.

Draught is the vertical distance between the lowest point of the ship's keel and the waterline. When the draughts of the ships are compared, the ship with the smaller draught needs less force for the manoeuvre they carry out. Also, their stopping distances are shorter and they have a better ability to turn. For this reason, ships which have smaller draught require smaller manoeuvring spaces. A ship in the ballast condition will have a greater manoeuvring capability compared to a loaded ship due to her having a smaller draught.

To be informed about the manoeuvring characteristics of a ship, turning circle manoeuvre tests and stopping ability tests are carried out. With these tests, information such as the space required for the ship to manoeuvre and the distance as well as the time required for her to stop are acquired.

The turning circle manoeuvre test is a test carried out to specify the turning performance of a ship. For this test to be carried out, the ship must proceed in a line until its speed is fixed. When the speed is fixed, the wheel is turned to 35° or the maximum rudder angle, either port or starboard side. The ship is made to turn 360°. With this test, the ship's parameters such as advance, transfer, tactical diameter, drift angle, and speed loss are specified. (Sukas et al., 2017; IMO, 2002) In Figure 3.2., the "turning circle manoeuvre test" that a ship may create is seen.

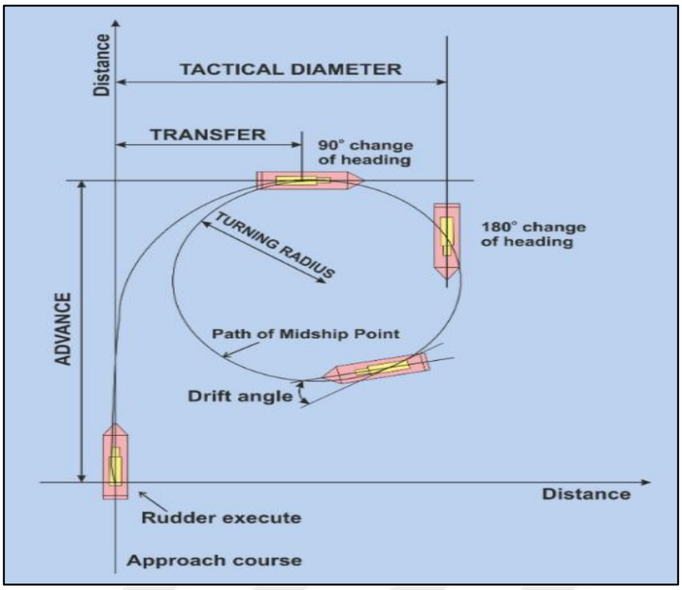


Figure 3.2. Turning circle manoeuvre test (Ghosh, 2019).

In the stopping test, a full astern command is issued when the ship is proceeding with a fixed speed. This process is carried out until the ship's speed above water reaches zero. The distance between the point where the full astern command was issued and the point where the ship comes to a halt is named the stopping distance (Sukas et al., 2017). This distance should not pass 15 times the size of the ship, and in ships with a large displacement, 20 times the size of the ship (IMO, 2002). In Figure 3.3., the path created by a ship during the stopping distance test is seen.

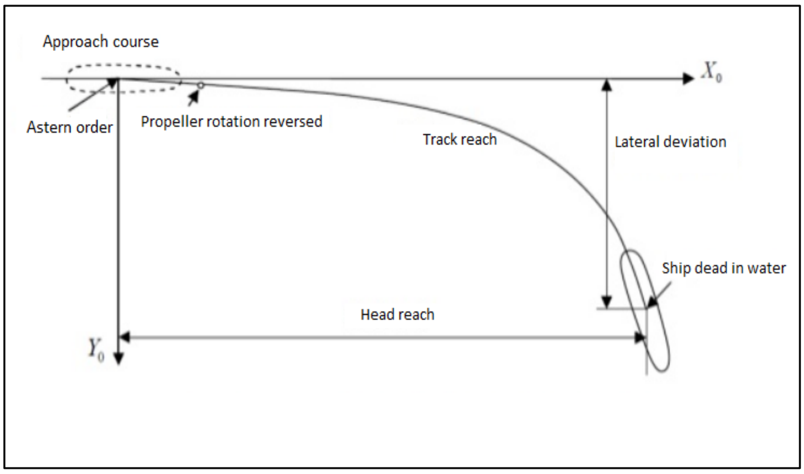


Figure 3.3. Path of ship during stopping ability test (Taha, 2016).

The ability to manoeuvre is especially important in areas with limited manoeuvring spaces such as ports. For a ship's length to increase, its breadth, draught and tonnage also need to grow. In Figure 3.4., the effects of the changes in a ship's length on its turning performance are shown. It is seen that as the ship's length increases, its turning circle diameter also grows.

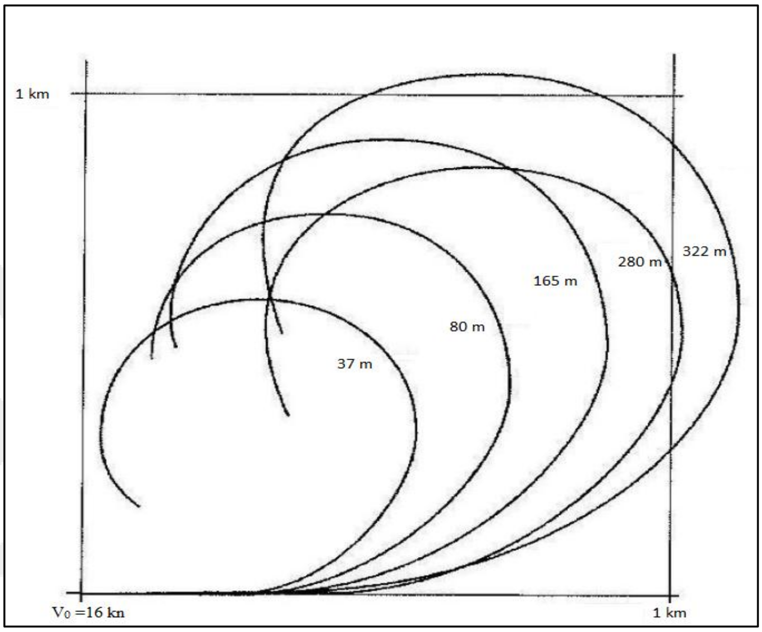


Figure 3.4. Effects of ship's dimension on turning performance (URL-3).

These factors affecting the ship's manoeuvre also defines a port's measurements. A ports depth, width limit, and berthing area details are dependant on the design specifications, and according to these specifications, the manoeuvring capabilities of the ships that will use the port. An increase in the ship's length, breadth, and draft will result in the required manoeuvring area to be deeper and wider. In addition to this, the ships will require wider and deeper berthing areas to board.

Ship types and structural features dependant on the type are also important factors affecting a ship's manoeuvre. For example; the higher freeboard of roll-on roll-off (ro-ro) ships result in these ships being affected by the wind during manoeuvring more. For container ships, the fact that their bridges are on the aft side of the ship will result in a decrease in the field of view when they are loaded with containers and this will restrict the manoeuvre (Zorba, 2007).

3.1.2. Ship Propulsion System Factors

A propulsion system is needed for a ship to move in a desired way on the water. The main engine, the propeller system, and the steering system are parts of this propulsion system. In addition, on many ships thrusters are present as propulsion devices. One of the most important forces under control during manoeuvring is the propulsion system. Uncontrolled forces can be controlled by using ship propulsion systems at the right place and time.

Engines producing the required force for a ship to move are called as the main engine. The main engine transfers the power it generates to the propeller through the propeller shaft and rotates it. The propeller system is the system that enables the ship to advance, that converts the power generated by the main engine into propelling force in order for the ship to move and that has a minimum of two and a maximum of seven wings (Ministry of National Education, 2013). The steering system, which is another propulsion system, is the system that allows a ship to be directed with the help of other propulsion systems.

Thrusters, which are especially present on container, ro-ro and passenger ships which carry out port manoeuvres often, are also defined as propulsion systems. Thrusters are systems that are generally used during port manoeuvres; they increase a ship's ability to manoeuvre, create a horizontal propeller force on the ship, and are effective at low speed. Thrusters are primarily located on the forward side of the ship but they may also be on the aft side. In case of the rudder not responding to the commands given by the helmsman not quickly enough or at all, the ship is moved in the desired direction with the help of thrusters. In case of the ship not having thrusters, or the force generated by the thrusters not being enough, tugs get involved to help the ship perform a proper manoeuvre.

When the propulsion systems are being decided on, factors such as the speed of the ship requested, the reliability of the main engine, the ease of maintenance, the volume occupied by the main engine and its weight, the type of fuel it uses and its consumption, the number of revolutions and compatibility with auxiliary engines are considered (Baykal & Dikili, 2002). In addition factors such as the type of the ship, the purpose of its use, and the frequency of its manoeuvres play an important role in deciding the main engine, propeller, and steering systems.

A malfunction on a ship can be thought of as; any equipment or machinery to stop due to a variety of reasons, for them to not work correctly, lose their function, or be damaged. Such malfunctions occurring on a ship, while resulting in great economic losses, also harbor great risks for navigational and environmental safety.

On ships; blackouts, electrical or mechanical malfunctions, auxiliary engine malfunctions, losses in fuel, oil or exhaust, cooling system malfunctions, and circuitry problems are engine malfunctions generally seen. With the maintenance done periodically on the ship's engines, the severity of possible malfunctions can be reduced and malfunctions prior to the expected service period can be prevented. Reasons such as the ship not being adequate for the ship area it operates in, correct and adequate maintenance not being done, aggressive cost saving or equipment expiring result in malfunctions. For these malfunctions to not occur, planned and routine maintenance should be done, and afterwards, for any breakdowns that may occur, permanent solutions instead of temporary ones should be applied.

Prior to port navigation, the engineers should carry out the necessary checks to ensure the propulsion system of the ship is ready for the manoeuvre to be done. If there is a situation that may affect the ship's navigation, the chief officer should inform the master about it. For any malfunctions that may occur during the navigation the pilot, if present, and the port authority, if needed, should be informed. The authorities should take the necessary precautions to minimize the risk of collision with the information provided by the ship.

3.1.3. Bridge Navigation Systems Factors

The bridge is the superstructure which includes areas such as the wheelhouse, the chartroom, and the bridge wings and is the location at the top extreme of the ship from which the ship is controlled. By positioning the bridge at the top of the ship, it is possible to control the ship and the environment easily.

The navigational aids that should be present on every ship depend on the ship's size and specifications. The navigational equipment that should be present on a ship is set by International Convention for the Safety of Life at Sea (SOLAS) Chapter 5 (Safety of Navigation) and equipment related to communication is set by SOLAS Chapter 4 (Radiocommunications) (IMO, 1974a). Generally, when a ship's bridge is examined; navigational aids such as gyro & magnetic compasses, radars (radio detection and ranging), the auto pilot, speed & distance log devices, the electronic chart display system (ECDIS), the global positioning system (GPS), the automatic identification system (AIS), the voyage data recorder (VDR), the navigational lights control panel, the engine order telegraph, thruster controllers, the daylight signaling light, the ship whistle controller, indicators such as speed, pitch, rudder angle, wind, speed, and communication devices such as the very high frequency radio (VHF), the medium / high frequency radio (MF/HF), the International Maritime Satellite System (INMARSAT) and the navigational telex (NAVTEX) are present.

For a safe port navigation, the navigational aids put to use on board the ship should be maintained, checked, and tested according to international rules and these equipment should be used by well-trained ship personnel with adequate knowledge and experience.

The risk of any accidents occurring is reduced by controlling the ship and observing the sea environment with the help of the navigational systems present on the bridge. Especially, the fitness for navigation of the ship is ensured by checking the bridge systems and equipment through the port state at the port boarded. If the ship is not fit for navigation, it is not allowed to sail. But such applications create economic troubles for shipping companies. To neither suffer economic losses nor cause a marine accident, it is important to adhere by the instructions set by international rules.

The technological advancements related to bridge navigational systems has created great advantages when it comes to controlling the ship for officers of the watch and masters. These advancements reduce the personnel's workload and increase their efficiency. As to not turn this advantage into a disadvantage, it is important to place the navigational aids present on the bridge ergonomically on the bridge for navigational safety (Kan & Kişi, 2016). A bridge not complying with ergonomic design makes it harder for navigational aids to be used efficiently. In addition, it results in the movement area on the bridge getting smaller.

For all deck officers to have adequate knowledge on the operation and the usage of navigational aids present on the bridge is important for navigational safety. Officers of the watch should study the manuals that belong to these systems; for them to be able to identify the possible malfunctions and alarms that may be given out by devices that belong to the navigational system and to know what kind of precaution should be taken in emergency situations such as these is important for navigational safety.

Any malfunctions that may occur during port navigation should especially be communicated to the pilot through the master. Precautions should be taken according to the malfunction that occurs, and if it endangers the safety of life and property, navigation should be stopped until the malfunction is taken care of.

3.1.4. Other Related Factors

A ship's loading condition, speed, and the use of its anchor are other factors affecting its manoeuvre. This part provides information about these factors.

3.1.4.1. Loading Condition Factors

Ships sail in either ballast or loaded condition. They usually sail to a loading port after discharging their cargo in another port in ballast condition.

The situation of the ship to not have any cargo loaded and having ballast water in tanks is called "ballast condition". Ballast water is the water kept in tanks built for it in order to balance the ship, reduce the stresses present, and to ensure the ship's propeller is immersed in water adequately (Ministry of National Education, 2011). The sea water is transferred to the tanks using the pumps present on the ship. Usually, a ship's ballast water capacity is about 30-35% of its cargo capacity.

For a ship to be loaded or in ballast condition affects its draught. For the draught of a ship to change is important for the water depth at the port to be adequate. A ship's draught in the loaded condition is greater than its draught in ballast condition. This means the ship will need a deeper area. Ships carrying cargo bound for different ports need to take the draught limitations of these ports and make their port arrangements accordingly.

Air draught is the distance between the upper extreme of the ship and the waterline. The differences made in the air draught by the load condition might create problems with ports that have a height restriction. Sometimes, in situations like this, ships takes sea water in their cargo holds to bypass this restriction. Air draught changes in relation to the loading condition.

Likewise, the ship's loading condition will change its manoeuvring characteristics. A ship's stopping distance and turning circle diameter are shorter in ballast condition than load condition. It allows the ship to respond to commands faster. The force needed for a loaded ship to be stopped or controlled is far greater than a ship in ballast condition. It is an important factor due to it being a situation to pay attention to during a manoeuvre. Also, it should not be forgotten that while a ship in ballast condition will be more susceptible to the wind than one that is loaded, a loaded ship will be more susceptible to currents than one in ballast condition.

3.1.4.2. Ship Speed

Ships not being able to correctly adjust their approach speeds cause many marine accidents within ports. When adjusting the ship's speed, many situations should be accounted for.

Squat is a factor affecting the ship's sinkage and trim values and is created by the differences in water pressure along the ship's length. The effects of squat are especially seen more in shallow water. Shallow water is defined as depths smaller than 1.5 times the ship's draught. (Zaman et al., 2016)

A higher ship speed is an element that increases the effects of squat. Especially in shallow water, a higher ship speed will result in stronger squat effects. When the formula for squat is analysed, the squat value for shallow water is twice the value for open seas.

$$Open\ sea: \quad Squat\ (\sigma) = C_b \frac{V^2}{100} (meters) \tag{2.1}$$

$$Shallow\ water: \quad Squat\ (\sigma) = 2C_b \frac{V^2}{100} (meters) \tag{2.2}$$

where

$$C_b = \frac{Displacement/1.026}{L\ X\ B\ X\ D} \tag{2.3}$$

L: length of ship B: breadth of ship D: draught of ship

C_b: block coefficient V^2: ship speed

While a higher speed will result in a higher squat value, very low speed will result in the ship's rudder not responding to commands. This will negatively impact the ship's manoeuvring capabilities.

Since a sudden drop in the ship's speed will result in losing the control of the ship, the speed needs to be reduced gradually. In addition, when the ship's speed is being adjusted, factors such as the steerageway, the tug's attachment situation, the tug taking a manoeuvre-ready position and the ship's stopping distance should be considered.

3.1.4.3. Ship Anchor

The anchor is a piece of equipment that allows the ship to resist environmental factors such as the wind and currents, that serves as a connection with the seabed to hold the ship in a specified area and that makes its connection with the ship via shackles. The correct use of the anchor can contribute to the manoeuvre that is desired to be done and the anchor may be used to prevent any undesired movement during the manoeuvre.

When the anchor is being used; the structure of the seabed, the depth of the area and the area to be anchored in should be ensured to be fitting for the manoeuvre. A wrong anchor manoeuvre may cause great damages. Also, the environment that is to be anchored in should be adequate for anchorage and the anchor should be dropped in such a way to ensure no other ship's movement is restricted.

3.2. Port Area Related Factors

Defining the manoeuvring constraints of a port is finalized with the evaluation of ship, port area, and environment related factors. While a port area is being designed; plans such as the manoeuvring circle, the berthing areas, the anchorage areas, breakwaters, port approach channel, internal communication channel, and special purpose areas should take priority (Altyapı Yatırımları Genel Müdürlüğü [AYGM], 2016). While planning these, environmental factors such as meteorological and oceanographic elements should not be overlooked. The purposes of these plans are to create the most adequate conditions for a ship coming into the port to complete its desired manoeuvre in the safest way and the shortest time. In addition to factors such as the ship's length, type, and breadth, the effects of environmental factors on the ship will define the limits of the plans.

A port being constructed in an area or being worked on should fulfill many conditions; (Oral et al., n.d.; Usluer & Alkan, 2015)

- Firstly, the area chosen should have the space that fulfills the required conditions in respect to both sea and land areas.

- The marine traffic conditions should be fitting for the port area. It should not create any situations that may risk the ship's manoeuvre.
- The port's topographic and bathymetric values should be sufficient for port construction.
- Conditions such as meteorological (wind, visibility, temperature, humidity), hydrographical (current, wave, tide), and oceanographical (the temperature of the sea water, its values such as density and pressure) factors should not affect the port operations negatively.
- The planned area should be geologically, geophysically, and geomorphologically fitting for port construction.

In conclusion, for a port's construction or expansion, firstly the planned area's meteorological and hydrographical features such as shore structure, water depth, topographical features, currents, winds, and waves should be analysed. While these analyses are being conducted, the port's fitness and limits should be identified with the help of fields such as geology, geophysics, meteorology, topography, hydrography, and seismology.

Terms defined below are terms that may be encountered when a port area is being considered.

- Navigable Waterway (Channel): Waterways with adequate depth and width for a ship to use in order to safely reach an intended position. The navigable waterway that will be referenced in this chapter is the navigation wise safe waterway used by a ship in order to reach the desired port.
- Berthing Area: Areas ships proceed to with the purposes of loading, discharcing, waiting or receiving certain services
- Breakwater: Structures built with the purposes of protecting the port from environmental factors such as waves and currents and to allow ships to manoeuvre safely and swiftly in this protected area.
- Manoeuvring Area: Water areas on which factors such as a ship's direction and speed are adjusted in order for the ship to board a specific place in port or to leave the said port.

In this section, ports' effects on ship manoeuvres were mentioned. The topics of port area, width and depth of the port entrance, depth of the port area, aids to navigation in the port area, air draught restrictions, berthing area, illuminations around the port area and traffic condition were explored.

3.2.1. Width of Port Area

When a port's width is being determined, the manoeuvring capabilities of the ships that will navigate in the area are an important matter to take into account. Every ship will have different manoeuvring characteristics depending on its features. A ship with thrusters has advantages in manoeuvring capabilities over one without thrusters, and passenger ships have an advantage over other types of ships. In addition, when channel width is being determined, the number of ships to pass the channel side by side at a time is an important factor.

A port's manoeuvring circle area should have twice the size of the LOA of the largest ship that can enter the port as its diameter. If tug services are unavailable in the port, the diameter of this circle should be three times the LOA (Figure 3.5). Since the negative effects of environmental conditions will increase the risk, the manoeuvring area is then expanded. (Permanent International Association of Navigation Congress [PIANC], 2014)

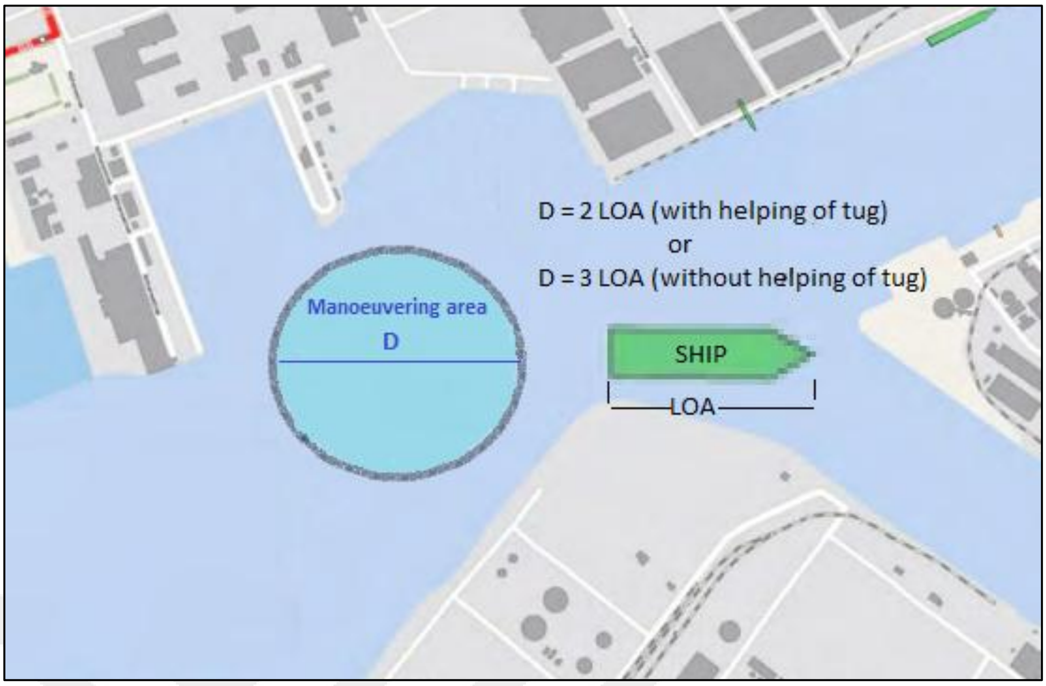


Figure 3.5. Minimum manoeuvring area for ships in port

The navigable waterway being one-way or two-way is an important criterion with respect to its width being determined. More than one ship navigating within the port will result in the required space to be expanded. In addition, the use of tugs is an important factor in determining the minimum width of the manoeuvring area. Since ships can manoeuvre in a smaller area with the help of tugs, the area required will be smaller than under normal circumstances.

Another important point to pay attention to with ports is the consideration of ships' stopping distances and the port having the necessary space. This distance should be determined while keeping the ship's speed while entering the port as well as situations such as the tugs making fast to the ship and getting into position in mind. The required port area will change depending on the type and characteristics of the ships to enter the port.

3.2.2. Width and Depth of Port Entrance

Port entrance is defined as the waterway entrance that connects the open seas and the port area. When the width of the port entrance is being determined, factors such as current, waves, wind, and ship length should be accounted for. The width of the port entrance should be the same as the LOA of the largest ship to enter the port (Figure 3.6.) (PIANC, 2014). The ship should not contact anything even if it turns completely to its side. In addition, a safety margin should be determined with respect to the effects of environmental factors.

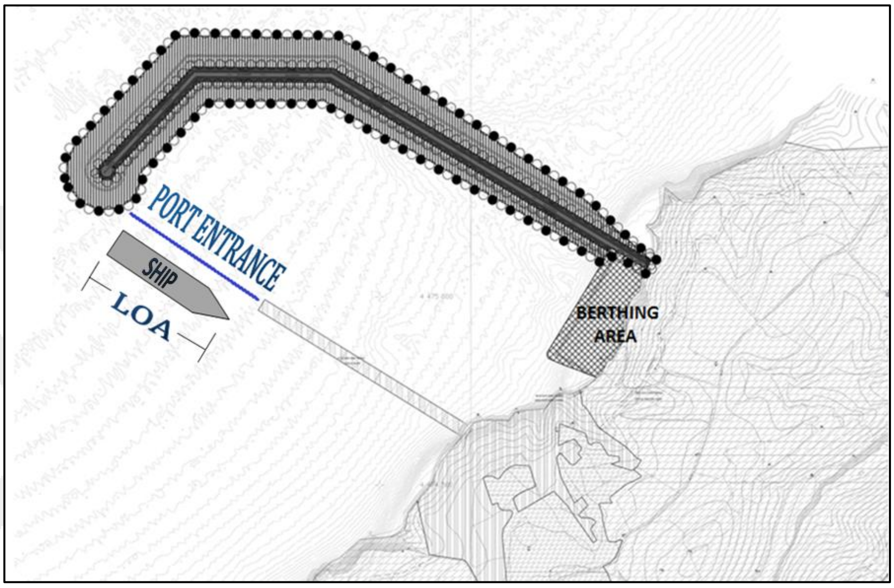


Figure 3.6. Width of port entrance

The depth of the port entrance should be as deep to allow the largest ship to enter the port can comfortably do so with the highest waves possible at the port entrance (PIANC, 2014). This should eliminate the risk of the ship grounding.

3.2.3. Depth of Port Area

There are many factors affecting the depth of a port. A port's depth should be ensured to be adequate for manoeuvring in order to prevent groundings. Factors mentioned below are considered when a port's depth is being calculated; (AYGM, 2016)

- **Ship's Draught**: The maximum draught of a ship that may enter a port depends on the depth of the said port. When the ship's draught is being calculated, the affect of the water density on the draught should not be forgotten. Especially when proceeding from salt water to fresh water, depending on the ship's size, every ship will have differences in its draught. This happens most noticeably in ports with low water density such as ports on rivers or channels. Sometimes, ships incorrectly calculating their draughts will result in groundings or them not being able to navigate through areas with draught restrictions such as the Panama Canal. These situations create great economic losses for shipping companies. When a ship's draught is considered, not only the draught values in static position but also the draught values in a dynamic position should be taken into account. A ship's draught in dynamic position is larger than its draught in static position. Factors such as differences in list, squat, differences in density, and differences brought by waves are amongst the elements that result in a ship's draught in dynamic position being larger.

- **Squat:** The ship's draught and aft trim increasing with squat is a reason for the ships needing more depth. The effects of squat are seen more in ports due to them being shallow. When the squat is being calculated, the effect of the ship's speed on the squat should not be forgotten. The ship's maximum speed within port limits should be taken into account. For the ship's master to correctly determine the safe speed of navigational speed for shallow waters and for them to proceed appropriately with the changing conditions is important for navigational safety.

- **Wave Height:** Wave height is a factor affecting water depth. In depth calculations, half of the wave height (wave/2) is added to the depth.

- **Tide:** When the effect of tide on the depth is being calculated, the tide's lowest value will be added to the depth. An incorrect tide calculation will result in groundings and the ship's keel being damaged.

- **Seabed Structure:** Structural differences in the seabed may result in differences in port depths. With underwater movements and with the effects of the microorganisms, changes in depths may occur. The port authorities should take the necessary precautions for risks posed by these kinds of situations. They should conduct depth measurements with set intervals. In addition, changes in depth that may occur while dredging should be accounted for. The seabed structure affects ships' keels as well as depth. For example; the ship's keel to be covered by microorganisms such as clams and algae will damage the structure of the ship as well as negatively affect the ship's manoeuvring capabilities.

3.2.4. Aids to Navigation in Port Area

Navigational aids, or aids to navigation, are systems and equipment which allow seafarers to check their positions and headings, they also warn seafarers about the hazards and obstructions to present above or underwater at the position they are at (International Association of Marine Aids and Lighthouse Authorities [IALA], 2010). Aids to navigation include objects present on land or floating on water such as lights, buoys, lightships, fog signals, radio beacons, and lighthouses. With these aids to navigation which act as guides, ships navigate safely and efficiently. As ships get closer to shore, hazards and obstructions increase this in turn increases the importance of navigational aids.

According to SOLAS (Chapter 5 Reg. 13), contracting governments undertake to provide such aids to navigation as the volume of traffic justifies and the degree of risk requires (IMO, 1974b). It is possible to get an idea about an area by analysing the shapes, colors, top marks, light characteristics, and sound features of aids to navigation in the specified area. Usually, during navigation, officers of the watch will check the aids to navigation which are marked on navigational charts and on the ECDIS by eye to ensure the position of the ship is correct.

It is important for aids to navigation to be present in port areas for a safe navigation. Navigational aids are especially important during coastal navigation in areas such as ports. For navigational aids to malfunction, for them to change their positions due to technical issues etc. may risk the port navigation. Problems such as these may make the navigation more difficult and may cause the pilot or the master to make mistakes. It is imperative for the contracting governments to take precautions for these kinds of risks in order to ensure marine safety.

3.2.5. Height Restriction

In certain ports, obstructions such as bridges, electricity cables, and power lines create problems for ships with high air draughts. As to not collide with any of these obstructions in port areas, the calculation of the air draught should be done correctly. The ship and the environment may suffer great damages in case of any contact with these height restrictions.

A ship navigating on a navigable waterway in a port should have a minimum of 0.05 times its air draught as the distance between its top extreme and any bridges it may cross during its navigation. A ship navigating on a navigable waterway outside of port boundaries should have 0.4 times its draught added to 0.05 times its air draught as the between its top extreme and any bridges it may cross during its navigation (PIANC, 2014). In Figure 3.7., the distance that should be present between a bridge and a ship that crosses under it is shown.

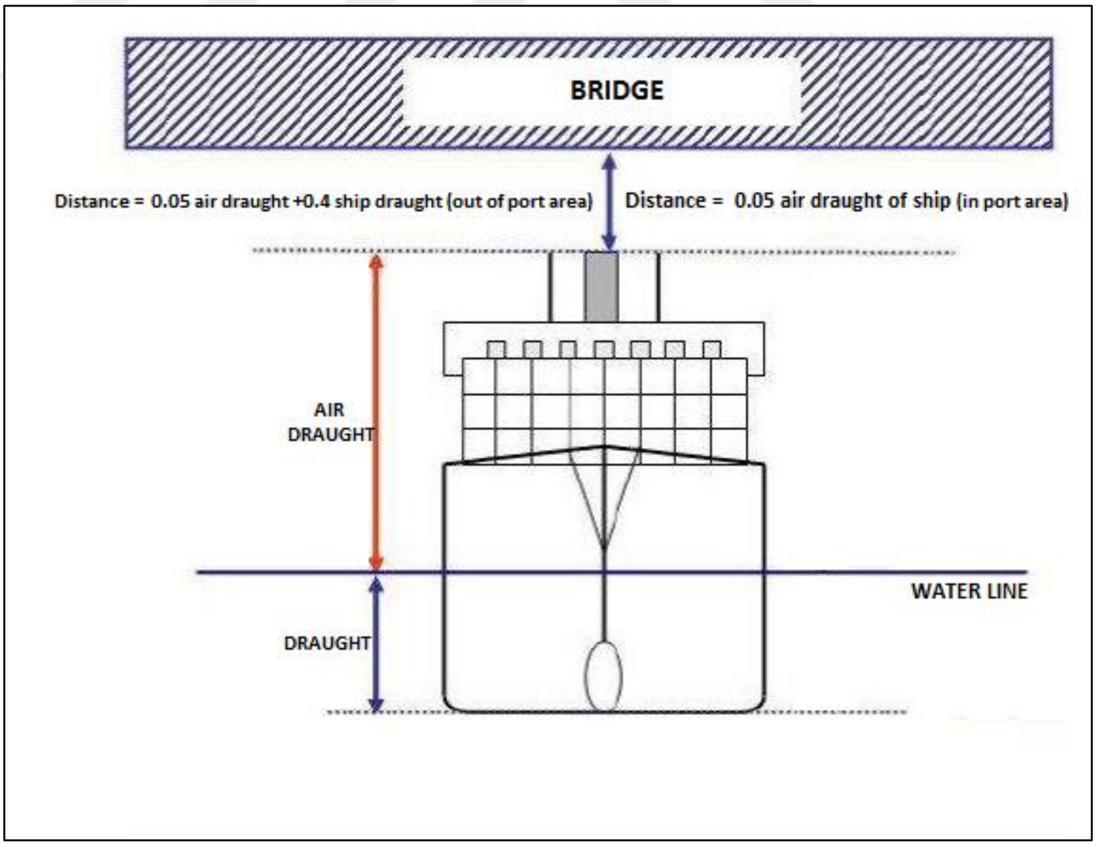


Figure 3.7. Distance between ship and height restriction (PIANC, 2014)

3.2.6. Berthing Area

A berthing area for a ship may be structures such as a dock, a pier, or a dolphin. These structures should have the adequate length and depth as well as a sea area fit for manoeuvring according to the ship’s dimensions they are designed for. If the ship to berth will need to anchor, the seabed structure and the sea area should be fitting for the anchoring operation. Additionally, the berthing area should be fitted with equipment such as fenders, bollards, etc. to allow the ship to berth to do so safely.

If multiple ships are to berth at the same berthing area, the structure should be built accordingly as to not allow any accidents. The berthing areas should be designed to let them be affected by environmental factors such as wind, current, tide, and wave at a minimum. If not, the berthing area and the ship might suffer great damages during manoeuvring or after mooring due to environmental factors.

3.2.7. Illuminations around Port Area

Illuminations around port areas aggravate port manoeuvres done at night. City lights, port illuminations, aids to navigation, and lights of the ships in the vicinity are illuminations that reduce visibility.

On the bridge, a great lookout should be conducted and the environment should be observed well as to correctly identify the lights seen in the vicinity for a smooth manoeuvre. Port illuminations should be placed in such a way as to affect manoeuvres at a minimum. Illuminations should be designed in a way to not obstruct the manoeuvres of ships, especially those that come from the sea side. If not, situations that risk navigational safety might occur.

3.2.8. Traffic Condition

The growth of the global trade fleet caused an increase in marine traffic density. This increase in density proportionally affects port traffic. In addition to merchant ships; tugs, pilot boats, fishing boats, special purpose ships engaging dredging and underwater operations, ships providing local services, yachts, platforms, and barges may also be listed as causes for the traffic density in ports.

Not only ships which are underway, but also ships which are waiting at anchor, coming alongside docks, conducting operations in sea areas, fishing boats casting their nets and waiting while drifting create traffic density within the port area. In addition to the number of ships increasing, the size of these ships growing has also negatively affects port traffic. All these factors draw attention as situations that affect port traffic directly and increase the risk of marine accidents at ports.

Port authorities plan a time table for the ships to enter or depart from a port, especially in larger ports due to high traffic density. When ships arrive at a port earlier than expected, they wait by either anchoring or drifting. The traffic density is aimed to be kept under control with this planning.

In port areas, obstructions that may limit a ship's manoeuvre are numerous. The master is required to take these obstructions that may limit the manoeuvre as well as the marine traffic during a manoeuvre. This situation results in the marine traffic that occurs in port areas to carry more risks than open seas. The occurring risk, then, results in the masters navigating in port areas needing to be more careful during their manoeuvres.

The bridge team present during the port navigation should carefully follow the traffic in the vicinity and should not deviate from the rules put in place by the Convention on the International Regulations for Preventing Collisions (COLREG). Additionally, any rules and recommendations set by the port authority should be followed to the letter. Necessary checks and tests should be completed prior to port navigation to reduce the risk of any malfunctions during the navigation to a minimum.

According to SOLAS (Chapter 5 Reg. 12), states may establish VTS at areas they deem to have high traffic density and thus risky (IMO, 1974c). VTS is a service that observes the marine traffic, that allows the ships to proceed safely and efficiently, that protects the environment and that warns ships about marine traffic, meteorological situations, and other hazards by broadcasting, VTS also provides momentary interventions via VHF if necessary (IMO, n.d.). In areas where navigational safety is at risk, the marine traffic may be controlled with VTS and the risk may be reduced.

Another important arrangement done to control the marine traffic is the Ship Routing System (SRS). It is a system that is established by contracting governments according to the rules set by the IMO with the purposes of controlling the marine traffic and minimizing risks of accidents occurring. The SRS defines areas such as traffic separation schemes, traffic lanes, separation zones or lines, roundabouts, inshore traffic zones, deep-water routes, precautionary areas, and areas to be avoided with one, or if needed more, routes in order to regulate the marine traffic. This system, depending on the area it is in, may be advisory or with the authorities' decision, compulsory. Even though the traffic that occurs around ports increases the risks, precautions taken locally and internationally allow safe port manoeuvres to be done. (IMO, 1974d; Official Gazette, 2009b)

3.3. External Factors

In this section, the effects of tugs being used in ports, day/night visibility, and environmental factors that set the weather and sea conditions such as wind, visibility conditions, wave, current, and tide on ship's manoeuvres were mentioned.

3.3.1. Weather Condition

The effects of wind and visibility on a ship within a port were explained.

3.3.1.1. Wind

Wind affects manoeuvres greatly due to it being uncontrollable and it being able to change its direction and force at any moment. Wind may cause certain movements on a ship to increase.

Ships have six movement components consisting of three linear and three rotational motions. These motions are called the “six degrees of freedom”. Surge, sway, and heave make up the linear motions; yaw, roll, and pitch make up the rotational motions. In Figure 3.8., these motions are shown on a ship. In the Figure, the back and forth movement alongside the ship’s length called “surge” is marked as X_1, the port and starboard movement alongside the ship’s breadth called “sway” is marked as X_2 and the up and down movement of sinkage and rise called “heave” is marked X_3. The longitudinal rotational movement called “roll” is marked as X_4, the transverse rotational movement called “pitch” is marked as X_5 and the vertical rotational movement called “yaw” is marked as X_6.

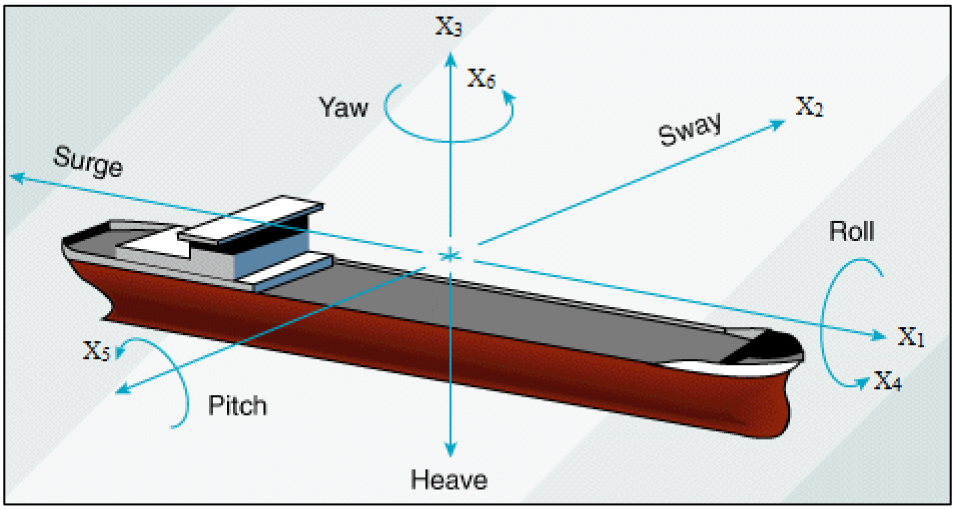


Figure 3.8. Vessel's six degrees of freedom (URL-4)

As well as changing the ship’s speed, the wind also causes an increase in the rotational movements seen on the ship. How these movements will affect a ship differs depending on the direction and force of the wind, the ship’s movement (forward, stop, astern), and the ship's structure above the water. The wind may ease the manoeuvre being done if it contacts the ship at an appropriate angle.

The wind shows different effects depending on the area on a ship it contacts. For example; while a wind that blows from ahead while the ship is moving forward will reduce its speed, it will also ease its steering and reduce its stopping distance. If the wind is blowing from the sides, the ship will "roll". A wind blowing from astern will increase a ship's speed and its stopping distance. Especially during berthing or departure manoeuvres, a position to feel the effects of the wind at a minimum should be taken.

The effects of the wind should be thought to be effective inversely with the ship's speed. As the ship's speed reduces, the force wind applies on the ship will increase. Additionally, ships with a larger wind area such as container, passenger, and Ro-Ro types get affected by the wind more.

If we can correctly estimate the effects of the wind on a ship, we can reduce these effects to a minimum with the precautions we can take, and in fact, turn this into an advantageous situation for the manoeuvre.

3.3.1.2. Visibility Condition

Visibility is the farthest distance an object with an appropriate size can be seen under daylight, or at night, is the distance at which an object being lit near daylight conditions can be seen (IALA, 2009). Weather events taking place in the atmosphere take an important role in determining and limiting the visibility.

COLREG (Rule 3) defines restricted visibility as causes such as fog, mist, falling snow, heavy rainstorms, sandstorms, or any similar situation limiting visibility (IMO, 1972). In COLREG Rule 19, ships navigating in areas with restricted visibility should proceed with a safe speed appropriate to the conditions present and the ship's engines should be ready to manoeuvre at all times. Navigating with a safe speed ensures that the pilot has more time to assess the manoeuvre to be done. In a restricted visibility situation, sound signals laid out in COLREG (Rule 35) to be given in restricted visibility conditions should be sounded. (IMO, 1972)

During navigation, with visibility getting restricted the importance of navigational equipment, especially radar and ECDIS, increases. In these conditions under which navigation by eye is difficult, our navigational equipment will function as our eyes.

A manoeuvre in which environmental conditions cannot be easily seen is a difficult one. Usually, under restricted visibility conditions the port authorities will not allow manoeuvres. Restricted visibility caused by meteorological events negatively affects port entry and departure navigations for their duration. Under restricted visibility conditions, the checks laid out in the “check list for navigation in restricted visibility” should be carried out and necessary preparations should be made.

Since the hazards closer to the forward of the ship are thought to be the most dangerous, a lookout stationed at the forecastle will benefit the navigational safety. The lookout positioned at the forecastle will ease the duties of the bridge team with their reports.

During restricted visibility, fixes should be made with small intervals as to be certain of the position of the ship. Additionally, the traffic in the vicinity should be checked with the help of electronic equipment and the intentions of these ships should be understood.

3.3.2. Sea State

In this section, factors that affect sea conditions such as wave, current, and tide were emphasized.

3.3.2.1. Wave

Waves, which are mostly created by the wind, occur due to the friction between the wind and the sea surface. Additionally, waves created by the tide called tidal waves may occur (National Oceanic and Atmospheric Administration [NOAA], 2018). Waves affect the ship's steering characteristics due to their hydrodynamic effects on the ship (Rameesha & Krishnankutty, 2019). It is important to know the effects of the waves on the manoeuvre to control the ship for the ship's safety.

Just as with the wind, contact of the waves with the ship creates oscillation movements in six degrees of freedom. When the effect of the waves on the ship increases, the effect of rolling and yawing movements also increase.

Changes in the ship's draught and air draught occur with these movements that happen due to present waves. Steering becomes harder, deviations from the course occur, drops in propeller performance occur and changes in the turning circle and stopping distance happen. The ship's structure may be damaged after hard contact. High waves may make it harder for the pilot to board a ship and may damage the pilot boat. In certain ports, pilots embark ships through the use of helicopters to eliminate such hazards. Additionally, high waves might cause shifts in cargo due to the movements they create on ships. The ship getting damaged may affect the port area or the traffic within the port area negatively. The master should ensure that the cargo loading has been done to suit harsh weather.

In addition to the wind, ships may also create waves with their movements within ports. The size of the wave changes depending on the size and the speed of the ship. When the waves contact ships moored to the port, they may cause rolling and thus resulting in the ships moving away from the dock or suffering hard contact with it. Additionally, the waves may cause more stress on the ship's lines and this may result in the lines breaking.

3.3.2.2. Current

The action of water on the sea surface being moved from its initial position to another point is called “current”. The current affects objects depending on its set and drift. The direction the water moves is called its set and the distance it travels is called its drift.

Currents too affect the ship according to the ship’s speed and course like the wind. But the effect of the current is far greater than that of the wind. The effects of current with 1-knot force is equivalent to those of wind with 30 knots force. The affecting current in an area, while dragging a ship towards its set with the same speed as itself, will drag a ship that’s moored or anchored towards its set until a certain amount of force is applied to the edge of the ship’s mooring or anchoring.

Elements such as the wind, tide, changes in water levels, sea water temperature, and sea water density create current (AYGM, 2016). Information about currents in a specific area can be found on nautical publications. During navigation, the effects of currents can be minimized with preventive routes.

Civil engineers design the docks built in rivers and canals in parallel with the prevailing current’s set and try to reduce the current’s impact on the manoeuvre of the ship that will berth that dock. Controlling a ship during a manoeuvre is relatively easier if the current comes from ahead to stern direction rather than the sides.

3.3.2.3. Tide

Tide occurs due to the pull effects of the Moon and the Sun over the Earth and causes movements on the sea surface. There are three types of tide called diurnal tide, semidiurnal tide, and mixed tide. The type of tide that may be encountered differs between different areas.

As a result of tidal movements, tidal currents occur. Ships, especially those restricted in their movement due to their draughts, should pay attention to the times of the high tide.

It is important for navigational safety to complete a manoeuvre swiftly and within the correct time frame. Additionally, the master should be informed about the tide height, tide times, tidal current's set and drift prior to port navigation.

3.3.3. Day / Night Vision

Navigation done during the night is more difficult than navigation during the daytime and it requires more information. During the night, eyes need a couple of minutes to adjust to the darkness and be able to start seeing the lights on the horizon. Additionally, during night navigations, people may get sleepy and this may cause attention deficiencies.

During night navigations, the vicinity should be observed well especially while approaching a port and all navigational aid illuminations should be identified correctly. While during the daytime it is easy to identify floating objects and land features, it is not as easy during the night. If a ship's lights can be perceived well, its approximate size, direction, and type can be estimated. Similarly, the characteristics of buoys and lights can be observed to get information helpful to the navigation.

Onboard ships, in order to be able to observe the vicinity, all illuminations on the bridge are kept at off position and illuminations of all equipment are kept at a minimum to not obstruct view. If these adjustments are not done, it cannot be expected of the bridge team to conduct a thorough lookout.

In a report released by MAIB (Marine Accident Investigation Branch) in 2017, it is remarked that a ship and a yacht have collided and in this collision, the lookout experienced difficulties due to 3 reasons. A lack of an environment fit for adjusting one's sight to darkness, the light pollution present on the bridge, and the lookout wearing photochromic lenses on the bridge are listed as the reasons that caused the accident to happen (Wynn et al., 2012).

It is obvious that navigation during nighttime has more risks than navigation during daytime. For the bridge to be prepared adequately for nighttime navigation and for the bridge team to be prepared for the navigation is important for nighttime navigation.

3.3.4. Tug Usage

Ships with high manoeuvrability are used to assist especially larger ships with boarding and departure manoeuvres. These ships are more powerful compared to other ships despite their sizes. They are important external aids to manoeuvring with their high manoeuvrability and powerful propulsion systems.

Tugs may be used to push or pull ships that cannot move on their own such as barges, pontoons, and platforms, to assist the manoeuvres as a salvage of ships that have sunk, has been in an accident or has lost their ability to manoeuvre after being damaged, they may be used as icebreakers in areas where ice navigation is being done and to intervene with emergency situations such as fires as well as search and rescue operations. In addition to these purposes, they are generally used to assist with ship's boarding and departure manoeuvres.

Tugs are divided into three categories as seagoing tugs, escort tugs, and harbor tugs according to their application and purpose.

- **Seagoing Tugs:** They may be used to assist ships in any sea are, regardless of the time of the year without limits. Generally, they are used to save or tow ships that have been in an accident, have grounded or have malfunctioned; they are also used to tow structures without the ability to manoeuvre on their own such as offshore platforms, wrecks, and barges to certain points (URL-5).

- **Escort Tugs:** In narrow channels and dangerous areas considering manoeuvring, they are used to assist the manoeuvres of large ships and to intervene in the case of any malfunctions occurring. During the ship's navigation, the tug proceeds close to the ship or makes fast to it with lines to be ready to intervene if needed. This situation is called an escort service (Eke, 2010).

- **Harbor Tugs:** These tugs are used in ports to assist with the ship's manoeuvres within the port and to allow the ship to proceed to the desired location swiftly and safely.

When a new port is being constructed or a change is being made in the port's structure, one of the first things to be considered is the tugs to be used during the manoeuvres. Compared to the past, ships growing in size and tonnage results in the number, and the power of the tugs needed to increase. When the capacities of the tugs are being determined, the features of the ports to manoeuvre in as well as the ship values should be taken into consideration. Especially the manoeuvring area is a very important factor in determining the tug capacity.

The number of tugs to be used in a manoeuvre is determined in some ports according to the gross tonnage of the ship to be assisted and in some ports according to the length of the ship to be assisted. But in addition, these, the most important things to consider are the meteorological conditions. The force and the direction of the wind and the current are important elements of estimating the difficulty of the manoeuvre. Another thing to consider is how much the ship will be affected by these conditions considering its design.

In Turkey, according to port regulations, ships that will come alongside a port, except for passenger ships, shall be assisted by the specified amount of tugs with appropriate minimum pulling forces according to the ship's gross tonnage as laid out in Table 3.2. The port authority of the port considered has the authority to increase this number if needed. Additionally, according to the regulations, all ships except ships longer than 200 meters and ships carrying dangerous goods, depending on the number of thrusters present on the ship and with the condition that at least one tug is being used, certain reductions in the minimum pulling forces of the tugs used may be acceptable. (Official Gazette, 2012)

Table 3.2. The number of tugs and the tugs' pulling powers required for ships and sea vessels according to gross tonnage (Official Gazette, 2012).

Ship GT	Ship Type	Amount of Required Tugs (minimum)	Total Pulling Power Required (minimum)	Remarks
2000 – 5000	All ships	1	16 tonnes	A minimum of 16 tonnes
5001 – 15000	All ships	2	32 tonnes	Each with a minimum of 16 tonnes
15001 – 30000	All ships	2	60 tonnes	Each with a minimum of 30 tonnes
30000 – 45000	All ships	2	75 tonnes	Each with a minimum of 30 tonnes
45000 and up	Ships not carrying dangerous cargo	2	90 tonnes	Each with a minimum of 30 tonnes
45001 – 75000	LPG, Flammable, Explosive and Chemical Tankers	3	90 tonnes	Each with a minimum of 30 tonnes
75 000 and up	LPG, Flammable, Explosive and Chemical Tankers	3	120 tonnes	Each with a minimum of 30 tonnes
All Tonnages	Ships carrying LNG	3	150 tonnes	Each with a minimum of 30 tonnes

When passenger ships are considered, conditions set in Table 3.3. are taken into consideration while the number of tugs and their minimum pulling power is being determined.

Table 3.3. The amount of tugs and tugs' pulling powers required for passenger ships according to gross tonnage (Official Gazette, 2012)

Ship LOA	**Total Pulling Power Required (minimum)**	**Comments**
Between 55 and 125 meters	A minimum of 30 tonnes	One 30 ton tug or two tugs with a minimum of 16 tonnes of power each.
Between 126 and 200 meters	A minimum of 45 tonnes	One 45 ton tug or two tugs with a minimum of 30 tonnes of power each
Between 201 and 300 meters	A minimum of 60 tonnes	One 60 ton tug or two tugs where one of them has a minimum of 30 tonnes of power
301 meters and up	A minimum of 90 tonnes	One 90 ton tug or two tugs where one of them has a minimum of 30 tonnes of power

To be able to conduct a manoeuvre in combination with a tug and for this manoeuvre to be completed safely and swiftly, the necessary information should be exchanged between the pilot and the master. Information should be shared between the pilot and the master about the number of tugs to be used, the power of the tugs, the point on the ship where the tugs will be used, the angle of pull of the tugs, the fastening method of the lines, the lines to be used, etc. The pilot should give detailed information to the master about the manoeuvre to be done. Additionally, any information deemed necessary should be communicated to the tug master by the pilot.

Communication is one of the most important topics during the operation. The VHF channel to be used for communication between the ship and the tug should be determined and tested beforehand.

As to not damage the ship’s equipment, the safe working load (SWL) of the said equipment and the force to be applied by the tug to this equipment should be paid attention to. The ship’s and the tug’s personnel should check the lines and the equipment to be used prior to the manoeuvre. During the manoeuvre, the lines being used should be checked by eye and if needed, the masters should be informed. During the operation, the ship’s personnel and the tug’s personnel should ensure their own safety and stay clear of the dangerous zone. The personnel should be informed and educated about the possible risks.

Tugs are used to board a ship to a port in a controlled manner. Tugs are generally belayed to ships via a single line and apply pulling or pushing force. Due to the manoeuvring space of a ship generally being restricted, the help of the tug is utilized to push or pull a ship in order to rotate it to a required angle. During the boarding of the ship, the unexpected movements of the ship are controlled with the tug and thus hard contacts with the dock are prevented. Especially to moor a ship parallel to a dock, the tugs present at forward and aft sides of the ship should manoeuvre carefully.

Just as during boarding manoeuvres, the use of tugs becomes necessary during departure manoeuvres in order to allow a ship to depart from a dock in a controlled manner. Especially in ports with affective wind and currents are present; tugs are one of the greatest assists when it comes to overcoming these forces. While tugs allow the manoeuvre to be done safely, they also contribute economically by allowing the manoeuvre to be done in a short time.

3.4. Human Related Factors

Despite the much advancement in technology, rules set locally and internationally, and the many precautions are taken, in a lot of places around the world, especially where ships are dense around the shore, the rate of marine accidents are still very high. The biggest element in these accidents is known as human errors. The share of the human factor in marine accidents is around 80% (Mousavi & Jafari, 2017).

Navigation within port limits carries more human error related risks than navigation done on the open seas. In addition to environmental factors, during any navigation done within port limits the number of people involved is directly or indirectly grows. This growth greatly affects the risk of an accident. While only the ship's personnel are considered when it comes to the open seas, within port limits in addition to the ship's personnel the mistakes of parties such as the pilot, the tug personnel, port personnel, VTS, port control and directory stations such as the pilot station play an important role in the safety of the ship and the environment.

One of the biggest problems faced during manoeuvring is communication. Insufficient internal or external communication, incorrect interpretations, and misunderstandings, sharing of insufficient or incorrect information, and problems about the working language are communication problems generally encountered.

Another important element is the lack of adequate environmental conditions. Factors such as noise in the area, vibration, difficult weather conditions, limits in working areas, and insufficient equipment push people into making mistakes.

Problems with physical and psychological origin also result in mistakes. Fatigue, alcohol and substance abuse, lack of sleep, attention deficiency, illness, and overworking may be listed as examples.

When the human factor is being considered, only taking the people involved in the operation process may mislead us. Wrong decisions made by people in company management may also cause mistakes during the navigation process. The wrong choices made in manning and applications cause human errors to increase. The main cause is to employ personnel that is unfit for the work, that is not well educated or that does not have adequate technical information and experience. Additionally, companies making the ship personnel perform unsuitable actions due to commercial reasons create the human error.

Inadequate watch handovers, bad lookouts, incorrect navigation planning and application, a lack of attention, prejudices about the personnel, incorrect decisions or evaluations, overconfidence, abuse of authority, incorrect business practices, incorrect reports, unfamiliarity with the ship and its auxiliary systems are other factors resulting in human error.

To minimize human errors; the personnel should be able to adapt to the given task, their skills should be suitable for the job, awareness of the task should be created, and they should be trained according to the job. Another important topic is to create a safety culture among people. This culture should be created in order to ensure people avoid unsafe actions.

Especially the companies should put weight on marine training, better the living and the working conditions of the personnel and pay adequate care to rest hours in order to reduce these mistakes. By following the local and international rules, these problems will cease to exist.

4. OVERVIEW OF RISK ANALYSIS TECHNIQUES IN MARITIME SECTOR

Compared to the past, there is a growth in demand for maritime transportation. With this growth, the size and the number of ships needed also increases. This situation also causes an escalation in the number and capacities of the ports. While these developments make great contributions to the economics of the maritime field, they also increase the density of marine traffic. This density creates riskier situations at sea. This situation causes human injuries, loss of life and property, and disasters such as environmental damages. As in many sectors, risk analysis studies have also gained importance in the maritime sector in order to control these risks, which cause great dangers.

In this section, studies on risk analysis in the field of maritime were mentioned. In the first part, the terms frequently used in risk analysis studies were explained. Then, risk analysis methods used in the maritime industry were mentioned. In section 3, risk analysis studies on the risks posed by the ships during port manoeuvres were examined. In the last part, an assessment of the risk analysis models used was made.

4.1. The Terminology in Risk Analysis Studies

In this section, terms used in risk analysis studies were explained. The topics of risk, risk assessment, and risk analysis were mentioned.

4.1.1. Risk

The word "risk" is generally defined as the probability of dangers that may occur during the process of realizing a purpose or a goal (Misra, 2008). The International Maritime Organization defines the word risk as "the combination of the frequency and the severity of the consequence." (IMO, 2013). The International Organization for Standardization (ISO), on the other hand, defines risk as the "combination of the probability of occurrence of harm and the severity of that harm." (ISO, 2019).

When we look at the definitions of risk, it is understood that risk has two components. These components are stated as the "probability of occurrence of harm" and the "severity of harm". The word "harm" mentioned in the definitions is used to mean human injury, harm to health, or damages to the environment (ISO, 2019).

4.1.2. Risk Assessment

"Risk assessment" is defined as the operation of collecting data and synthesizing the data collected to understand risks present in any process or system (Mousavi et al., 2016; American Bureau of Shipping [ABS], 2000). The purpose of the risk assessments done is to define the dangers present in a process or a system, analysing these risks in order to develop precautions to reduce any unfavorable circumstances or to keep them at a minimum. With the risk assessment work done, the risks determined are kept at the lowest level reachable.

To understand the possible risks that may occur during any process, the answers to these three questions should be known (ABS, 2000);

- ✓ What can go wrong?
- ✓ How likely is it?
- ✓ What are the impacts?

An accurate risk assessment can be made with the answers to these three questions.

Risk assessment processes are followed step by step to ensure the evaluations are proceeding correctly. When risk assessment processes are analyzed, firstly the dangers present in the system concerned should be defined. Afterward, the defined risks should be analyzed and evaluated with a risk analysis method. A decision should be made on how to keep the high-risk situations determined with the risk analysis method under control. Lastly, the determined control methods should be applied and their efficiencies should be monitored. If the controls do not contribute to reducing the risks, work should be done on new precautions. To ensure the risk assessment study gives correct results, it is important for these evaluations are done by experts in their respective fields. In Figure T, risk assessment processes are shown.

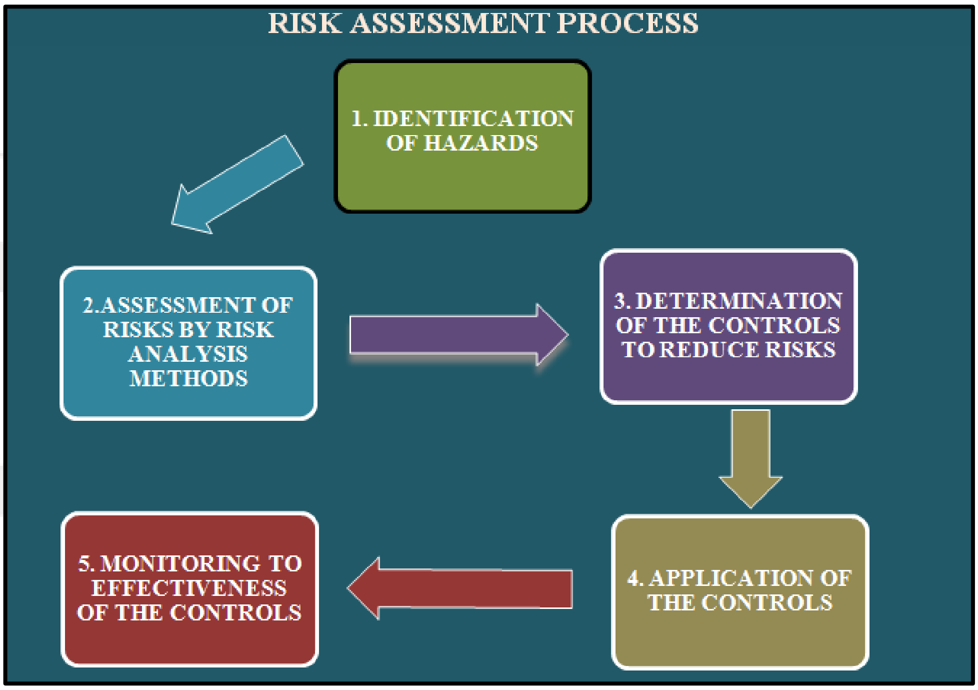


Figure 4.1. Risk assessment process

The fact that the risks that may be encountered in any process may cause great damage and that increases the importance of risk assessment studies. Past accidents especially reveal how important the risk assessment studies are.

4.1.3. Risk Analysis

Risk analysis is the process that defines the potential hazards in any given situation, finds out and analyzes the probability of occurrence for the hazards defined, and makes sure that the available information is used systematically (ISO, 2019; Rouse, 2020).

The purpose of risk analysis is to identify the risk that may arise and to analyze the said risk in order to avoid or minimize the possible risks. With the risk analysis, the occurrence of an undesired event, how risky it is and the extent of the damage it can cause is determined. With this, the decision of whether the work that creates the said risk should be carried out or not is made. The size of the effect of the resulting risk is determined. For a risk analysis to be carried out, firstly the possible hazards should be determined and the possibility of occurrence for these hazards should be guessed.

Risk analysis is one of the risk assessment processes. With the risk analysis done, the next step of the risk assessment is shaped. The results of risk analysis play an important role in determining the other processes of risk assessment.

4.2. Risk Analysis Studies in Maritime Sector

Within the maritime field, many risk analysis studies are done. The purpose of the studies done in this field is to provide safety at sea, to prevent injuries or loss of life and to prevent or minimize the damages the risk may do to property or the environment. Risk analysis studies are helpful for ships to carry out their operations safely and for a safe environment to form.

In 1988, 167 people lost their lives due to a platform named Piper Alpha exploding at the North Sea. After this explosion, risk analysis studies done within the maritime field has gained importance. IMO has prepared a guide called "Formal Safety Assessment (FSA)" and has recommended the use of this guide in risk evaluations. With the FSA prepared by the IMO, a standard method for risk evaluation has been developed. The process of FSA consists of five main steps. For a good risk assessment, the IMO recommends these five steps laid out in the FSA. These steps are (IMO, 2013);

- Hazard identification
- Risk analysis
- Risk control options
- Cost benefit assessment

- Recommendations for decision making

Many risk analysis techniques and models are used to perform a risk assessment for any given topic. Though, a correct result is only acquired through the use of an appropriate risk analysis method. These methods are good guides for the correct interpretation of the risks within the maritime field.

Within the maritime field, many risk analysis studies are done with different methods. With these methods, the aim is to identify the levels of marine accident risks at sea and to prevent or minimize the possible risks. When a literature review is done on the risk analysis systems used within the maritime field, it is possible to encounter many risk analysis methods such as; hazard identification (HAZID), hazard and operability studies (HAZOP), preliminary hazard analysis (PHA), hazard checklist analysis (HCA), structural what-if technique analysis (SWIFT), functional hazard assessment (FHA), risk matrix, failure modes and effects analysis (FMEA), fault tree analysis (FTA), event tree analysis (ETA), bow tie analysis, preliminary risk analysis (PRA), barrier and operational risk analysis (BORA), bayesian belief network (BBN), pareto analysis, analytic hierarchy process (AHP), Monte Carlo simulation and human error assessment reduction technique (HEART). (Talay, 2012; Ozbaş, 2013)

The risk analysis method to apply is chosen according to the topic of the study. It is important to choose the appropriate analysis method to get the correct results. The fact that studies are done on a lot of different topics has resulted in the varieties of risk analysis methods increasing. In addition, comparing studies done on the same topic with different analysis methods have allowed testing the consistency of the data acquired.

4.3. Literature Review

When marine accidents are examined, it is understood that the risk of accidents increases as the ships approach the land. It is understood that especially when approaching port limits, due to circumstances such as denser marine traffic, narrow waterways, and topographical features, the risk of an accident reaches high levels. When a literature review is carried out on this topic, it is seen that similar information is available and a lot of risk analysis studies are done. It is understood that in these studies, the researchers have applied different models to put forth the most correct model to use.

When risk analysis studies done on risks within port limits are reviewed, it is understood that every study is specific to the area it's conducted at and for every new study, the environmental conditions and features should be considered for the given area and all hazards for that area should be identified one by one.

Below, risk analysis studies done on hazards created by ship manoeuvres within port limits are reviewed. In these studies, the apparent risks were tried to be analyzed by using different analysis methods. When the studies within the literature are considered, the lack of adequate retrospective data is often mentioned. It is also seen that ship bridge simulator being used in many studies due to them being a good source for acquiring data. In addition, it is also understood that data acquired from AIS is used as a source in some studies.

When the risk analysis studies on ship manoeuvres around port limits are examined, "Environmental Stress Model (ES MODEL)" is seen as one of the most used models. Inoue (2000), with this model they have created, aimed to contribute in determining the ship handling difficulty of areas with limited manoeuvring spaces such as port areas and designing better waterways. In the ES Model, which is a quantitative model, topographical conditions (shoal, land, breakwater, fishing nets, etc.), traffic conditions (ship density in the vicinity, traffic flow, etc.), and external disturbances (wind, current, etc. Environmental conditions such as) are considered. In the model created, an index was made between the stress on the ship's user due to the manoeuvre made and the dangers that may occur during the manoeuvre, and the calculation of the stress load during the manoeuvre was aimed. In the study, the stress value that determines the risk of manoeuvre performed is expressed with a numerical value between 0 and 1000. The determined value indicates the degree of difficulty of the manoeuvre. These values were obtained as a result of experiments carried out on bridge simulators by Japanese pilots and ship masters. The heartbeats of the captains participating in the experiment were measured and a connection was looked for between the hazards the captains faced and their heartbeats. In the study, it was found that there is a relationship between the captains’ heartbeats and the hazards they face. In addition, the “time to collision (TTC)” of any “target” in these scenarios was calculated and it was observed that these had a relationship with the stress on the ship's user. The relationship between the hazard present during the manoeuvre and the heart rate has allowed evaluating how risky the manoeuvre was. The ES model was able to numerically express the stress created by the manoeuvre on the ship's user, taking environmental conditions into account.

To be able to test the model he has created, Inoue (2000) has made six seafarers carry out port entry manoeuvres in a bridge simulator. It was seen that there was a relation between the stress evaluation carried out and the difficulty created by the area’s topographical features and traffic density. With this simulation study, it was concluded that the ES Model could be used to evaluate the ship handling difficulty created by a port’s environmental conditions. This model created by Inoue has contributed to many studies since. Especially, for many ports that have been newly constructed or have been widened, the method created by Inoue was used as the risk analysis method in the port modeling report.

Gucma (2004) wanted to create a risk assessment model for manoeuvres in port areas. Certain manoeuvres were made around port areas with a group of masters and pilots in bridge simulators. In the study conducted, the types of accidents were divided into two. As the first type of accidents, accidents due to the horizontal movements of ships on the water were discussed. As the second type of accidents, "grounding", which occurred due to insufficient water depth, was considered. In the first type of accidents, the applications made in real-time simulation by masters and pilots were applied to “Markov Chains Theory”, “Non-stationary Poisson Process” and “Monte Carlo Method” and a general risk model was tried to be created. The second type of accidents was modeled using “Monte Carlo Simulation”. In the study, it was concluded that “Monte Carlo method with non-homogenous Poisson process” is the most appropriate analysis method for the first type of accidents. In this study, general risk models that can be used in risk assessment in limited areas such as ports are presented.

Yurtören et al. (2008) conducted a risk analysis to determine the effects of a container port to be established in Izmit Bay on the surrounding port traffic. In the study, "ES Model" developed by Inoue was applied. Scenarios fit for the environmental conditions were determined by the expert team. These scenarios were then implemented by the pilots in a bridge simulator. A risk analysis was carried out with the data obtained from these applications. As a result of the study, it was concluded that the risk level of the container port project is low and the construction posed no problems.

Nas (2008) conducted a study in Nemrut Bay to identify the risks posed by ships when manoeuvring. As there were no accident records for the region in the study, it was decided to conduct a risk analysis study by applying the "perceptual risk evaluation method". Firstly, the threats that may occur in the region were determined by brainstorming with the experts working in the area. The 35 piers present in the area were evaluated individually by the experts. The probability of occurrence of the hazards determined for each berthing area and the impact scale of the results were determined through perceptual measurements. Evaluations were made by transferring the probabilities and the resulting data to a risk matrix. In line with the results obtained with the risk matrix, the hazards that may occur during the manoeuvring of a ship in the region were defined, risk analyzes were made and the risk preventive precautions to be taken are determined.

Nas & Zorba (2011) taking the study done in Nemrut Bay, have conducted a similar study on the berthing areas in the Port of Alsancak. In the study, the hazards that may arise due to ships' manoeuvres in the Port of Alsancak, İzmir were identified and their risk assessments were done. Due to a lack of enough information about past accidents in the area, experts' views were considered. Taking the hazards in the area identified by the experts into account, each hazard took its place in the risk matrix. Each of the 26 berthing areas in the port were evaluated one by one by the group conducting the study and high-risk areas were identified. The possibility of occurrence and the affects of such situations were identified one by one for each area. 12 scenarios in total were created for these high-risk areas and "bridge simulators" were used to evaluate and test the situations evaluated by the experts. Risk assessment evaluation studies were done one by one for the 26 berthing areas. With these studies, the risks that may affect the manoeuvre negatively were identified. The precautions to be taken for these high-risk areas were listed and for the hazards that were deemed to be at an unacceptable level, precautions to lower the risk were recommended.

Inoue et al. (2011) analyzed the hardships of ship handling in Hanshin Port area in Kobe using bridge simulators. In this study, firstly the piers were evaluated, navigation routes from the port's entry to the pier were analyzed and lastly, the routes set by experienced pilots and pilot candidates were compared and risk assessments were done. AHP method was used in this study. With this study, the risks posed by the piers in the port of call and the navigational routes used were evaluated. The study was thought to be of help to the pilots in training with their future manoeuvres in the area.

Kim et al. (2011) used two different evaluation methods in the study they conducted. With the statistical data on the past marine accidents in the area, they have compared the two models and analyzed these models' consistency. For the area of the study, the Port of Ulsan in The Republic of South Korea was chosen. In the study, "ES Model" was used alongside the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) recommended, and IMO approved "IALA Waterway Risk Assessment Program" (IWRAP) model. The IWRAP model is a model that gives quantitative data on the risk of a ship grounding or getting involved in an accident in a given area by entering the traffic condition (the volume of traffic, waterway traffic distribution, depth, width, meteorological conditions) data. The model uses AIS data and Bayesian Belief Networks (BBN) to calculate the frequency of groundings and collisions.

In the doctorate thesis of Talay (2012)**,** driving factors of accidents that took place in the Port of Haydarpaşa area were analyzed and an accident data table was created. At the first step of the study, PHA and FTA methods were applied with the data present. The hazards were identified with the study done and the root causes of the accidents that took place were specified. The Fuzzy-AHP model (F-AHP) was used at the second step of the study. At this step, a survey fitting for the data acquired from the FTA was prepared. The survey was done on the people experts in the field working at the area. With the data acquired, the driving factors for accidents that happen in the port area were weighted. The weights specified were then analyzed with the AHP model and the general weights of the driving factors in accidents were specified. The results of both models used in the study were then compared at the end of the study and the results were analyzed. It was seen that the results gotten were consistent with each other. The results gotten at the end of the study were then evaluated and recommendations for the port area were made.

The “Potential Assessment of Risk” (PARK) model was developed in Korea by Park et al. (2013) to create a domestic evaluation model. The “PARK model” developed by the Korean team is a model that calculates the elements of a ship that may affect marine traffic safety by regression analysis. In the study, a survey was conducted to measure the subjective risk recognition of ship users. The survey was prepared in a way to evaluate the Korean shores and Korean seafarers. This was done to ensure that the study pays attention to the risk recognition of Korean seafarers and the area’s conditions. With the data acquired from the survey, the elements that may affect marine traffic safety were divided into two categories as internal elements (type of ship, tonnage, length, width, career, licence, position) and external elements (crossing situation, approaching side, inside/outside harbor, speed correlation, speed difference, distance). Afterwards, the effects of these elements were calculated using regression analysis. A scale of risk from 0 to 7 was created. On this scale, $0 \leq Risk \leq 4$ was designated as “negligible”, $4 < Risk \leq 5$ as “marginal”, $5 < Risk \leq 6$ as “critical, and $6 < Risk \leq 7$ was designated as “catastrophic”. The sum of the risk values created by the elements then, state the significance of the risk. To evaluate the model, firstly a previous accident in Korea was applied in a bridge simulator. The scenarios in the simulator were modeled according to the Port of Busan. In addition, a realistic traffic situation was created by applying real AIS data to the simulator through the ECDIS. The aim of the study was to effectively evaluate the level of risk that may arise around the Port of Busan. With the study, it was concluded that the “PARK Model” can be used to identify the level of risk created by the traffic in a given sea area. The study states that many studies use the ES Model but this model does not reflect the risk recognition of Korean seafarers and that the PARK Model measures the subjective risk perception of the seafarers accurately. Additionally, the PARK Model and the ES Model were compared during the simulation application and it was observed that the PARK Model gives more realistic results. The authors then recommend the use of this model.

Gug et al. (2014)**,** in their study, used a method called the “gas molecular collision calculation model”. In the study, a week’s worth of AIS data from the Busan North Port was used to conduct a risk analysis for the area. In the mentioned model, the areas to be calculated for collision risk were divided into cells, and then a risk analysis was conducted for each cell. In the study, the collision risk was calculated in accordance with the data from the ships such as the relative angle, the relative speed, and the density of traffic in the vicinity. With the data acquired from the model, the riskiness of each cell was calculated and with the data acquired from the AIS, the change in risk with time for each cell was observed. It was also seen that the risk created by the environmental factors could also be analyzed with the study. With the model used, the risky areas within the Busan North Port were able to be identified.

In the study conducted by Khaled & Kawamura (2015), collisions in Chittagong Port were evaluated. While "Collision risk" was analyzed with the IWRAP Model recommended by IALA, "causation probability" was analyzed using the BBN model. In order to test the validity of the developed model, the collision probabilities predicted by the model were compared to historical data. AIS data was used to calculate the traffic volume and distribution in the area and it was determined that IWRAP had an important effect on making accurate evaluations. It is believed that the study is a model that can be used not only in Chittagong Port but also in other ports.

Senol & Sahin (2016) created a dynamic risk assessment model that named "Real-Time Continuous Fuzzy Fault Tree Analysis". They tried this model they created in a simulator environment. With this model, the risks of collision and grounding of a ship have been determined by using different parameters such as the closest point of approach (CPA), bridge navigational watch alarm system (BNWAS), closeness to shallowness and cross track errors. In this model, the risk was continuously calculated by applying the data from the sensors to certain algorithms. Also, fuzzy-fault tree analysis (F-FTA) was used in the study. The accuracy of the model was tested by comparing the results of the model with the results of F-FTA. It is concluded that the created model can be used for the analysis of the risks that may occur in port areas.

Otoi et al. (2016) used the ES Model, the IWRAP and the PARK Model (Potential assessment of risk model) to calculate the risk created by the marine traffic around Mombasa Port. In the study, evaluations were made using the data obtained from AIS. The study was conducted to evaluate the navigational risk created for transit traffic by the local ferry traffic around Mombasa port. It is thought that the data obtained as a result of the studies carried out could be beneficial in ensuring the navigational safety of the region. The fact that the PARK Model includes the internal and external elements of the ship in the elements that may affect the marine traffic has made it more advantageous than the ES Model. In the study, the frequencies of the risks caused by local traffic in the region were determined by applying 3 different models. As a result of obtained in the study, the measures that can be taken around Mombasa Port were emphasized.

Sahin (2016), in the study, only the marine traffic present in the port area was considered. The statistical data is from the data of marine accidents that took place in the area between the years 2001 and 2008. When the statistical data for the area and the results of the two models were compared, the real data falls between the values gotten from the two models. Though, the data acquired from the “ES Model” was seen to be closer to the statistical data. In the study, it was concluded that the “ES Model” is a more through reflection of the seafarers’ risk awareness.

In their study, Yücel & Yurtören (2019) used the ES Model and the fuzzy logic model together to determine the risk factors and their weight in port manoeuvres. Until then, the risk factors and the weights of these factors have not been known in the studies about “ES Model”. As a result of the studies, only an evaluation of how risky the manoeuvre could be was made. In order to determine the risk factors and to determine their weight, fuzzy logic was applied in the studies. In this study, different commercial ports were chosen, these ports were then modeled on a bridge simulator and 30 different ship manoeuvres were performed. The questionnaires prepared were then given to the experts and risk assessments were made with the fuzzy logic method. With this study, the root causes of the risks obtained from the ES model have been analyzed and these root causes have been evaluated. It is also mentioned that this study may contribute to the use of this method in the modeling reports requested by the Ministry of Transport and Infrastructure in the construction of coastal facilities.

4.4. Assessment

Increasing risk analysis studies in the maritime field will contribute to the prevention of dangers in the maritime area and minimize the loss of lives and property. The fact that manoeuvres, especially around port environments, have higher risks compared to other navigational areas, indicates that more studies should be done in this field.

When studies on the risks caused by the use of ships in port manoeuvres are examined, it is understood that different risk analysis methods are used. With the "ES Model" as the leading model, "PARK Model", "IWRAP" and "Risk Matrix" models are seen as the most used methods. In addition to these studies, the use of methods such as PHA, FTA, AHP, BBN, Monte Carlo, and Fuzzy also contributes to the development of the field. As studies are compared, it is understood that some studies give more consistent results than others. However, it cannot be said that these studies fully reflect the risks present.

ES Model, which stands out as the most used model, avoids subjective judgments and gives quantitive values, making it preferred in many studies. In addition, the model taking all environmental conditions into account increases the importance of the study it's used in. However, in the model, the failure to evaluate the effects of ship features on the manoeuvre is considered as a shortcoming of the study. Moreover, the stress value coefficients in the ES Model being calculated according to the risk perception of Japanese seafarers is seen as another shortcoming. Because seafarers with different nationalities are thought to have different risk perceptions. It is considered that repeating and comparing the study by different nations is necessary in order to test the reliability of the model.

The study by Yücel & Yurtören (2019) attracts attention as a study contributing to the development of ES Model. In this study, the fuzzy logic method was used together with the ES Model. The root causes of the risks identified by the ES Model have been clearly identified with this method and any uncertainties has been eliminated. It is understood that these and similar studies will eliminate many deficiencies by being used together with different methods.

The “IWRAP Model” is a quantitative assessment method and it performs risk analysis by giving the frequencies of collision and grounding in a given waterway. It allows analyses to be done by using AIS data. The model conducting the analyses with data allows objective results to be formed. However, it is difficult to produce consistent results in regions with insufficient data. Especially in the newly constructed port areas, the absence of sufficient data may cause inaccurate results. In addition, it is seen as a disadvantage that the model only calculates the risk posed by marine traffic and that it does not take environmental factors into account. It is thought that the IWRAP Model does not reflect the risks present completely when the results of studies done are considered and the fact that it does not take environmental factors into account is considered.

Including the internal and external elements of the ship in the elements that may affect marine traffic has put the PARK model in a more advantageous position than the ES Model. However, it is an important deficiency that the model does not take environmental factors into consideration. Especially, the PARK model being created particularly for Korea raises questions about its usage in different regions.

When these three models are compared, the ES Model taking the environmental factors into consideration along with the marine traffic creates an advantage over the IWRAP and PARK Model, the PARK model taking the effects of ship’s particulars on a manoeuvre into account, and the IWRAP Model giving objective results about the risks present by the use of AIS data puts the respective models in an advantageous position.

In the risk matrix studies done using the “Perceptual risk evaluation method”, the fact that experts’ knowledge and experiences are used can be considered as an important source for correct evaluations. The use of this method will prove especially useful in studies with insufficient data and difficult analyses. But the heavy use of subjective judgements in the method used will result in the trustworthiness of the study being questioned. It is needed for the number of experts consulted in such studies to be high for the trustworthiness and the consistency of the study. The comments provided by the experts will benefit the study but they may also lead to wrong evaluations. The analysis done by the risk matrix should be compared with different methods for the consistency of the study. It is also important for the fields of the experts chosen to be relevant to achieve consistent results with the study.

When other studies are reviewed, with the use of different analysis methods such as AHP, FTA, F-AHP, and BBN, the root causes for the risks present can be identified and the weights of these causes can be found out. Results may be gotten using the subjective judgements of experts just as in a risk matrix, analyses may also be done using past accident records.

Senol & Sahin (2016) stands out as one of the remarkable studies. In the study, a new model was created by using different data obtained from different ship systems. With the study, a different perspective was brought on. Clearer evaluations about the model will be made with the increase of similar studies. This and similar studies will play an important role in the formation of new models.

It is obvious when studies are compared that every study has positive and negative aspects. The absence of a quantitative study that covers all factors that go into the formation of risk prevents a completely satisfactory analysis from being done. It is understood that studies done using multiple risk analysis methods give more consistent results. It is seen that even though a full evaluation may not be possible, the methods used contribute greatly to minimizing risks present. It is seen that with the increase in studies being done, more comprehensive risk analysis models will be created. Any new method being created will allow more correct risk analyses to be done.

5. AN APPLICATION ON SHIP MANOEUVRES IN SIMULATION SYSTEMS

Just as with many fields, simulation systems are used in the maritime field as well. With the development of simulation systems, an increase in the use of these systems in maritime training and other research topics within the maritime field is seen. These systems, in addition to marine trainings, are used in fields such as marine traffic risk analyses, marine pollution risk assessments, port/terminal capacity analyses, and container terminal operations (Ozkan & Nas, 2016). It is inevitable that the use of simulation systems will benefit many branches of work within the maritime industry

In this section, firstly information about the simulation systems and simulators used in maritime were given. Afterwards, the process of analyzing the suitability for ship manoeuvres of a port in Turkey with the use of simulation systems was explained.

5.1. Simulation Systems & Simulators in Maritime Sector

A simulation is a system that mimics an operation or a system while representing real or operational conditions. A simulator is the hardware or the apparatus that makes up the simulation (Board, 1996).

Simulators are widely used in maritime. Ship's bridge simulators, engine room simulators, cargo handling simulators, and communication/GMDSS simulators are systems commonly used in marine training. These simulators often include many operational consoles and numerous displays to represent the virtual environment.

Simulation operations can be ran in two different time modes. These modes are called real-time simulation and fast-time simulation. In either simulation system, the simulation software consists of mathematical models of ship's manoeuvre, geographical area databases, and analysis tools (Marcjan & Gucma, 2018).

In a real-time simulation, the simulated ship is controlled by humans in real-time. However, in fast time simulation, the ship is controlled by autopilot algorithms instead and the simulation, proportional to the speed of the main computer used, may be ran a lot faster than real-time (Board & National Research Council, 1992).

The human factor is important in a real-time simulation for it has a critical role in the validity and the reliability of the results. In real-time simulations, the existence of the human factor makes it mandatory for them to be conducted in real-time. Especially in ship's bridge simulations, unlike fast time simulations, in the scenarios created in these simulations, the controls and navigational equipment on a ship's bridge are used in order for the simulation to closely resemble reality. An area containing all technical equipment needed during manoeuvres is present.

Real-time simulations being run in real-time allows the inclusion of the human factor in this algorithm. The simulator, being designed fittingly for all operations on the bridge both physically and behaviourally, allows scenarios close to reality to be applied.

The ship's bridge simulator is one of the most used simulators in maritime. This simulator, when utilized in studies on ship handling, allows the simulation of environmental conditions that are impossible to recreate on a ship and scenarios involving great hazards. These simulators are safe laboratories for applying risky processes in tough conditions. With the system used, the six degrees of freedom ship motions (pitch, heave, roll, surge, sway, and yaw) that occur due to the commands were given to the ship by the user can be observed.

Ship bridge simulators are used for marine trainings and to acquire scientific data in various study topics. Additionally, they are used to evaluate the fitness of a port that is planned to be built or expanded for ship's manoeuvres. The simulation work done on the simulators allows the analysis of ships' movements within port limits, the effects of environmental factors on ships, and the risks they bear. Manoeuvres which are difficult to apply on the sea may be applied in scenarios created and the risks that may occur may be analyzed. With simulation studies, the correct identification of hazards in high risk areas with respect to ship handling such as port areas and the making of correct decisions may be ensured.

The simulation application in the study is done on the class approved NT-Pro 5000 model full mission bridge simulator system present at the Piri Reis University. Full mission bridge simulators are simulators designed to conduct manoeuvres in restricted waterways under various circumstances and that have the ability to carry out bridge operations in their entirety (Board, 1996).

The 270° ship bridge simulator used in the scenarios meets the requirements set by the “Communique on Evaluation of Shore Facility Construction Demands” laid out in the legal gazette of Turkey issue 21770, published on 15.03.2009 (Official Gazette, 2009a). In Figure 5.1., the simulator system used in the manoeuvres is shown.

Figure 5.1. Simulator system used in manoeuvres

Capabilities of NTPRO 5000 ship bridge simulator are listed below: (Transas, 2014)

- Manoeuvring and handling a ship in all conditions;

- Planning a passage plan;
- Maintaining a safe navigational watch with ECDIS and RADAR;
- Operating remote controls of propulsion plant and engineering systems and services;
- Responding to emergencies;
- Responding to a distress signal at sea;
- Conducting telephone conversations via Intercom and VHF station;
- Determining position and the accuracy of resultant position fix by any means;
- Determining and allowing for compass errors;
- Co-ordinating search and rescue operations;
- Establishing watchkeeping arrangements and procedures;
- Ice navigation;
- Fishing operations.

5.2. Simulation System Process for Analyzing the Suitability of a Port for Ship Manoeuvres

In this study, the aim is to identify the manoeuvring risks that may occur during the berthing of a ship and assessing analytical data of a pier in a port within the İstanbul Area with respect to environmental conditions. In the study, the simulation systems belonging to the Piri Reis University Maritime Faculty Simulator Centre were utilized.

In this section, the studies done on the risk assessment of a pier in a port using a ship bridge simulation system were mentioned. While this study was being carried out, many processes took place. The proper modeling of the area chosen, the creation of scenarios with respect to environmental features, and the application of these scenarios were the main topics during this process.

In the first part of the study, the topic of how a port is modeled was mentioned. In the second part, information about the content of the scenarios created was given. In the last section, details about how the scenarios are applied were presented.

5.2.1. Modeling of the Port Area

Various computer software is used in order to be able to simulate a chosen area. Each simulator manufacturer develops the appropriate program fit for their systems for the realization of the intended simulation software. These programs of each simulator manufacturer are special to their own systems and will not work with other simulation software.

To model the port area and design the simulation environment, the software “Model Wizard Version 6.50.” was used. With this software, the creation of the port area in three dimensions, the adjustment of water depth and the height of the port structures, the creation of navigational aids, the addition of port equipment to the area, the creation of various objects on water and land areas and the perception of the area created through ECDIS, RADAR and other electronic devices are made possible.

During the modeling of the port, the port was created with the “Scene Editor” module of the software. While modeling the port, various sources and documents such as layout plans, bathymetry charts, photographs of the port area, and Google Earth were utilized. Objects and shore structures that may obstruct the navigation on water were placed. For the design of the objects used during the modeling of the port, the software “3Ds Studio Max 2015” was used. Environmental arrangements were paid attention to for the study to reflect the port area identically. With this, an improvement in visual quality and the creation of a simulation environment close to real port conditions were ensured. A three-dimensional overview model of the port is shown in Figure 5.2.

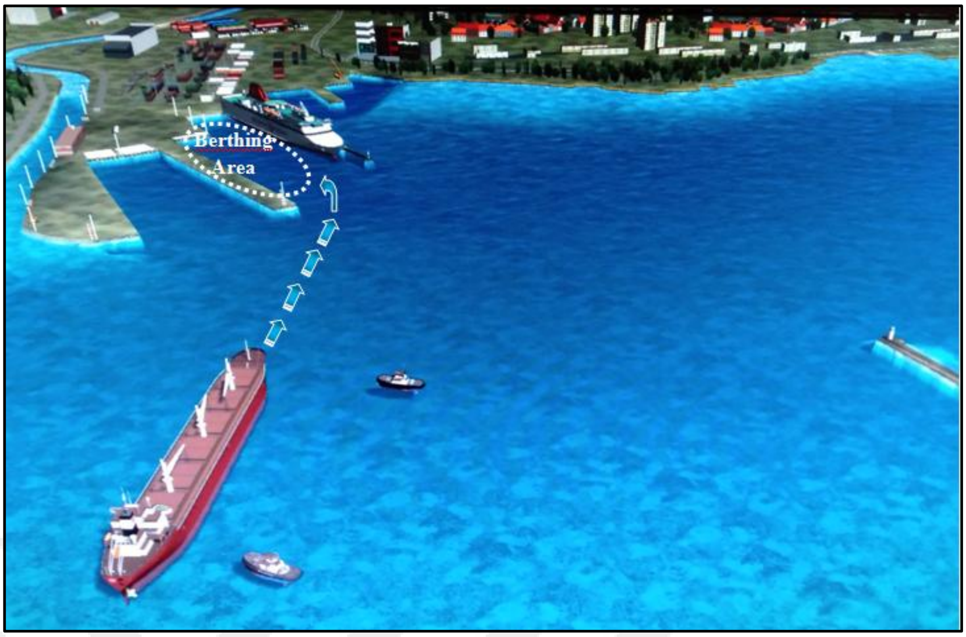


Figure 5.2. 3D general view of the port

The bathymetric data of the port was defined on the port within the module with the use of “AutoCad 2013” software. A two-dimensional model that shows the depths within the port created with the “Scene Editor” is shown in Figure 5.3.

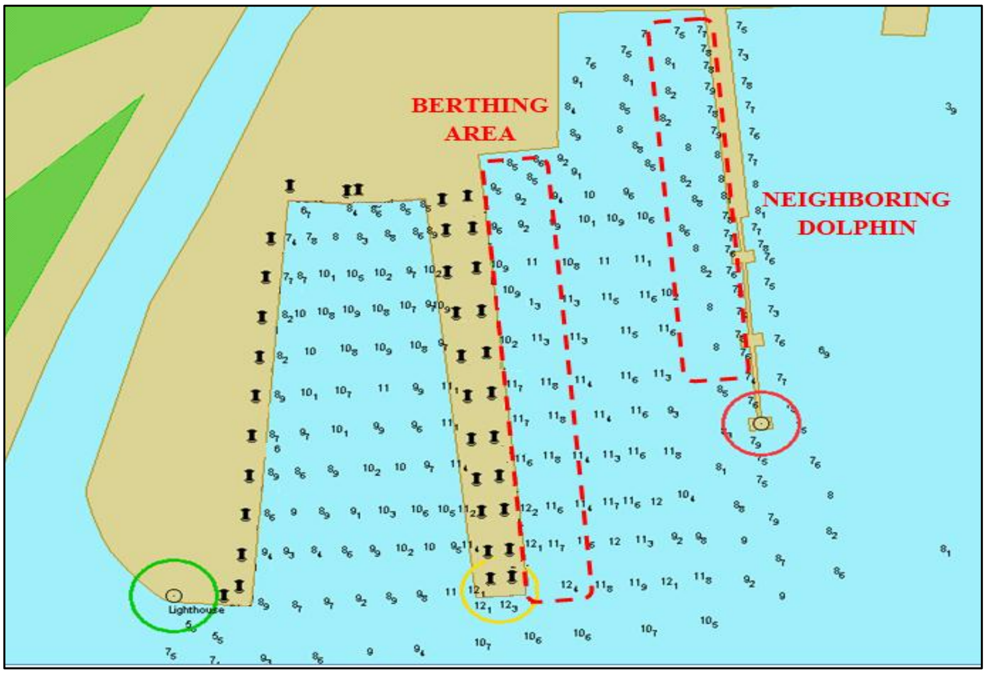


Figure 5.3. 2D model showing the depths of the port

When the area in which the model ship will berth is analysed, it is seen that the minimum depth is 8.5 meters. When the neighboring dolphin is analysed, the minimum depth drops to 7.4 meters. The possibility of the ship moving towards the neighboring dolphin under heavy weather should not be forgotten.

The pier at which the simulation applications are to be carried out was modeled with respect to the two-dimensional AutoCad drawing and measurements. The measurements of the pier are shown in Figure 5.4. The length of the pier that the model ship will berth is seen as 222 meters. The length of the pier also determines the maximum length of the ships that may board it. According to Port Regulations, a ship's length may not exceed the length of the pier it will board (Official Gazette, 2012).

If the distance between the pier and the neighboring dolphin is examined, it is seen that this width changes between 99 and 101 meters. This situation creates limits in the manoeuvres that may be carried out in this area. Such limits created by the width of the area place importance to the breadth and the manoeuvring characteristics of ships that may manoeuvre within the area. Correspondingly, they have an important role in determining the capacities of the tugs required.

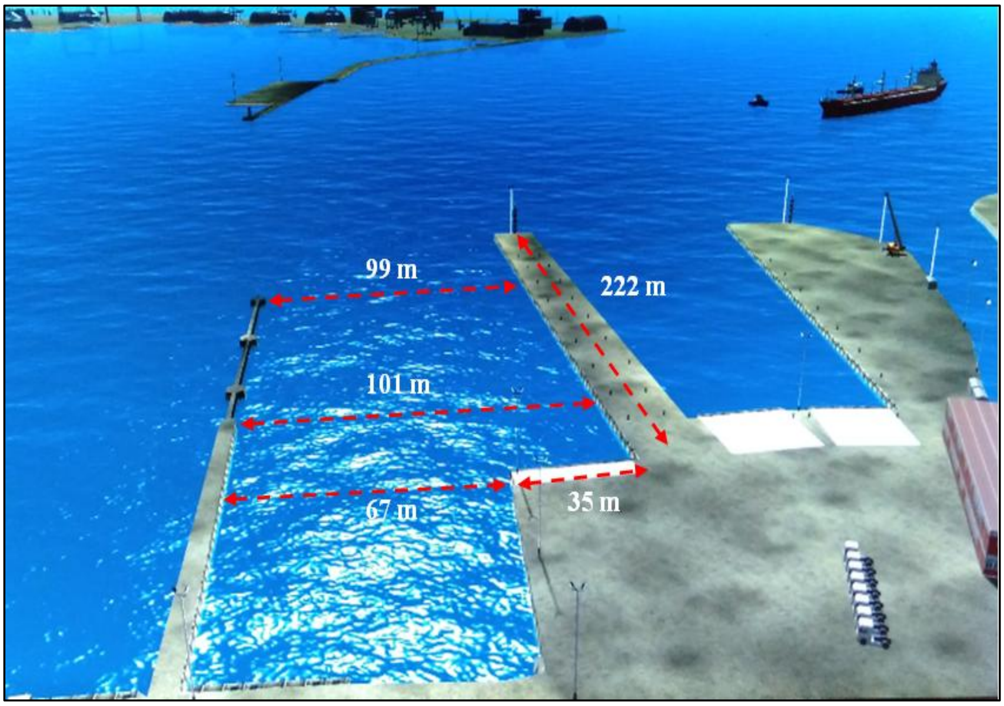


Figure 5.4. The dimensions of the pier where the model ship coming alongside

Ships desire to approach the area they will berth in a certain manoeuvring angle. The ship requires a manoeuvring area in order to be able to enter the berthing area in an appropriate position. This manoeuvring space needs to be large enough to let the ship turn 180 degrees if need be. In Figure 5.5., the large area the ship may manoeuvre in before approaching the pier is shown. This area is especially needed while berthing stern first. When Figure 5.5. is analysed, it is seen that the narrowest distance is between the edge of the pier and the jetty and that this distance is 412 meters. It is thought to be an adequate distance for the ships to assume a position with ease.

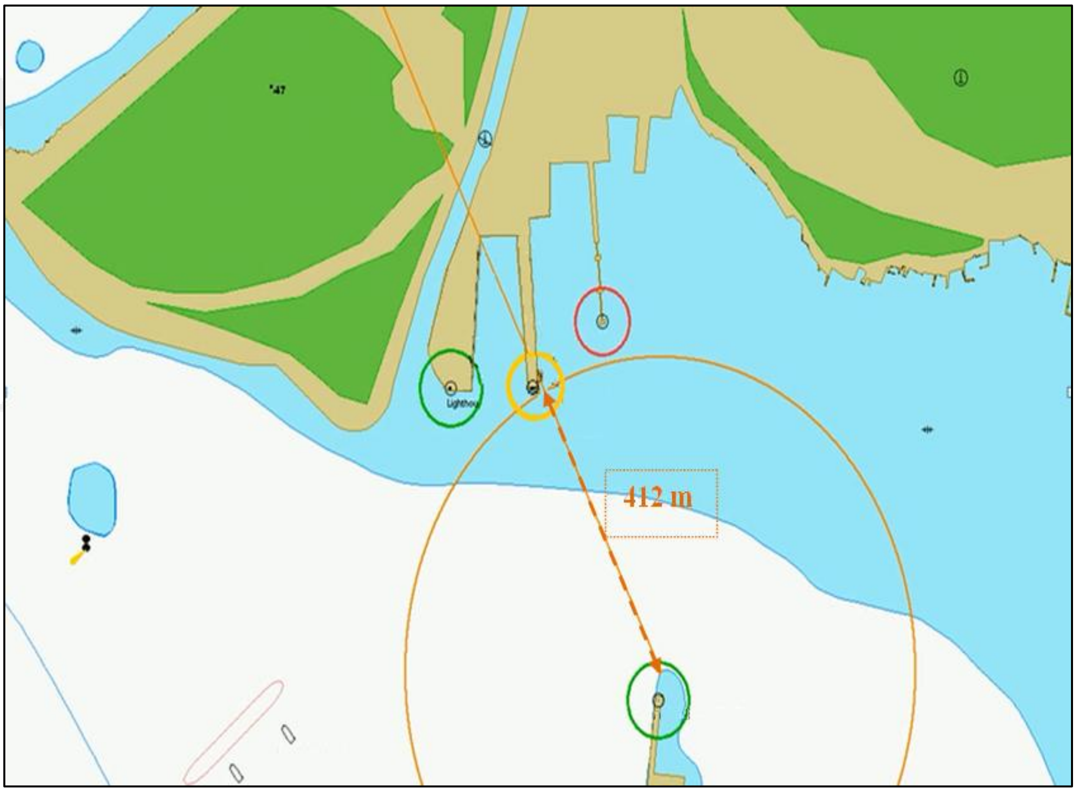


Figure 5.5. Manoeuvring area of port

Lastly, the three dimensional model of the simulation area created with the Model Wizards software and charts of the area were loaded into the simulation system.

5.2.2. Creation of Scenarios

After the modeled port is loaded into the system, preparations for the creation of scenarios were carried out. In the first section, work put into environmental conditions was explained. In the second section, information about the model ship was given and in the third section, information about the tugs that will be used in order to assist the manoeuvre was given. In the fourth section, information about the experts carrying out the manoeuvre was given. In the last section, details about the manoeuvring scenarios were presented.

5.2.2.1. Creation of Environmental Conditions

In order to set the environmental conditions for the port area, the "Environmental Settings" window of the NTPro 5000 simulation system was utilized. In Figure 5.6., the "Environmental Settings" window is shown.

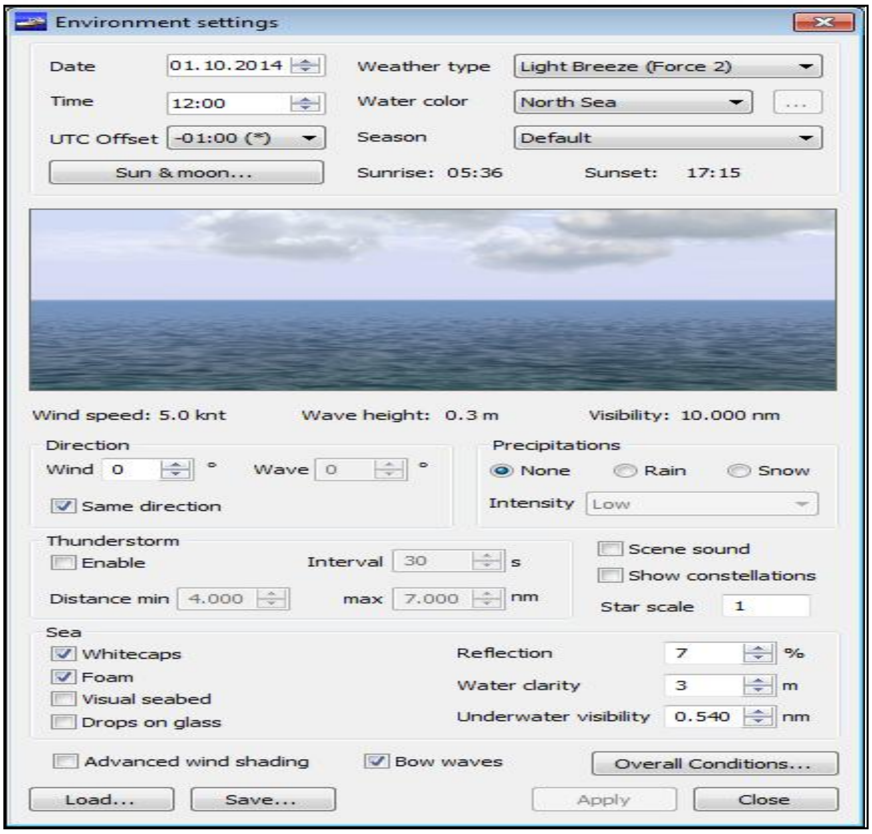


Figure 5.6. Environmental setting window (Transas, 2014)

In the Environment settings window the following environmental conditions can be set; (Transas, 2014)

- Exercise date and time
- Weather type
- Colour of water
- Season
- Sun and moon position
- Wind and wave direction
- Precipitations
- Thunderstorm conditions
- Sea visual presentation
- Scene sounds
- Constellation display
- Additional visual effects: advanced wind shading and bow waves

Information about the weather condition and the sea state of the port area was given under the subheadings. A phone call with the port authorities was made in order to acquire data about the weather conditions and the sea state of the area. The authority stated that they did not have any statistical data records. From the regional meteorological directorate, only the wind data of the area were able to be acquired. In order to be able to identify the conditions of the area, the assists of two pilots, one oceangoing master, and one port operation manager that know the area well and work in the area were received.

- <u>Weather Conditions</u>

Information about the weather conditions of the port was acquired through correspondences with the General Directorate of Meteorology, 1st Regional Directorate and the views of experts. Below are the explanations about the wind and visibility conditions of the port area.

❖ <u>Wind</u>

An appeal was made to the General Directorate of Meteorology, 1st Regional Directorate in order to find out about the wind data of the area. Data belonging to an observation station 500 meters away from the port were acquired. In Table 5.1., "monthly maximum wind direction and speed (m/sec)" values of the area between January 2016 and March 2020 are shown.

Table 5.1. Monthly maximum wind direction and speed (m/sec)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2016	N 30.7	W 27.7	E 27.8	WNW	E 30.5	NE 26.8	E 27.9	ENE 29.2	NE 24.7	NE 29.5	WNW	W 32.4
2017	W 29.5	NNW 26.8	S 30.8	N 30.3	W 31.0	NNE 30.2	NW 29.1	WSW	SE 26.4	N 29.3	W 26.7	WSW
2018	W 32.4	N 27.8	W 29.7	NE 32.0	WNW 31.4	W 26.1	W 27.9	ENE 17.5	NE 17.1	N 16.3	NNE 18.0	NNE 17.9
2019	N 16.3	WSW 17.3	NE 18.5	NE 14.5	W 21.1	NE 15.4	NNE 15.4	SW 21.9	NE 18.5	W 28.1	W 23.6	NNE 19.1
2020	NNE 21.8	WNW	W 10.9									

In Table 5.2., “monthly average wind speed (m/sec)” values of the area between January 2016 and March 2020 are shown.

Table 5.2. Monthly average wind speed (m/sec)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
2016	4.0	3.8	4.1	3.2	4.0	4.4	5.5	5.6	4.8	4.7	4.1	4.8
2017	5.4	3.6	4.1	3.8	4.5	3.9	5.3	4.8	4.1	3.7	3.8	4.0
2018	4.0	5.1	3.8	4.0	4.4	4.6	4.0	5.5	4.9	4.5	4.9	4.2
2019	4.6	4.5	4.5	4.1	3.6	4.2	4.7	4.9	4.6	4.2	3.4	3.7
2020	4.4	4.2	2.4									

When the long period wind bulletin and bulletin that includes monthly wind data acquired from the General Directorate of Meteorology, 1st Regional Directorate are analysed, the prevailing wind directions are identified to be north (N), northeast (NE), west (W) and southwest (SW).

With the result of the assessments done with respect to data acquired from the General Directorate of Meteorology, 1st Regional Directorate and the prevailing wind directions encountered within the area by the experts, it was decided that the simulation studies would be done with two prevailing winds with the directions of NE and W. Additionally, while the port authorities only allow manoeuvres to be done under up to 4 beaufort wind in order to not risk the navigational safety, boarding manoeuvres were carried out under up to 6 beaufort wind in the scenarios.

- Visibility Condition

Scenarios were carried out with adequate visibility conditions for manoeuvring. It is assumed that the port authorities would not allow manoeuvres under inadequate visibility conditions.

- Sea State

Below, assessments on the sea state of the port area were done.

- Wave

Local experts have stated that effective waves do not occur in the area. The wind height was then decided to be 0,3 meters in the scenarios.

- Current

Experts have stated that due to the geographic structure of the port area, the current values are at an insignificant level. With the result of the assessments done with the local experts, it is understood that the currents present in the area can be ignored. No currents were applied in the scenarios.

- Tide

Local experts have stated that no tides that may affect ship manoeuvres occur in the area. Tide values were ignored in the scenarios.

❖ Day/ Night vision

Simulation studies were conducted during day hours. It was established that the simulation system cannot simulate night conditions close enough to reality.

5.2.2.2. Determination of the Model Ship

With respect to the PIANC recommendations, the model ship to be used in the simulations was noted to have the weakest manoeuvring capabilities with the largest LOA and breadth that may be planned for the operation (PIANC, 1997). With respect to the Port Regulations from the Legal Gazette issue 28453 which was published on 30.11.2020 (Official Gazette, 2012), the model ship with the largest LOA that was still shorter than the length of the pier was chosen. Additionally, since the port is fit for bulk operations, it was decided that a bulk carrier type ship would be chosen. The most fitting model for these conditions within the simulation system was determined to be a model ship with 200 meters of length. In Figure 5.7., specifications of the model ship used in the simulations are shown.

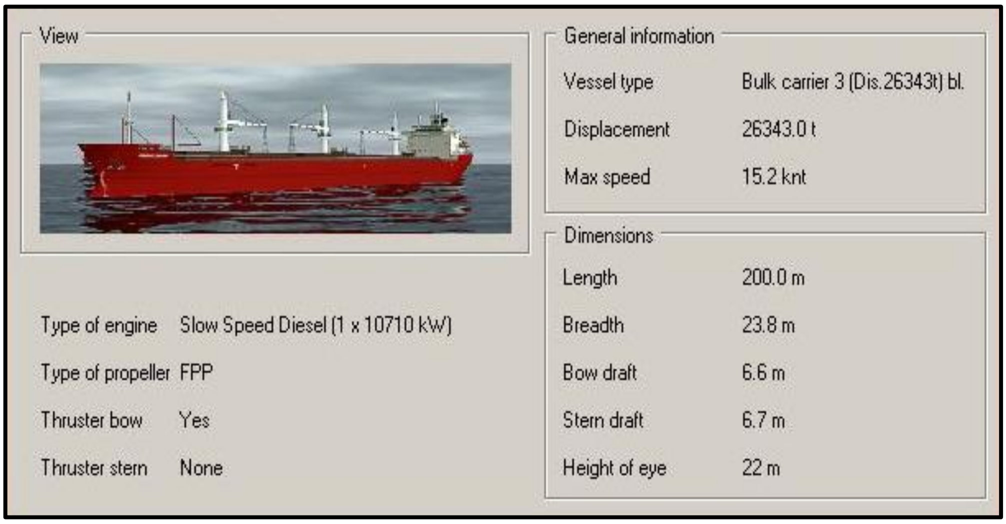


Figure 5.7. Ship model used in simulation

Even though the model ship has bow thrusters, since these types of ships generally do not have bow thrusters, the bow thrusters were not allowed to be used during the scenarios. Additionally, to be able to observe the maximum effects of the wind on the model ship, the ship was ensured to be in ballast condition.

5.2.2.3. Determination of Model Tugs

When determining the capacity and the number of tugs to be used in the simulations, the conditions required by the Port Regulations from the Legal Gazette issue 28453 dated 30.11.2020 and the specifications of the tugs of the company that supplies the tug services in the area were considered. During the manoeuvres in the simulator, 2 tugboats were used, one of which was at the head of the ship model and the other was at the stern. Both model tugs used in the simulation were identical. In Figure 5.8., specifications of the tug model used are shown.

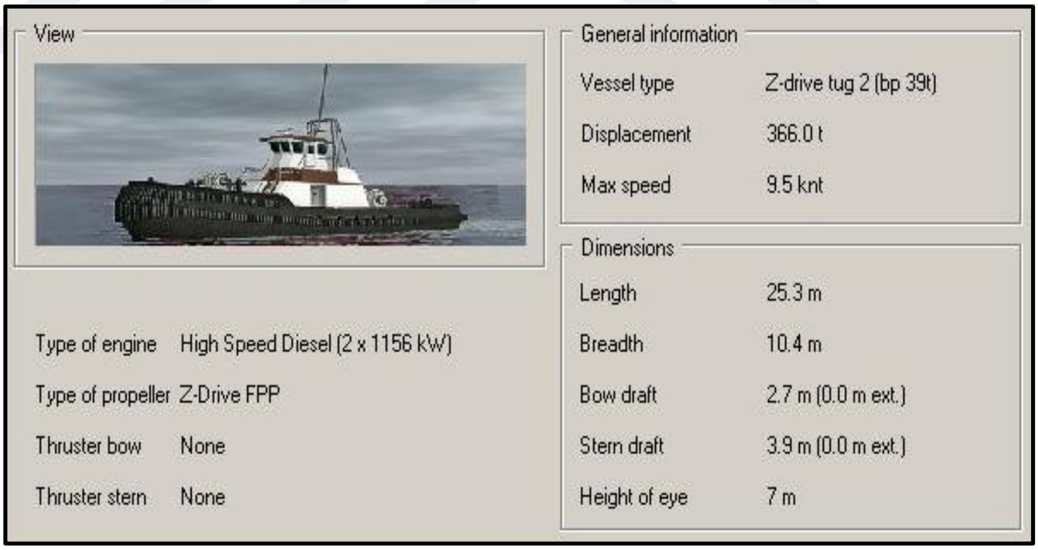


Figure 5.8. Model tug used in simulation

Experts have noted that the tugs utilized by the company that provides the service in the area have a pulling force of 30 tonnes. Though the chosen tug model has a pulling force of 39 tonnes, it was set to 30 tonnes to reflect real conditions.

5.2.2.4. Determination of Experts

A condition of having an “oceangoing master licence” at the least was exercised during the selection of people that would join the simulation studies. Six people possessing the licence have joined the studies. These experts have previously worked as oceangoing masters on different types of ships. Two of the experts that took part in the scenarios are pilots in the area, two of them are academicians at the maritime faculty, one of them is a simulator center coordinator at the maritime faculty and one of them is a training coordinator at a maritime firm.

A person possessing an oceangoing watchkeeping officer licence was assigned to the bridge simulator to assist the experts during manoeuvres. Additionally, one person was tasked in the simulator control center to carry out the commands given to the tugs by the experts.

5.2.2.5. Determination of Details of Manoeuvre Scenarios

The details of the scenarios to be applied in the simulations were determined with the results of discussions had with the experts. The port area’s features were paid attention to while determining the scenarios. In Table 5.3., the details of scenarios that were simulated are presented.

Table 5.3. Details of scenerios applied in simulation

Scenario No	Wind Direction	Wind Force (knots)	Beaufort Scale	Number of Ship Berthed Neighboring Dolphin	Current Information	Wave Height (meter)	Visibility	Number of Tug Used
1	-	0	0	NIL	IGNORED	0.3	IGNORED	2 PCS
2	NE	3	1	NIL	IGNORED	0.3	IGNORED	2 PCS
3	NE	7	2	NIL	IGNORED	0.3	IGNORED	2 PCS
4	NE	10	3	NIL	IGNORED	0.3	IGNORED	2 PCS
5	NE	16	4	NIL	IGNORED	0.3	IGNORED	2 PCS
6	NE	21	5	NIL	IGNORED	0.3	IGNORED	2 PCS
7	NE	27	6	NIL	IGNORED	0.3	IGNORED	2 PCS
8	W	3	1	NIL	IGNORED	0.3	IGNORED	2 PCS
9	W	7	2	NIL	IGNORED	0.3	IGNORED	2 PCS
10	W	10	3	NIL	IGNORED	0.3	IGNORED	2 PCS
11	W	16	4	NIL	IGNORED	0.3	IGNORED	2 PCS
12	W	21	5	NIL	IGNORED	0.3	IGNORED	2 PCS
13	W	27	6	NIL	IGNORED	0.3	IGNORED	2 PCS
14	-	0	0	1	IGNORED	0.3	IGNORED	2 PCS
15	NE	3	1	1	IGNORED	0.3	IGNORED	2 PCS
16	NE	7	2	1	IGNORED	0.3	IGNORED	2 PCS
17	NE	10	3	1	IGNORED	0.3	IGNORED	2 PCS
18	NE	16	4	1	IGNORED	0.3	IGNORED	2 PCS
19	NE	21	5	1	IGNORED	0.3	IGNORED	2 PCS
20	NE	27	6	1	IGNORED	0.3	IGNORED	2 PCS
21	W	3	1	1	IGNORED	0.3	IGNORED	2 PCS
22	W	7	2	1	IGNORED	0.3	IGNORED	2 PCS
23	W	10	3	1	IGNORED	0.3	IGNORED	2 PCS
24	W	16	4	1	IGNORED	0.3	IGNORED	2 PCS
25	W	21	5	1	IGNORED	0.3	IGNORED	2 PCS
26	W	27	6	1	IGNORED	0.3	IGNORED	2 PCS

When the scenarios realized are examined;

- ❖ A total of 26 scenarios were carried out at the ship bridge simulator.
- ❖ Manoeuvres were done with two prevailing wind directions, namely NE and W.

- According to the information acquired from the pilots, the port authorities allow coming alongside manoeuvres under up to 15 knots of wind. However, scenarios with up to 27 knots of winds were conducted during the simulations. The wind forces applied in the scenarios were determined according to the beaufort scale, and manoeuvres were done at every beaufort level from calm weather to 6 Beaufort. For every beaufort value, the maximum force value of wind was applied. For example; When the beaufort scale is examined, 6 beaufort corresponds to the range of 22-27 knots wind force. In scenarios, 27 knots wind force was applied as 6 beaufort.
- Experts have stated that a ship berthed at the neighboring dolphin will negatively affect manoeuvres done. This was noted in the simulation studies that were carried out. The first 13 simulations were done without any ships at the neighboring dolphin. From simulation number 14 onwards, the scenarios were conducted with another ship model berthed at the neighboring dolphin. A study was done on the ships berthing at the said dolphin and it was seen that these ships are usually Ro-Ro ships with 26 meters of breadth and 193 meters of length. The most adequate model ship to simulate this condition was chosen and berthed in the simulation applications. The specifications of the ship model which is berthed to neighboring dolphin are shown in Figure 5.9.

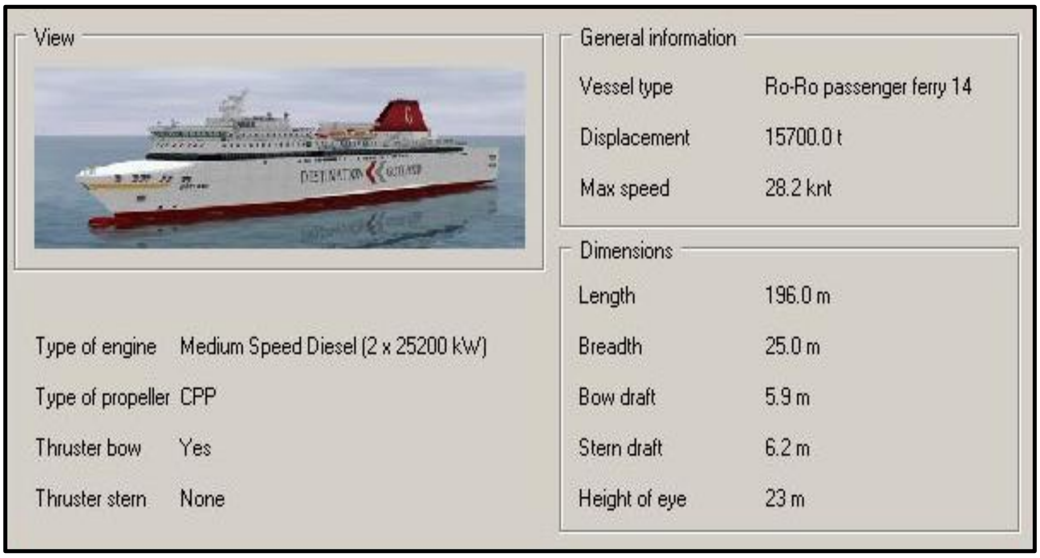


Figure 5.9. Ship model berthed to neighboring dolphin

- The current factor was ignored due to a significant enough current to affect manoeuvres does not occur in the area and due to a lack of current data.
- Experts have noted that effective waves do not form in the area. In all scenarios, waves with 0,3 meters of length were applied.
- In the scenarios, visibility conditions adequate for manoeuvring were simulated. Visibility conditions were ignored during the assessment.
- In all scenarios, two tugs were simulated to carry out the directions of the experts.

5.2.3. Application of the Scenarios

In the scenarios, initially ship bridge simulator equipment, their general features and the technical specifications of the ship model to be used were explained to the experts that would take part in the simulations for the first time. Ship particular documents and the details present on the wheelhouse poster of the ship model were presented to the experts. They were also informed on the technical specifications of the tugs to be used and how to command them.

After the discussions had with the experts, it was decided that in all scenarios the ship would berth forward first. The scenarios were initially started with an adequate distance allowing for manoeuvres and in the engine stop position.

During the manoeuvre, one additional person was tasked on the ship bridge simulator alongside the expert. This person carrying out the watchkeeping officer role would carry out the directions of the expert. The watchkeeping officer would apply the engine commands, steer the ship, and inform the expert about the ship's speed and the distance to certain points. In Figure 5.10., a ship's tracks during the boarding process are shown.

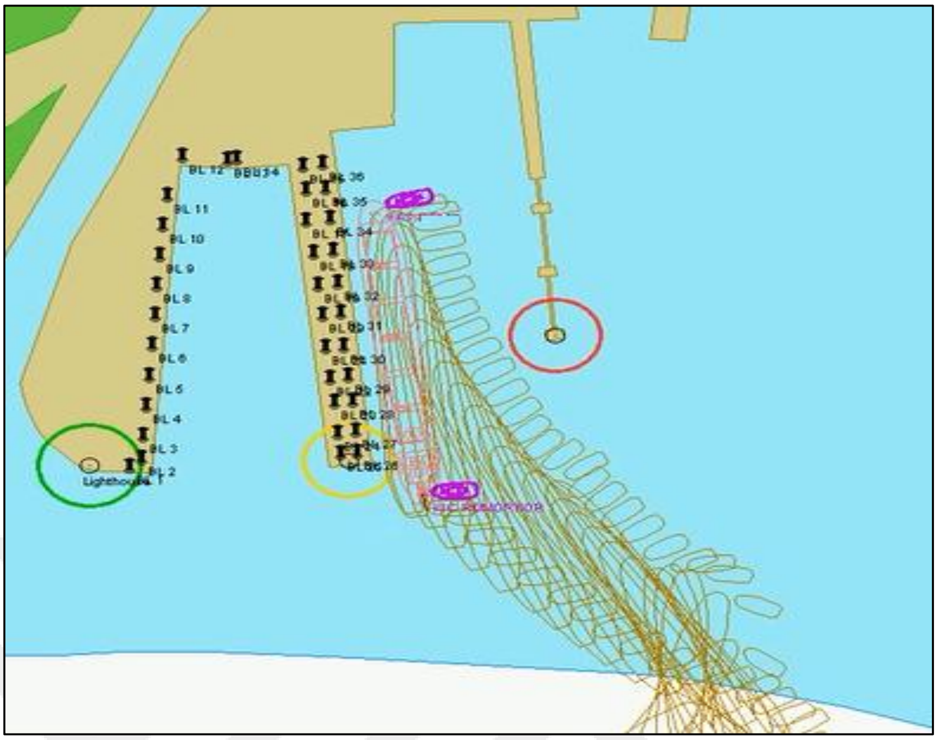


Figure 5.10. Tracks created by the ship during coming alongside

In order to apply the directions given to the tugs, one additional person was tasked at the ship bridge simulator control center. All directions given by the expert through the intercom system were applied in this center. The push or pull commands issued by the expert were carried out through the application window present on a computer within the control center. In Figure 5.11., the command window used for applying the tugs' commands is shown.

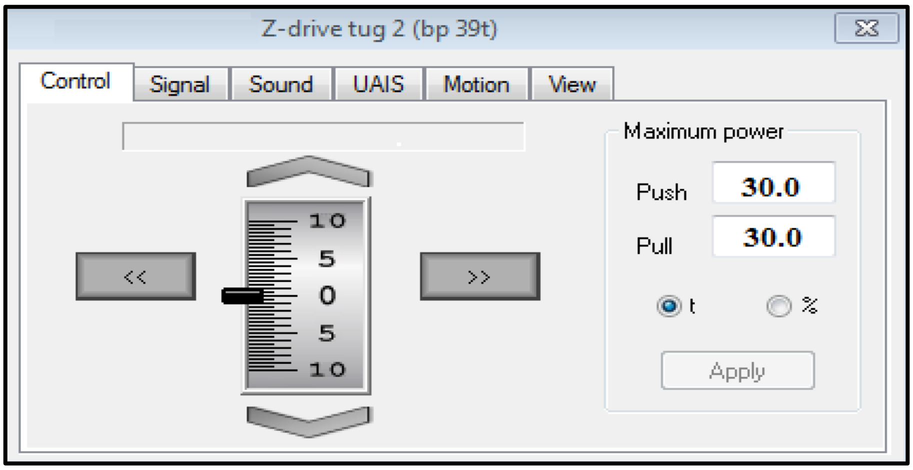


Figure 5.11. Tug remote control window

Due to the manoeuvring space being narrow, the tugs were made fast to the ship with American Fastening. Scenarios were deemed complete when the ship has boarded the pier, the engine has stopped and the ship’s speed has been reduced controllably. At the end of each scenario, the study was concluded with an assessment on the manoeuvre done with the expert that has conducted the manoeuvre.

6. METHODS USED IN RISK ANALYSIS

When risk analysis studies were analysed, it is seen that many different methods are applied. The purpose of these studies is to get consistent results by applying the most correct risk analysis method. The risk analysis methods to be used in the study are determined for this purpose. In this chapter, the “Fuzzy Logic” and the “Fine Kinney” methods which were chosen as the risk analysis methods were explained.

6.1. Fuzzy Logic

Fuzzy logic is a method widely used for solving numerous problems. It is used in many studies due to the method having a wide area of application and giving positive results when used. (Kaftan et al., 2013). Fuzzy logic, which can be defined as a flexible and precise calculation method, is a method which especially lets us decide in situations of uncertainty.

The fuzzy logic theorem was first suggested by the Azerbaijani-American scientist Lotfi A. Zadeh. This theorem was first explained in an article named “The Theory of Fuzzy Logic and Fuzzy Sets”. The first application of fuzzy logic was done in order to control a steam engine in 1973 (Ozdemir, 2019). The first commercial use of it was in 1980 for controlling the furnace of a cement factory (Isikli, 2008).

Fuzzy logic is generally used to model decisions specified verbally, that are defined by an expert and are uncertain, mathematically. This model is named fuzzy since the results consist of uncertain fuzzy clusters. This method allows getting meaningful results in studies in which experts can not get certain results but can draw limits locally. The purpose of fuzzy logic applications is then getting consistent results from uncertain information. Fuzzy logic is used in numerous systems which have parameters that constantly change, which does not have any mathematical models or which are difficult to model and apply (Mikail, 2007).

In classical logic, a statement is deemed as either a correct or an incorrect one. If a statement is a correct or an incorrect one, they are represented with a 1 or a 0 respectively. This clear distinction of classical logic is insufficient when it comes to defining uncertainties faced in daily life. Fuzzy logic then steps in in order to scale these uncertainties. With fuzzy logic, the solution of complex problems that include uncertainties is eased. With the use of this method, it is made possible to digitize verbal situations. In fuzzy logic, everything is graded between 0 and 1 and defined with verbal statements.

Below, the advantages and disadvantages of fuzzy logic are laid out. (Behrooz et al., 2018; Ozbek, 2017)

Advantages of fuzzy logic;

- Its reasoning is similar to that of a person's thought process.
- It can evaluate uncertain information.
- It produces results from verbal statements.
- It allows the modeling of non-linear complex systems using simple math.
- It provides convenience while solving complex problems.
- It is an easily constructed system.
- It is not complex and it is easy to understand.
- It is precise.
- It works fast.
- The software needed is simple and inexpensive.

Disadvantages of fuzzy logic;

- An expert is required in order to properly decide the choices.
- It may not be easy to define the conditions and the memberships.
- Trial and error is used for optimization.

- More precise results are tried to be achieved with trial and error, this may result in a waste of time.
- It does not produce certain results.

In this section fuzzy sets, membership functions of fuzzy sets, and structure of fuzzy systems are mentioned in order.

6.1.1. Fuzzy Sets

When classical sets are compared to fuzzy sets; in classical sets, an object is either a member of the set or not. In fuzzy sets, however, an object might be a member of more than one set. In other words, an object might be a member of a set only partially. In classical sets, if an object is a member of a set, they take the value of either 1 or 0. In fuzzy logic, however, every member is graduated members of a set. This graduation provides uncertainty for the limits of fuzzy sets. A member of a fuzzy set is converted to a real value between [0,1]. With fuzzy, With Fuzzy, information on to what extent a member can belong to a set is reached.

In Figure 6.1., a graphical representation of classic and fuzzy sets is shown. In Figure 6.1., the x-axis represents the universal set while the y-axis shows the grade of membership. These membership functions may be triangular, trapezoidal, singleton, or gaussian.

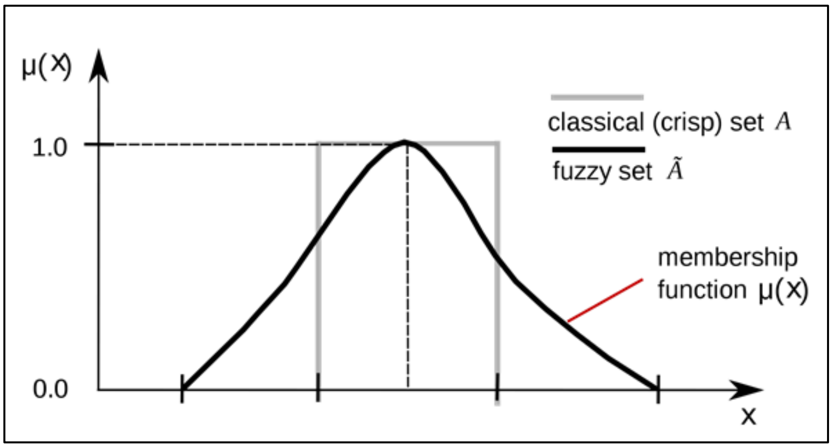


Figure 6.1. Graphic representation of a fuzzy set with a classic set (URL-6)

When Figure 6.1. is analysed, it is seen that the fuzzy set has values between 0 and 1 compared to the sharp limits of a classical set. Any value between 0 and 1 defines a partial member of a fuzzy set. In short, a fuzzy set is a set that consists of partial members that have neither 0 nor 1 as an answer but rather a value between 0 and 1.

6.1.2. Membership Functions of Fuzzy Sets

Functions that equate the members of a fuzzy set to a defined interval of numbers are named as “membership functions”. Membership functions are used to show to what extent the elements are a member of the set. According to the fuzzy logic theorem, the interval of the results of a membership function is defined as [0, 1]. While in a classic set the membership functions are defined as a point or a line, in fuzzy sets they are shown as a linear or a curvilinear function.

Classical Logic Membership Function is defined as shown in (6.1.).

$$\mu A(x) = \begin{cases} 1; & x \in A \\ 0; & x \notin A \end{cases} \tag{6.1.}$$

Fuzzy Logic Membership Function is defined as shown in (6.2.).

$$\mu A(x) = E\,[0,1] \qquad (6.2.)$$

The main constructional components of a membership function are comprised of four components. These are defined as the core, the support, the boundary, and the height (Figure 6.2.).

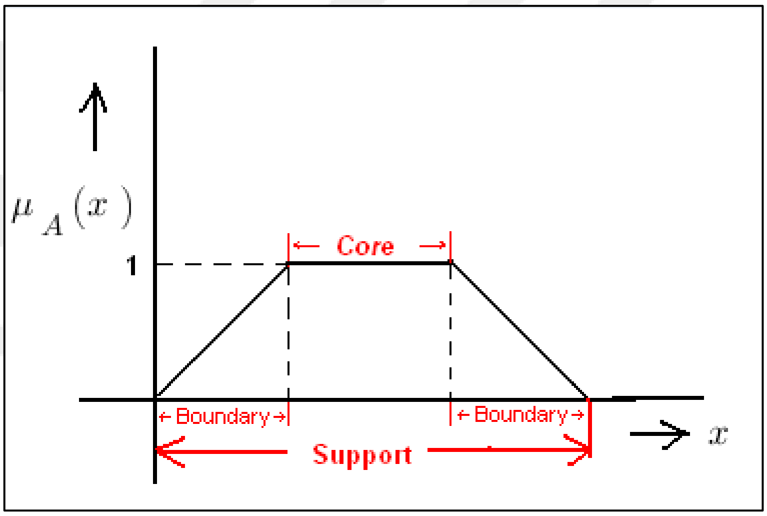


Figure 6.2. Components of membership functions (URL-7)

Below, the constructional components of membership functions are defined; (Kaya & Askerbeyli, 2018)

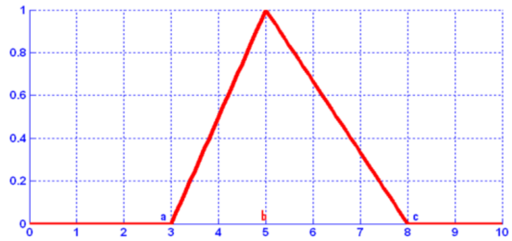
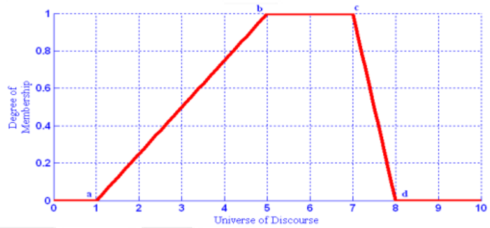
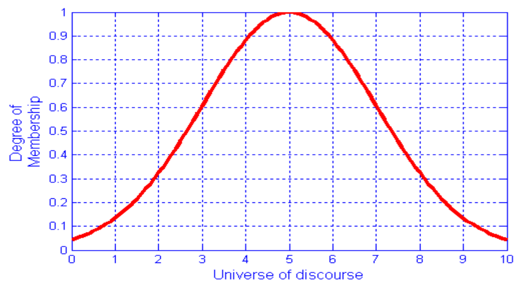
- Core: Represents the region where the membership function equals to 1. In this region, the function has full membership. It is represented as $\mu A(x) = 1$.
- Support: It is defined as the regions where the function equals to values other than 0. It is defined as $\mu A(x) > 0$.
- Boundary: It represents the region where the function does not equal to neither 0 or a whole number and is defined as $0 < \mu A(x) < 1$.
- Height: Represents the highest degree of membership of a fuzzy set. It is defined as Max [$\mu A(x)$].

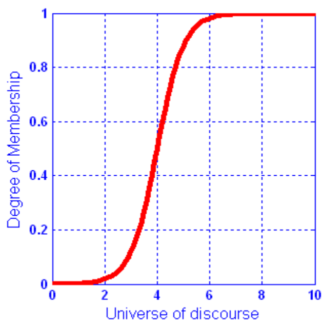
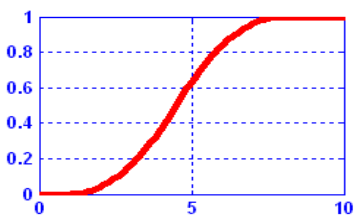
Different membership functions are used depending on the specifications of the study being conducted. Membership functions that are generally encountered are given below:

- Triangular Membership Function
- Trapezoidal Membership Function
- Gaussian Membership Function
- Sigmoidal Membership Function
- S-Shape Membership Function

It is important to take studies done in similar fields when deciding on which membership function is to be used in order to get fast and correct results. The function equations and function graphics information of the functions given above are shown in Table 6.1.

Table 6.1. Types of membership functions (Ross, 2010)

<table>
<tr><th>Types of Function</th><th>Function Equation</th><th>Function Graphic</th></tr>
<tr><td rowspan="2">Triangular Membership Function</td><td>$$\text{Triangular } (x;a,b,c) = \begin{cases} 0 & x < a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{c-x}{c-b} & b \le x \le c \\ 0 & c \le x \end{cases}$$</td><td rowspan="2">
</td></tr>
<tr><td>a, b, c: x coordinate for capital triangle
x: the real value from the private variable fuzzy universe of discourse.</td></tr>
<tr><td rowspan="2">Trapezoidal Membership Function</td><td>$$\text{Trapezoidal } (x;a,b,c,d) = \begin{cases} 0 & x < a \\ \frac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \frac{d-x}{d-c} & c \le x \le d \\ 0 & d \le x \end{cases}$$</td><td rowspan="2">
</td></tr>
<tr><td>a, b, c, d: x- coordinates of the four heads of the trapezoidal</td></tr>
<tr><td rowspan="2">Gaussian Membership Function</td><td>$$\text{Gaussian } (x;c,\sigma) = e^{\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2}$$</td><td rowspan="2">
</td></tr>
<tr><td>c: function center

σ: the function width</td></tr>
<tr><td rowspan="2">Sigmoidal Membership Function</td><td>s</td><td rowspan="2">
</td></tr>
<tr><td>c: The point at which the curved change its direction and this point has a degree of membership 0.5 (μ(c)) = 0.5.
a: controls the slope at the intersection point x = c.</td></tr>
<tr><td rowspan="2">S-Shape Membership Function</td><td>$$\text{S-Shape } (x;a,b,c,d) = \begin{cases} 0 \; x \le a \\ 2\left(\frac{x-a}{a-b}\right)^2 \; a \le x \le \left(\frac{a+b}{2}\right) \\ 1-2\left(\frac{x-b}{b-a}\right)^2, \left(\frac{a+b}{2}\right) a \le x \le a \end{cases}$$</td><td rowspan="2">
</td></tr>
<tr><td>a, b: x- coordinates</td></tr>
</table>

6.1.3. Structure of Fuzzy Systems

Fuzzy sets and systems made up of graded membership systems are defined as fuzzy systems. In Figure C, a simple fuzzy system structure is shown. The process between the time of input and output is shown in Figure 6.3.

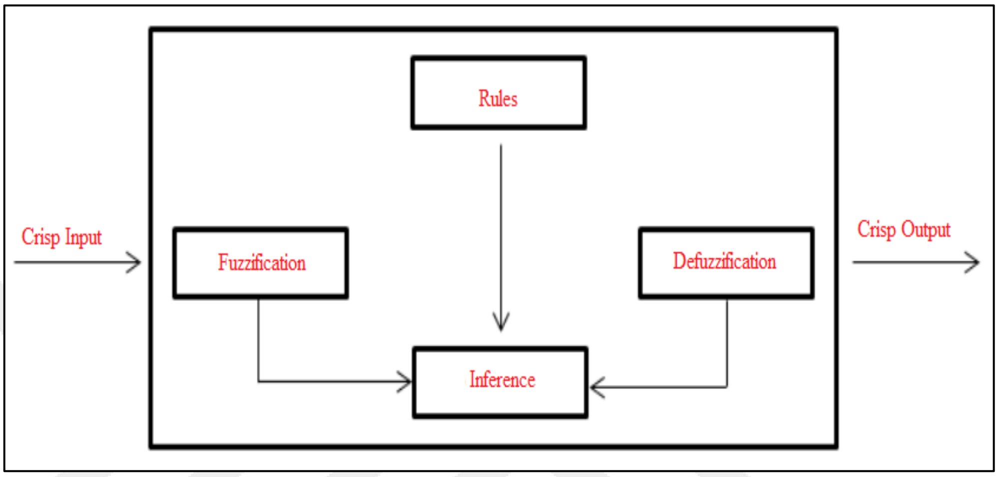


Figure 6.3. Basic Fuzzy sytem (Zoroğlu, 2015)

Below, processes that take place in a fuzzy system structure are explained.

6.1.3.1. Fuzzification

The process of converting numerical variable inputs into verbal statements is called fuzzification. On this step, the process of fuzzification of certain numbers into fuzzy numbers is carried out. The creation of fuzzy values is completed after the uncertainty in certain values are defined. These values are shown with membership conversion functions. Since the use of inputs and outputs has a simple structure, the fuzzification process is carried out with triangular membership functions.

The fuzzification of the bare inputs is done during this process. In other words, the degree of membership of each input for the fuzzy set is calculated. During the fuzzification process, crisp numbers need to be assigned membership values. This assignment can be done with various methods. Below, examples of generally used assignment methods are given (Zoroğlu, 2015).

- Expert Based Assignment: The appropriate assignments are done according to experts' knowledge and experience.
- Inference: Deductions based on current information are utilized.
- Sort Method: The process of comparing and sorting the data at hand is carried out.
- Neural Networks: The assignment process is carried out using neural networks.
- Genetic Algorithms: If the data at hand is appropriate, the assignments can be done with genetic algorithms.
- Inductive Reasoning: To be able to carry out this process, there must be great amounts of data and this data must ensured to be correct.

6.1.3.2. Rules

These are the if-then rules that connect the inputs in the database to output variables (Kaftan, 2013). This is the part of the fuzzy system used in order to infer results. Which results are to be inferred is determined during this process according to the data. It includes the fuzzy rules designed in order to acquire information. It shows the information at hand in a cause and effect relationship within the ruleset.

6.1.3.3. Inference

This process is carried out with the rules section. It is used to infer results from the fuzzy values acquired with the rules process. It is the process that allows new information to be acquired using the existing data.

There are two inference methods commonly used in fuzzy systems. These are the "Mandani" and the "Takagi Sugeno" systems. Mandani method is one of the most commonly used inference methods. It is a method that requires expert knowledge. It is an inference method used in various problems. It has a wide range of application due to the method being compatible with human behaviour. The method having an easy design, it addressing human perception and it being advantageous when it comes to the ease of interpretation makes it preferred more.

The Sugeno inference method is generally preferred in control problems. It is used in problems which do not have too many variables and whose variables do not further divide into subsets. When the Sugeno and the Mandani methods are compared, while "Mandani inference" gives the output as fuzzy values, the "Sugeno inference" gives the output as functions.

6.1.3.4. Defuzzification

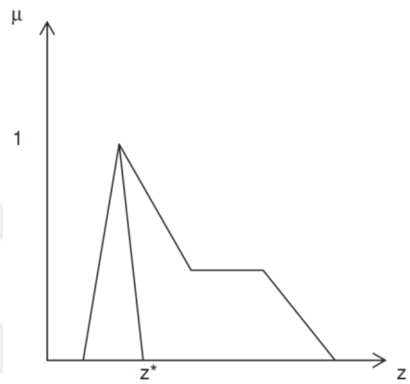
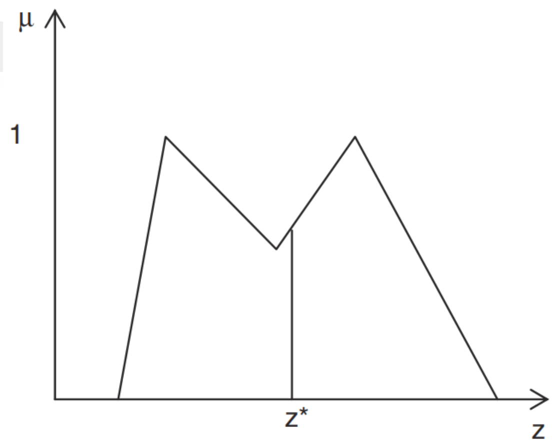
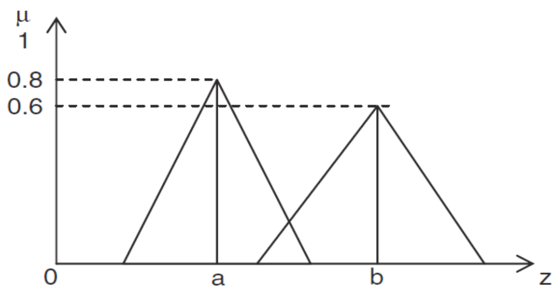
This is the process of scaling the fuzzy data acquired from the inference process into an interval and getting results. In this process, fuzzy numbers are converted into crisp numbers or sets. Fuzzy variables are converted back into numerical values in this process.

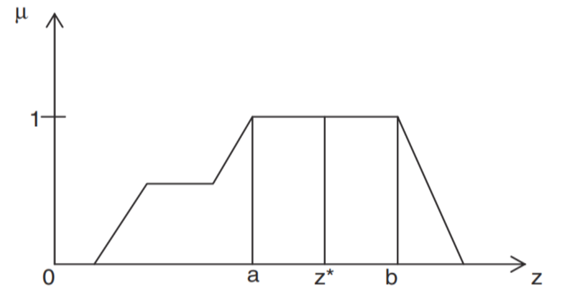
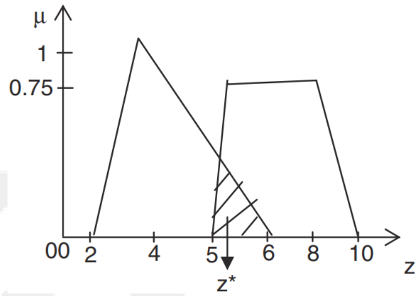
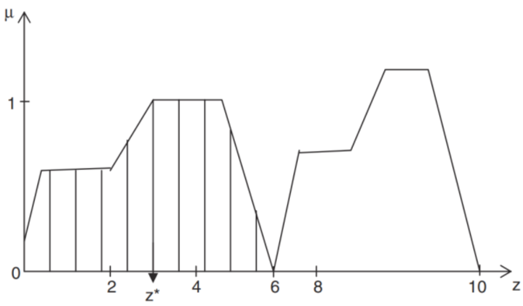
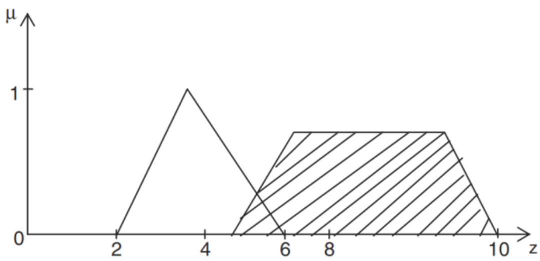
When defuzzification methods are analysed, it is seen that generally the below mentioned methods are used; (Kaya & Askerbeyli, 2018)

- Max-membership principle
- Centroid method
- Weighted average method
- Mean–max membership
- Centre of sums
- Centre of largest area
- First of maxima or last of maxima

In Table 6.2., the expression and the graphs of the defuzzification methods used are given.

Table 6.2. Expression and the graphs of the defuzzification methods (Ross, 2010)

Defuzzification Methods	**Expression**	**Graphic**
Max-membership principle	$\mu_{\underset{\sim}{C}}(z^*) \geq \mu_{\underset{\sim}{C}}(z)$ for all $z \in z$.	
Centroid method	$z^* = \int \frac{\mu_{\underset{\sim}{C}}(z)\, z\mathrm{d}z}{\mu_{\underset{\sim}{C}}(z)\,\mathrm{d}z}$,	
Weighted average method	$z^* = \frac{\sum \mu_{\underset{\sim}{C}}(\bar{z})\ \bar{z}}{\sum \mu_{\underset{\sim}{C}}(\bar{z})}$,	

Mean–max membership	$z^* = \dfrac{a+b}{2}$	
Centre of sums	$z^* = \dfrac{\int_2 z \sum_{k=1}^{n} \mu_{\underset{\sim}{C_k}}(z)\,\mathrm{d}z}{\int_2 z \sum_{k=1}^{n} \mu_{\underset{\sim}{C_k}}(z)\,\mathrm{d}z}.$	
Center of largest area	$z^* = \dfrac{\int \mu_{\underset{\sim}{c_m}}(z)\, z\mathrm{d}z}{\int \mu_{\underset{\sim}{c_m}}(z)\,\mathrm{d}z},$	
First of maxima or last of maxima	First of Maxima $z^* = \inf_{z \in z} \left\{ z \in z / \mu_{\underset{\sim}{c_k}}(z) = hgt\left(\underset{\sim}{c_k}\right) \right\}.$ Last of Maxima $z^* = \sup_{z \in z} \left\{ z \in z / \mu_{\underset{\sim}{c_k}}(z) = hgt\left(\underset{\sim}{c_k}\right) \right\}.$	

6.2. Fine-Kinney Method

Fine-Kinney is another analysis method used in risk analysis studies. This method was first introduced in 1971 by William T. Fine in a study named “Mathematical Evaluations for Controlling Hazards” (Fine, 1971). Afterwards, the method was expanded and published in a study named “Practical Risk Analysis for Safety Management” in 1976 by G.F Kinney and A.D Wiruth (Kinney & Wiruth, 1976). It is also called the "Kinney Method" in some studies.

The Fine-Kinney method, which is a quantitative risk model, has a simple structure. To be able to get consistent results, the parameters used in determining the risk score should be determined correctly. In the Fine-Kinney Method, three parameters are used in order to determine the risk score. These are; probability, frequency, and consequence. These parameters are defined below; (Kinney & Wiruth, 1976)

Probability is defined as the possibility of exposed to a dangerous event. Ratings and classifications of probability are expressed under seven classes, presented in Table 6.3.

Table 6.3. Value and classifications of probability (Kinney & Wiruth, 1976)

P Value	Probability (P)
10	Might well be expected
6	Quite possible
3	Unusual but possible
1	Only remotely possible
0.5	Conceivable but very unlikely
0.2	Practically impossible
0.1	Virtually impossible

Frequency (F) or expousure (E) is frequency of occurrence of the hazard-event (the undesired event which could start the accident-sequence). Ratings and classifications of frequency are expressed under seven classes, presented in Table 6.4.

Table 6.4. Value and classifications of frequency (Kinney & Wiruth, 1976)

F Value	Frequency (F)
10	Continuous
6	Frequently (daily)
3	Occasional (weekly)
2	Unusual (monthly)
1	Rare (a few per year)
0.5	Very rare (yearly)

Consequences (C) is defined as the most probable results of a potential accident, including injuries and property damage. Ratings and classifications of frequency are expressed under seven classes, presented in Table 6.5.

Table 6.5. Value and calssifications of consequences (Kinney & Wiruth, 1976)

C Value	Consequences(C)
100	Catastrophic (many fatalities, or > $\$10^7$ damage)
40	Disaster (few fatality, or > $\$10^6$ damage)
15	Very serious (fatality, or > $\$10^5$ damage)
7	Serious (serious injury, or > $\$10^4$ damage)
3	Important (disability, or > $\$10^3$ damage)
1	Noticeable (minor first aid accident, or > $\$10^2$ damage)

In the Fine-Kinney risk analysis method, the risk score is calculated while taking the consequence of an accident, the frequency of the hazard-event, and the probability into account. The Fine-Kinney risk score is calculated as shown in (6.3),

$$\text{Risk (R)} = \text{Probability (P) x Frequency (F) x Consequence (C)} \qquad (5.3)$$

Table 6.6. Risk scores and action plan (Kinney & Wiruth, 1976)

Risk score	Risk Level	Actions for Risk
$R < 20$	Risk	Perhaps acceptable
$20 \leq R < 70$	Possible risk	Attention indicated
$70 \leq R < 200$	Substantial risk	Correction needed
$200 \leq R \leq 400$	High risk	Immediate correction required
$R > 400$	Very high risk	Consider discontinuing operation

The levels of risk present in the risk score are divided into 5 categories. This categorization helps us understand the level of the risk. Below evaluations are done by studying the risk score results;

- If R < 20, then the risk is at an acceptable level. The present precautions are adequate.
- If 20 ≤ R < 70, the present precautions should be continued. But it should not be forgotten that the risk core is critical. This is the interval most commonly encountered during applications.
- If the risk score is 70 ≤ R < 200, preventive and corrective actions should be taken and the risk score should be lowered.
- In the 200 ≤ R ≤ 400 interval, immediate precautions should be taken. The operation should be held off until the risk score is lowered.
- If R > 400, no operation should be carried out. Long term solutions should be thought of.

7. APPLICATION OF RISK ANALYSIS METHODS

In this chapter, the aim is to determine the level of the risk that occurs during the coming alongside manoeuvre of a ship to a pier in different environmental conditions. In the application, two methods, namely the Fine-Kinney and the Fuzzy Fine-Kinney methods, were utilized.

In the first part of the application, the hazards that may occur during the process of a ship boarding a pier were identified. In the second part, the process of determining the risk analysis methods to be applied was explained. In the third part, information about the process of application for the Fuzzy Fine-Kinney method was given. In the last part, the findings were explained.

7.1. Determination of Hazards

A focus group study was conducted in order to determine the hazards that may occur during the coming alongside process of the model ship used in the scenarios. The focus group study, which is a qualitative data acquisition technique, is a study done with a small group that allows data to be collected by discussions and opinions (Cokluk et al., 2011).

The focus group consisted of two pilots, one academician and one oceangoing master, and all of whom have an oceangoing master licence and at least ten years of sea experience. Especially the pilots, having worked at the area that the risk analysis study is to be conducted, were a big advantage when it comes to identifying the hazards.

The experts, as a result of the focus group study, identified the hazards that may occur in the manoeuvring area. These hazards were categorized under 5 categories. In

Table 7.1., types of hazards that may be encountered during the process of the model ship boarding a pier are shown.

Table 7.1. Defined hazard types that can occur during the model ship is coming alongside to the pier

Type No	Defined Hazard Types
1	Hard contact of the model ship with the boarding pier
2	Hard contact of the model ship with the neighbouring dolphin
3	Collision between the model ship and ship at the boarding the neighbouring dolphin
4	Squeezing of the tugs and be damaged
5	Grounding of the model ship

In Figure 7.1., the regional distribution of the hazard types within the manoeuvring area is shown. When Figure 7.1. examined;

- In region number 1, hard contact of the model ship with the neighbouring dolphin was defined as a hazard.
- In region number 2, when there is no ship in the neighboring dolphin, hard contact of the model ship with the neighbouring dolphin was defined as a hazard.
- In region number 3, collision between the model ship and ship at the coming alongside the neighbouring dolphin was defined as a hazard.
- In region number 4, due to tug does not have enough manoeuvring area, Squeezing of the tugs between ships and be damaged of tugs was defined as a hazard.
- In region number 5, because of this area determined as shallow water, grounding of the model ship was defined as a hazard.

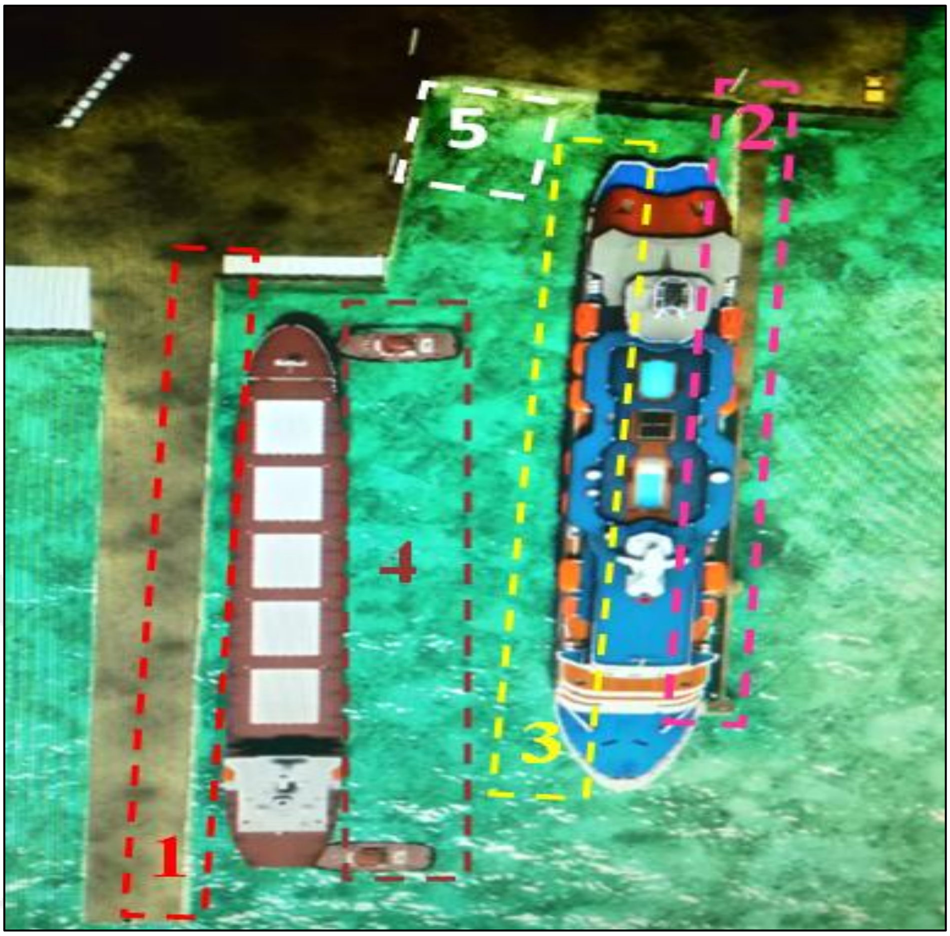


Figure 7.1. Regional distrubition of hazard types that can occur during the model ship is coming alongside to the pier

7.2. Determination of Risk Analysis Method

When the risk analysis method was being determined, the literature review that was done was considered. In addition, the risk analysis methods utilized by institute for port modeling studies were analysed. Two risk analysis methods become prominent after the analyses. One of which is the ES Model, and the other is the “Risk Matrix” method.

Both of these methods were evaluated. The stress value constants of ES Model were determined as a result of a measurement made approximately 20 years ago. When the studies were analysed, no other studies that aimed to test the reliability of this evaluation were found. Additionally, the stress constants used in the ES Model were calculated according to the risk perception of Japanese sailors. When the literature review was done in chapter 3 is considered, it is remarked that risk perception may vary between nations. This situation causes analyses done with the ES Model to be doubted.

However, when risk matrix studies are analysed, the inclusion of experts in the studies increase the reliability of the studies. Especially in studies with inadequate amounts of data and in which analysis is difficult, utilizing the knowledge and the experience of experts is an advantage when it comes to correctly identify the risks that occur. It is very important to choose the right experts in risk analysis studies made with the risk matrix. Consistent results can only be achieved through the correct choice of experts. The number of experts that take part in the study is also important. Assessment of people working in different fields who are knowledgeable about analysis will contribute to the studies.

In risk matrix studies, risk matrix scales such as 3x3, 4x4 and 5x5 are used. The risk matrix has two parameters as probability and severity. The risk score is acquired by multiplying these two numbers. When the ship manoeuvre risk evaluation studies are analysed, it is seen that generally 5x5 risk matrix scales are used. Each increase in the parameters of the matrix allows it to produce various levels and this in turn produces more risk evaluation notes (Elmontsri, 2013). This, in turn, allows the evaluation to produce more detailed and certain results. It is obvious that increasing parameters will benefit studies.

When the risk studies on ship manoeuvres within ports are considered, it is seen that situations such as having inadequate statistical data belonging to the study area and not testing the consistency of the study create problems for the application of these methods. When risk analysis studies on ship manoeuvres within ports are taken into account, it is determined that analyses done by correctly chosen experts produce more consistent results.

When the risk analysis studies on this topic are analysed, it is seen that the Fine-Kinney method which has a wider risk parameter is not being utilized in the field. It has wider probability and consequence scales compared to the risk matrix. In addition, unlike the risk matrix, it has a frequency parameter. It is thought that this method will produce results on a wider scale and more precisely due to it having a more extensive risk evaluation.

In many studies done in various fields, a comparison between the risk matrix and the Fine-Kinney method was seen. The following results have been achieved from these studies.

Okumuş & Barlas (2016) have compared the risk matrix and the Fine-Kinney method in their study about workplace accidents in the ship construction sector and have stated that the Fine-Kinney method produces more precise results.

Bekdemir (2019) has compared the two risk analysis methods in their study about the construction sector. As a result of the study, it was determined that the risk matrix is inadequate in certain circumstances. It was also determined that the Fine-Kinney method has an advantage due to it having a frequency parameter.

Zaloglu (2019) has conducted a risk analysis study using the Fine-Kinney and the risk matrix methods in his post-graduate thesis about risk assessment on fossil locality. She has stated that the Fine-Kinney risk analysis method has a more extensive interval when it comes to identifying and evaluating the severity of the risks. It was then thought this in turn produces analysis results closer to reality. It was stated that the Fine-Kinney method produces more functional and more precise results.

Olcucu & Ersoz (2019) have conducted risk analysis studies on a facility. Similarly, the two analysis methods were compared and it was stated that the Fine-Kinney method produces more consistent and more extensive results.

Usanmaz & Kose (2020) have used the Fine-Kinney and L type (5x5) matrix risk analysis methods for a laboratory of a university in which work was being done using chemicals. They have stated in their study that the frequency parameters affect the determination of the risk levels greatly. It was emphasized that the priorities of preventive actions taken for work that is being done everyday and for work that is being done a few times annually should not be the same and the Fine-Kinney method can be utilized for these evaluations. In addition, they have determined that analyses done using the Fine-Kinney method are more extensive in scale and this allows priority hazards to be eliminated in a shorter amount of time and produce more effective results.

When the literature review was done and the experts' views were considered, it is understood that the Fine-Kinney method is more advantageous than the risk matrix method. It is determined that the frequency parameter is an especially important factor. Another thing to consider is that in the Fine-Kinney method the severity scale has seven factors and the probability scale has six factors, which provides a more extensive evaluation for the risk analysis studies being done. With these advantages in mind, it was decided that the Fine-Kinney method would be used for the risk analysis study.

Additionally, in the literature review, it was found out that a Fuzzy Fine-Kinney Method that uses the probability, frequency and consequence parameters of the Fine-Kinney method as inputs were developed. In these studies, the Fine-Kinney method and the Fuzzy Fine-Kinney method were compared and it was determined that the Fuzzy Fine-Kinney method produces more precise results (Erdebilli & Gür, 2020; Oturakçı & Dağsuyu, 2017; Boran et al., 2018; Yegin, 2019).

With these studies in mind, it was decided that both the Fine-Kinney Method and the Fuzzy Fine-Kinney methods would be applied in the study and these two methods would be compared.

7.3. Application of Fine-Kinney Method

26 scenarios applied in the risk analysis study have been evaluated by experts. Random scenarios were applied by each expert. The experts then evaluated the manoeuvre they have conducted. The experts were then asked to evaluate the possibility of a maritime accident taking place at the end of each manoeuvre. They have carried out this evaluation by assigning points to the possibility and consequence parameters.

To be able to determine the frequency parameter, situations such as the wind data of the area, the boarding frequency of the model ship to the chosen pier, and the frequency of a ship being present at the neighboring dolphin were considered. Daily average wind speed and wind direction data for the past year were acquired from the General Directorate of Meteorology. Information about the frequency of a ship being present at the neighboring dolphin was supplied from a port manager. Lastly, information about the frequency of a ship similar to the chosen model ship mooring to the chosen pier was supplied from the person in charge of the port's operations. With these information in mind, the frequency evaluations of all scenarios were done by pilots working in the area. While these evaluations were being done, the experiences of these pilots were utilized.

As a result of these evaluations, a risk score was acquired for each manoeuvre. With the acquired parameters, the risk score in the Fine-Kinney Method was determined. Additionally, experts have identified types of hazards that can occur for each scenario which is risk level defined as "substantial risk" (SR) or higher risk level. While determining these hazard types, hazards defined in Table 7.1. was used and defined hazard types are specified in Table 7.6.

7.4. Application of Fuzzy Fine-Kinney Method By Using Matlab

The Fuzzy Fine-Kinney method was applied in order to eliminate the uncertainties that occur during the grading of the parameters (Erdebilli & Gür, 2020). The fuzzy logic calculations were done with the Fuzzy Logic Designer present in Matlab R2020 (Mathworks, 2020). In the Fuzzy Inference System (FIS), probability, frequency and consequence were defined as the inputs while the risk score was defined as the output (Figure 7.2.). In the Fuzzy Inference System, the "Mandani Min Max" method was utilized. "Centroid" was chosen as the defuzzification method.

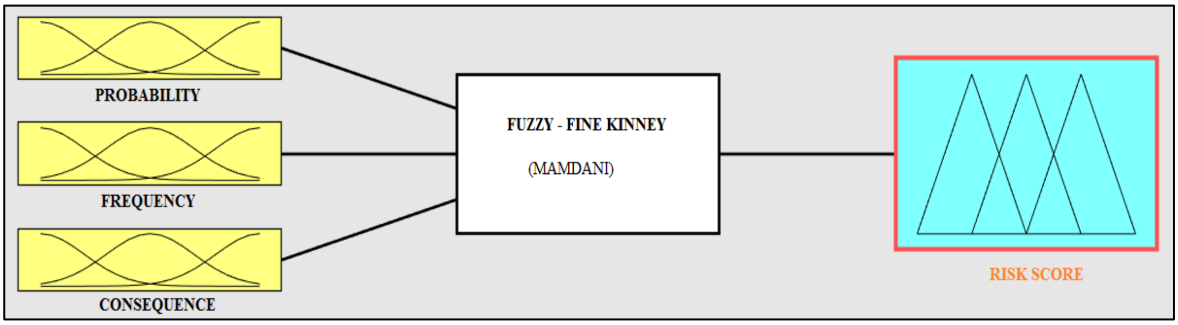


Figure 7.2. Inputs and output in FIS

The membership functions were specified after the inputs and the output was defined in the application. The membership function was chosen as the “triangular membership function”. This function was chosen due to its ease of use and it being utilized in similar studies. When the membership functions were being specified, values of parameters were utilized. During the determination of the membership functions of the inputs, one higher and one lower value scales of the concerned parameter were used. In Table 7.2., the fuzzy values of the probability scale are shown.

Table 7.2. Fuzzy value of probability input

P Value	Probability (P)	Fuzzy Value
10	Might well be expected (MWE)	(6, 10, 10)
6	Quite possible (QP)	(3, 6, 10)
3	Unusual but possible (UBP)	(1, 3, 6)
1	Only remotely possible (ORP)	(0.5, 1, 3
0.5	Conceivable but very unlikely (CVU)	(0.2, 0.5, 1)
0.2	Practically impossible (PI)	(0.1, 0.2, 0.5)
0.1	Virtually impossible (VI)	(0, 0.1, 0.2)

For example, while the fuzzy value of “quite possible” was being determined, the 3 value of “unusual but possible” and 10 value of “might well be expected” were taken into consideration. With this, the fuzzy value was determined as (3, 6,10). Similar processes were carried out for the other input parameters. In Table 7.3., the fuzzy values of the frequency scale and in Table 7.4., the fuzzy values of the consequence scale are shown.

Table 7.3. Fuzzy value of frequency input

F Value	Frequency (F)	Fuzzy Value
10	Continuous (C) - (weekly)	(6, 10, 10)
6	Frequently (F) - (monthly)	(3, 6, 10)
3	Occasional (O) - (once every 3 months)	(2, 3, 6)
2	Unusual (U) - (once every six months)	(1, 2, 3)
1	Rare (R) - (once a year)	(0.5, 1, 2)
0.5	Very rare (VR) - (once every 5 years)	(0, 0.5, 1)

Table 7.4. Fuzzy value of consequence input

C Value	Consequences(C)	Fuzzy Value
100	Catastrophic (Ca) - (many fatalities, or > $10^7 damage)	(40, 100, 100)
40	Disaster (D) - (few fatality, or > $10^6 damage)	(15, 40, 100)
15	Very serious (VS) - (fatality, or > $10^5 damage)	(7, 15, 40)
7	Serious (S) - (serious injury, or > $10^4 damage)	(3, 7, 15)
3	Important (I) - (disability, or > $10^3 damage)	(1, 3, 7)
1	Noticeable (N) - (minor first aid accident, or > $10^2 damage)	(0, 1, 3)

The fuzzy values of the output were determined while taking the risk score values into consideration. The mean values of the risk score intervals were used during the determination of these values. For example, while the fuzzy values for the risk score in the R < 20 intervals were being determined, the initial point was accepted as 0, and the midpoint of the middle values in the interval between 0 and 20 was accepted as 10. The last value was then determined by taking the average value of the one higher risk score interval. As such, the fuzzy value was applied as (0, 10, 45). The maximum fuzzy value was applied as 1000. It was observed that other values would give inconsistent results. In Table 7.5., the fuzzy values of the risk score scale are given.

Table 7.5. Fuzzy value of risk score output

Risk score	Risk Level	Actions for Risk	Fuzzy Value
R < 20	Risk (R)	Perhaps acceptable	(0, 10, 45)
20 ≤ R < 70	Possible risk (PR)	Attention indicated	(10, 45, 135)
70 ≤ R < 200	Substantial risk (SR)	Correction needed	(45, 135, 300)
200 ≤ R ≤ 400	High risk (HR)	Immediate correction required	(135, 300, 650)
R > 400	Very high risk (VHR)	Consider discontinuing operation	(300, 650, 1000)

The probability, frequency, and consequence inputs were transferred to the fuzzy values membership function determined for the risk score output. In Figure 7.3., Figure 7.4., Figure 7.5., and Figure 7.6., these diagrams are shown.

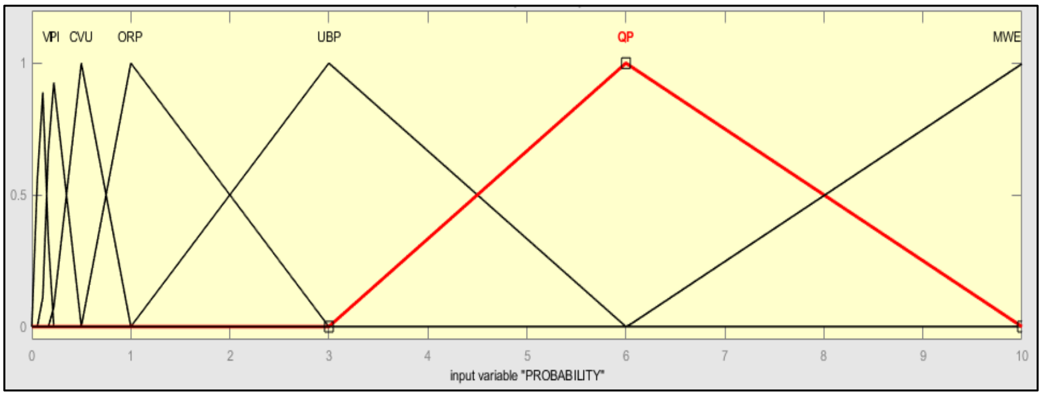


Figure 7.3. Fuzzy diagram of probability input

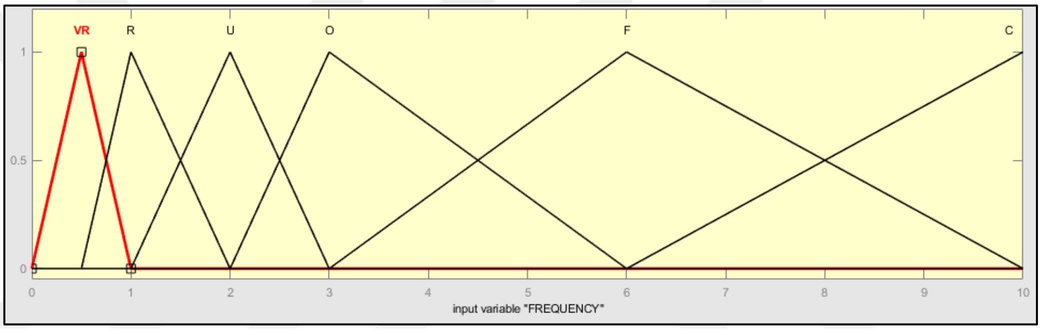


Figure 7.4. Fuzzy diagram of frequency input

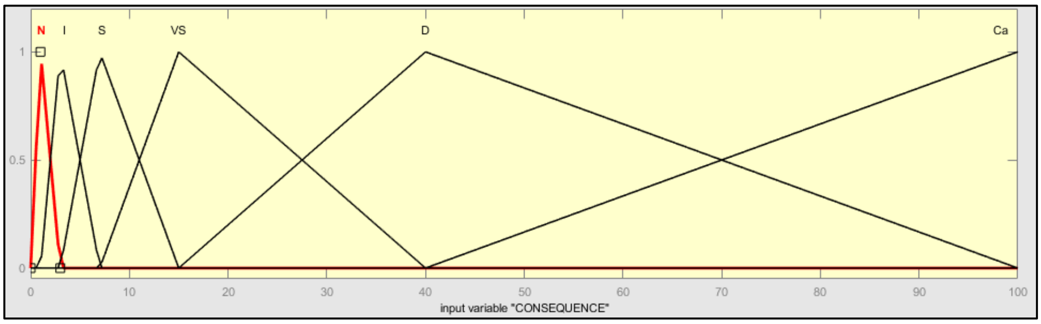


Figure 7.5. Fuzzy diagram of consequence input

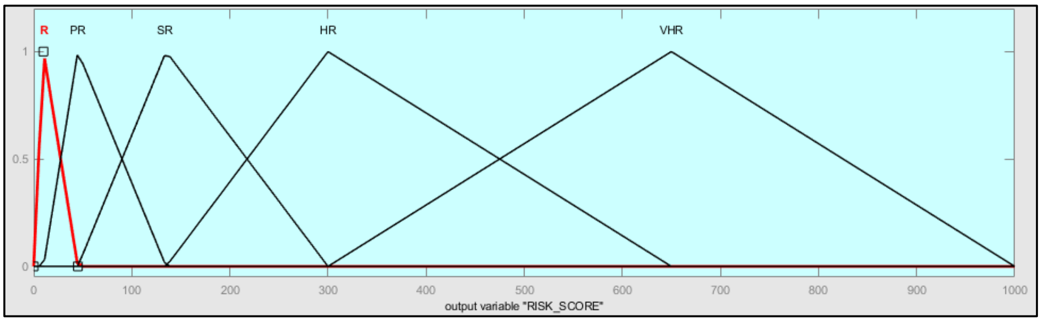


Figure 7.6. Fuzzy diagram of risk score output

After the completion of the triangular membership functions, 252 rules were defined in the program using the rule editor. The linguistic variables present in the probability, frequency, and consequence parameters define these rules. The results were defined by the linguistic variables present in the risk score. In Figure 7.7., the rule editor window of the fuzzy logic designer is shown.

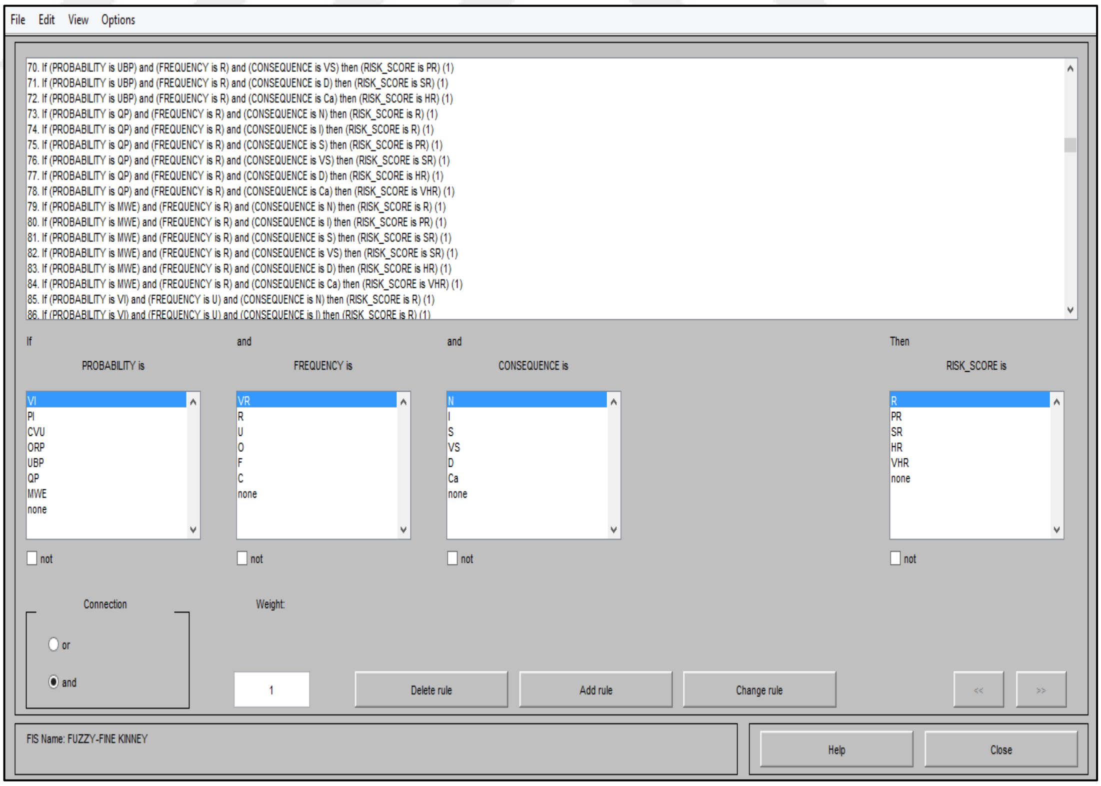


Figure 7.7. Rule editor interface

In the rule editor, the rules are determined according to the parameters inputted. The output variable is then determined according to the probability, frequency, and consequence inputs. With this, the rules are determined. Below, examples of some rules defined within the rule editor are given.

- Rule 70
  If probability is (UBP) and frequency is (R) and consequence is (VS); then risk score is (PR)

- Rule 73
  If probability is (QP) and frequency is (R) and consequence is (N); then risk score is (R)

- Rule 85
  If probability is (VI) and frequency is (U) and consequence is (N); then risk score is (R)

After all of the rules are defined, the fuzzified risk scores were acquired from the "rule viewer" window of the fuzzy logic designer by entering the parameter values. In Figure 7.8., the rule viewer window is shown.

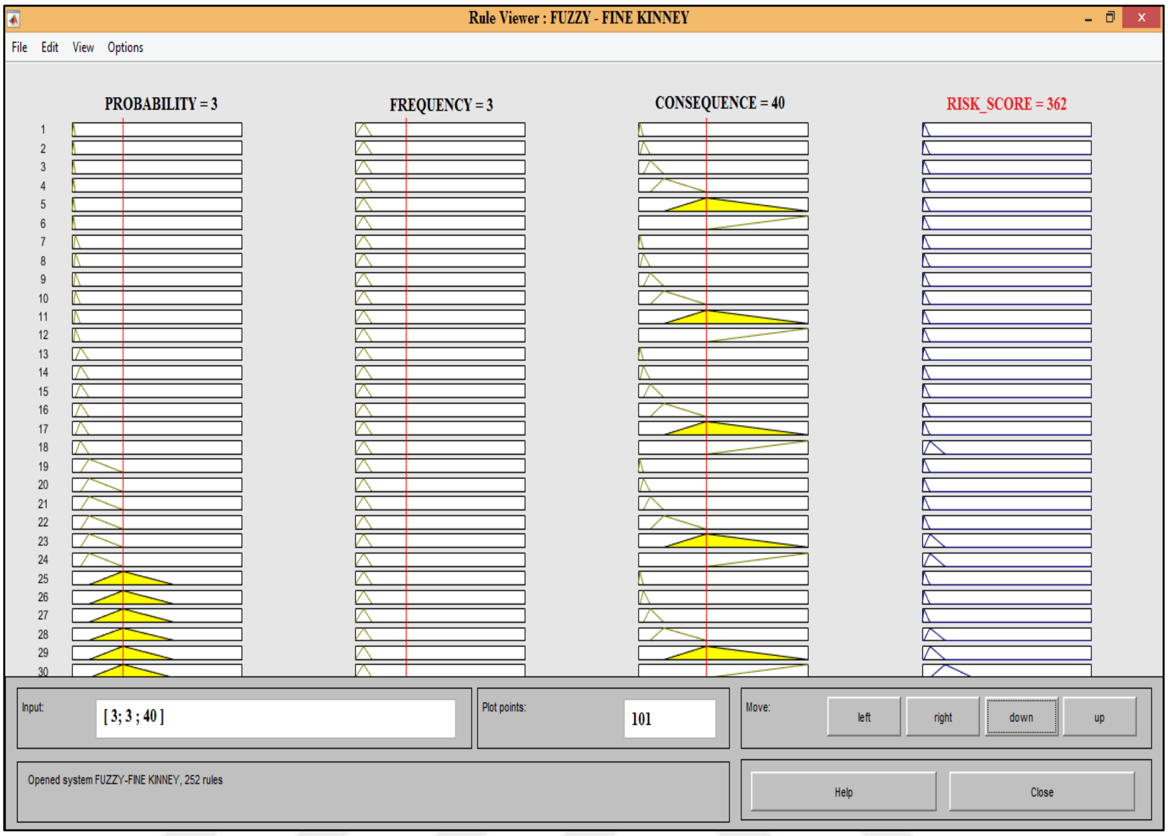


Figure 7.8. Rule viewer in fuzzy logic designer

When Figure 7.8., is examined; it is seen that when the probability, frequency, and consequence values are set as (3;3;40) respectively, the risk score is calculated as 362 in the rule viewer.

7.5. Findings

With the parameters acquired, the Fine-Kinney risk scores of all scenarios were determined. In Table 7.6., scenarios applied and probability, frequency, and consequence values of these scenarios were given. The risk score and the risk level of each scenario determined by these parameters are shown in this table. The "Defined Hazard Type Codes" part of the table defines the hazards that determine the risk level of scenarios with risk levels of "Substantial Risk (SR)" and above. The below results were achieved by analysing Table 7.6.

While the wind blows from NE and no ship is present at the neighboring dolphin;

- Low levels of risk were observed in 0, 1, 2, and 3 beaufort.
- In 4 and 5 beaufort, the risk level has increased to the level of possible risk. Especially in 5 beaufort, it is observed that the level of risk approaches “substantial risk”.
- In 6 beaufort , the risk level has reached “high risk”. It is determined that a hazard defined as “hard contact of the model ship with the boarding pier” causes an increase in the risk score. The wind blowing from NE causes the ship to swiftly approach the pier. It is determined that this causes the ship to suffer from hard contact with the pier.
- When the first 6 scenarios were evaluated by the experts, it was determined that the first 4 scenarios were appropriate for coming alongside manoeuvres. It was remarked that in 5 beaufort however, the risk level increases, and additional precautions are necessary. It is anticipated that increasing the pulling power of the tugs or increasing the number of tugs to 3 will lower the risk level. However, in 6 beaufort, it was determined that a model ship with this feature should not be manoeuvred, and the measures to be taken will not reduce the risk level sufficiently.

While the wind blows from W and there is no ship present at the neighboring dolphin;

- Low levels of risk were observed in 0, 1, 2, 3, and 4 beaufort.
- In 5 beaufort, the risk level was defined as “substantial risk”. It was determined that precautions to lower the level of risk should be taken. “Hard contact of the model ship with the neighboring dolphin” was determined as a hazard that may be encountered. It was observed that the wind blowing from W has an effect on the creation of this hazard.
- In 6 beaufort, the risk level was defined as “high risk”. In the scenario conducted, it was observed that two types of hazards were prominent. These were determined as “hard contact of the model ship with the boarding pier” and “hard contact of the model ship with the neighboring dolphin”. The wind force has caused in a loss of control of the ship and these two hazards occurring.
- The experts have stated that manoeuvres can be conducted in 1, 2, 3 and 4 beaufort if the wind is blowing from W and there are no ships present at the neighboring dolphin. They have remarked that in 5 beaufort however, increasing the pulling power of the

tugs or increasing the number of the tugs to three may lower the risk level. They have also indicated that 6 beaufort, no precautions taken can lower the risk level to an acceptable level and due to this they have advised against doing manoeuvres under these conditions.

While the wind blows from NE and there is a ship moored at the neighboring dolphin;

- Low levels of risk were observed under 0 and 1 beaufort.
- The risk level was calculated as "possible risk" in 2 and 3 beaufort.
- In 4 beaufort, the risk level has increased to "high risk". The possibilities of two hazards occurring were determined to be high. These hazards were identified as "hard contact of the model ship with the boarding pier" and "squeezing and damaging of the tugs".
- In 5 and 6 beaufort, the risk level was determined as "very high risk". As a result of the scenarios applied, 3 different hazards were determined to be possible to encounter. These hazards were defined as "hard contact of the model ship with the coming alongside pier", "collision between the model ship and the ship coming alongside the neighboring dolphin" and "squeezing and damaging of the tugs".
- According to the experts, a ship being present at the neighboring dolphin narrows down the manoeuvring space too much. This results in the manoeuvring area to be inadequate. It was observed in the scenarios applied that the more the wind increases in force, the more the model ship approaches the ship moored at the neighboring dolphin. Additionally, the tugs could not be utilized efficiently due to the narrow manoeuvring area, and especially the tug stationed at the forward of the ship has suffered damages due to being stuck between the two ships. The experts have stated that in 4 beaufort and up, the current situation does not allow safe manoeuvres. They have also advised a spare tug to be on stand by in case of emergencies in 2 and 3 beaufort.

While the wind blows from W and there is a ship moored at the neighboring dolphin;

- Low levels of risk were observed in 1 and 2 beaufort.
- In 3 beaufort, the risk level was determined as “possible risk”.
- It was observed that in 4 beaufort, the risk level increases to “substantial risk”. The hazards that the ship might face were defined as “collision between the model ship and the ship boarding the neighboring dolphin” and “squeezing and damaging of the tugs”.
- In 5 beaufort , the risk level was determined as “high risk”. As a result of the manoeuvres, it was determined that the hazards defined as “hard contact of the model ship with the boarding pier”, “collision between the model ship and the ship boarding the neighboring dolphin” and “squeezing and damaging of the tugs” could occur.
- In 6 beaufort, the risk level of the manoeuvre was calculated as “very high risk”. In these manoeuvres, “hard contact of the model ship with the boarding pier”, “collision between the model ship and the ship boarding the neighboring dolphin” and “squeezing and damaging of the tugs” were identified as the hazards that may be encountered.
- When there is a ship at the neighboring dolphin and the wind blows from W; it was remarked that in 1, 2 and 3 beaufort manoeuvres can be done. But in 3 beaufort, it was remarked that an additional tug should be stationed forward as a stand by as a precaution. 4 beaufort and over wind were evaluated as unsuitable for manoeuvres due to the basin width affecting the manoeuvre negatively and the presence of various hazards.

When all scenarios were examined;

It was understood that the direction of the wind is an important factor with the force of the wind. Types of hazards vary with the direction of the wind. It was seen that generally, under winds blowing from NE, the hazard “hard contact of the model ship with the boarding pier” was encountered. Under winds blowing from W however, if there is no ship present at the neighboring pier, it was seen that the hazard “hard contact of the model ship with the neighboring dolphin” was encountered. If there is a ship present at the neighboring dolphin, especially the hazards “collision between the model ship and ship at the coming alongside the neighboring dolphin” and “squeezing of the tugs and be damaged” were encountered. Additionally, it was determined that as the force of the wind increases, the types of hazards that may be encountered also increases. It is understood that if a ship is present at the neighboring dolphin, the manoeuvring space narrows quite a lot and this situation increases the risk level of the manoeuvre. It was seen that the narrowing manoeuvring space especially lowers the efficiency of the tugs. It was also determined that as the wind force increases, the tugs may be damaged.

The risk scores determined with the Fine-Kinney method were then calculated with the Fuzzy Fine-Kinney method. These scores are compared in Table 7.7. When the comparisons are analysed, it was observed that the risk levels do not change between the methods. But when the risk scores of the scenarios are analysed, it is seen that scores calculated with the Fuzzy Fine-Kinney method are higher than those calculated with the Fine-Kinney method. It is seen that only for scenarios 19, 20, and 25, the scores calculated with the Fuzzy Fine-Kinney method are lower than those calculated with the Fine-Kinney method. It is thought that this situation is affected by the fuzzy values defined to the risk levels. For example; due to the fuzzy values assigned to the “Very High Risk” level being (300, 650, 1000), the highest assigned risk score is 650.

The results acquired from both methods were compared by the experts. The experts have stated that both methods give consistent results, but the results of the Fuzzy Fine-Kinney method are more precise and consistent. Additionally, the experts have advised similar studies to be conducted with different scenarios in order to expand the study.

Table 7.6. Risk score results of Fine-Kinney Method

Scenario	Wind Direction	Wind Force	Beaufort Scale	Berthed Ship	P	F	C	Risk Score	Fine-Kinney Risk Level	Defined Hazard Type Codes
1	0	0	0	0	0,2	0,5	1	0,1	Risk (Perhaps acceptable)	
2	NE	3	1	0	0,2	1	1	0,2	Risk (Perhaps acceptable)	
3	NE	7	2	0	0,2	6	1	1,2	Risk (Perhaps acceptable)	
4	NE	10	3	0	0,5	10	3	15	Risk (Perhaps acceptable)	
5	NE	16	4	0	1	10	3	30	Possible risk (Attention indicated)	
6	NE	21	5	0	3	3	7	63	Possible risk (Attention indicated)	
7	NE	27	6	0	10	2	15	300	High risk (Immediate correction required)	1
8	W	3	1	0	0,2	0,5	1	0,1	Risk (Perhaps acceptable)	
9	W	7	2	0	0,2	3	1	0,6	Risk (Perhaps acceptable)	
10	W	10	3	0	0,2	3	3	1,8	Risk (Perhaps acceptable)	
11	W	16	4	0	3	2	3	18	Risk (Perhaps acceptable)	
12	W	21	5	0	6	2	7	84	Substantial risk (Correction needed)	2
13	W	27	6	0	10	0,5	40	200	High risk (Immediate correction required)	1,2
14	0	0	0	1	0,2	0,5	1	0,1	Risk (Perhaps acceptable)	
15	NE	3	1	1	0,5	0,5	3	0,75	Risk (Perhaps acceptable)	
16	NE	7	2	1	3	3	3	27	Possible risk (Attention indicated)	
17	NE	10	3	1	3	6	3	54	Possible risk (Attention indicated)	
18	NE	16	4	1	3	6	15	270	High risk (Immediate correction required)	1,4
19	NE	21	5	1	10	2	40	800	Very high risk (Consider discontinuing opr.)	1,3,4
20	NE	27	6	1	10	1	100	1000	Very high risk (Consider discontinuing opr.)	1,3,4
21	W	3	1	1	1	0,5	3	1,5	Risk (Perhaps acceptable)	
22	W	7	2	1	1	2	3	6	Risk (Perhaps acceptable)	
23	W	10	3	1	6	3	3	54	Possible risk (Attention indicated)	
24	W	16	4	1	10	1	15	150	Substantial risk (Correction needed)	3,4
25	W	21	5	1	10	1	40	400	High risk (Immediate correction required)	1,3,4
26	W	27	6	1	10	0,5	100	500	Very high risk (Consider discontinuing opr.)	1,3,4

Table 7.7. Comparision of Fine-Kinney Method and Fuzzy Fine-Kinney Method risk scores

Scenario	Wind Direction	Wind Force	Beaufort Scale	Berthed Ship	Fine-Kinney Risk Score	Fuzzy Fine-Kinney Risk Score	Fine-Kinney Risk Level	Fuzzy Fine-Kinney Risk Level
1	0	0	0	0	0,1	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
2	NE	3	1	0	0,2	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
3	NE	7	2	0	1,2	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
4	NE	10	3	0	15,0	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
5	NE	16	4	0	30,0	63,6	Possible risk (Attention indicated)	Possible risk (Attention indicated)
6	NE	21	5	0	63,0	63,6	Possible risk (Attention indicated)	Possible risk (Attention indicated)
7	NE	27	6	0	300,0	362,0	High risk (Immediate correction required)	High risk (Immediate correction required)
8	W	3	1	0	0,1	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
9	W	7	2	0	0,6	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
10	W	10	3	0	1,8	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
11	W	16	4	0	18,0	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
12	W	21	5	0	84,0	160,0	Substantial risk (Correction needed)	Substantial risk (Correction needed)
13	W	27	6	0	200,0	362,0	High risk (Immediate correction required)	High risk (Immediate correction required)
14	0	0	0	1	0,1	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
15	NE	3	1	1	0,8	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
16	NE	7	2	1	27,0	63,6	Possible risk (Attention indicated)	Possible risk (Attention indicated)
17	NE	10	3	1	54,0	63,6	Possible risk (Attention indicated)	Possible risk (Attention indicated)
18	NE	16	4	1	270,0	362,0	High risk (Immediate correction required)	High risk (Immediate correction required)
19	NE	21	5	1	800,0	650,0	Very high risk (Consider discontinuing opr.)	Very high risk (Consider discontinuing opr.)
20	NE	27	6	1	1000,0	650,0	Very high risk (Consider discontinuing opr.)	Very high risk (Consider discontinuing opr.)
21	W	3	1	1	1,5	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
22	W	7	2	1	6,0	18,8	Risk (Perhaps acceptable)	Risk (Perhaps acceptable)
23	W	10	3	1	54,0	63,6	Possible risk (Attention indicated)	Possible risk (Attention indicated)
24	W	16	4	1	150,0	160,0	Substantial risk (Correction needed)	Substantial risk (Correction needed)
25	W	21	5	1	400,0	362,0	High risk (Immediate correction required)	High risk (Immediate correction required)
26	W	27	6	1	500,0	650,0	Very high risk (Consider discontinuing opr.)	Very high risk (Consider discontinuing opr.)

8. A MODEL ON RISK ANALYSIS METHODS IN SHIP HANDLING DURING PORT MANOEUVRES

In the previous chapters, the studies for determining which ships are suitable for manoeuvring in a port and under which environmental conditions ship can manoeuvre were described. While determining these steps, the communique published by the ministry (Official Gazette, 2009a) was taken into consideration. In this chapter, the studies were presented as a model for use in modeling reports. The model created consists of six steps. These steps are explained below.

1. Application for Modeling Report: The process related to the preparation of the modeling report begins with the application of the investor who wants to carry out the port project to the authorized institution.

2. Modeling of Port Area: Firstly, the port area where the manoeuvres will be performed must be modeled. The software of the simulation system is used to model the port area. With this software, it is ensured that the creation of the port area in three dimensions, the adjustment of water depth, the creation of navigational aids, the addition of port equipment to the area, the creation of various objects on water and land areas and the detection of the created area by ECDIS, RADAR and other electronic devices. While modeling the port area, different documents and resources such as layout plans, bathymetry charts, photographs of the port area and satellite images are utilized. By loading the prepared port model to the simulation system, the modeling process of the port area is completed.

3. Creation of Scenarios: After modeling the port, details of the scenarios to be applied are determined. These details are explained below.

<u>Creation of Environmental Conditions:</u> While creating scenarios, environmental conditions of the manoeuvred area should be taken into consideration. The factors affecting the manoeuvre such as wind, visibility condition, wave, current, tide, day/night vision of the

region should be considered. Depending on the characteristics of the simulation system used, these environmental features can be further detailed. In order to obtain data on these factors, technical support should be taken from authorized institutions such as the general directorate of meteorology, port authority, port operators, the office of hydrography and oceanography.

Determination of Model Ship: Details such as the type, size, and technical specifications of the ships to be used in maneuvres are determined by considering the port characteristics.

Determination of Model Tugs: The tugs to be used during the manoeuvre must be determined by taking into account the Ports Regulation (Official Gazette, 2012).

Determination of Experts: It is important that the designated experts have maritime experience in terms of manoeuvring practices and application of risk analysis. Experts that continue their careers in different fields in the maritime industry contribute to making the correct evaluations. A focus group is created by the experts involved in the study. With this group, details of the scenarios to be implemented are determined and risk analysis methods are applied.

Determination of Details of Manoeuvre Scenarios: Scenarios for the manoeuvres to be implemented are determined by taking the opinions of the experts into account. While creating these scenarios, details such as the traffic situation of the port area, the details of the manoeuvre to be made by the ship, and the number of scenarios to be realized should be determined.

4. Application of Scenarios: The determined manoeuvring scenarios are carried out by experts. After each scenario applied, the evaluation survey prepared is filled out by the experts performing the manoeuvre. These evaluation surveys are used in the risk analysis study. The records and data of the scenarios must be recorded for use in the modeling report to be prepared.

5. Application of Risk Analysis Methods: After the scenarios are completed, the risk analysis methods are applied by using the data obtained from the evaluation survey. In the study, Fine-Kinney and Fuzzy Fine-Kinney methods are applied as the risk analysis methods.

6. Preparation of Modeling Report: The modeling report detailed in the communique published by the Turkish Ministry of Transport and Infrastructure (Official Gazette, 2009a) is prepared to take the results obtained from the study into account. The process is completed by delivering the prepared modeling report to the investor.

Model created for the evaluation of a port in terms of ship manoeuvres is shown in Table 8.1. The modeling report is completed by applying this six steps specified in the model.

Table 8.1. Model for the evaluation of a port in terms of ship manoeuvres

Step 1.	**Application for Modeling Report**
» Application of investor to the authorized-institution for modeling report.	

▼

Step 2.	**Modeling of Port Area**
» Creation of the port area in three dimension by utilizing layout plan.	
» Adjustment of water depth by using bathymetry chart.	
» Creation of navigational aids.	
» Addition of port equipment to the area.	
» Creation of various objects on water and land areas.	

▼

Step 3.	**Creation of Scenarios**
» Creation of Environmental Conditions: Determination of the factors affecting the maneuver such as wind, visibility condition, wave, current, tide, day/night vision of the region, etc.	
» Determination of Model Ship	
» Determination of Model Tugs	
» Determination of Experts	
» Determination of Details of Manoeuvre Scenarios	

▼

Step 4.	**Application of Scenarios**
» Performing of the created manoeuvring scenarios by experts.	
» Filling the evaluation surveys by experts.	

▼

Step 5.	**Application of Risk Analysis Methods**
» Application of Fine-Kinney Method	
» Application of Fuzzy Fine-Kinney Method	

▼

Step 6.	**Preparation of Modeling Report**
» Preparation of the modeling report considering the results obtained from the study.	
» Delivery of the prepared modeling report to the investor	

9. CONCLUSION

Manoeuvres performed in the port area present risks for ships and environmental safety. If precautions are not taken to prevent these risks, marine accidents become inevitable. This situation can lead to human deaths and injuries, property losses, even environmental disasters.

In order to eliminate these risks, the Ministry of Transport and Infrastructure requests a modeling report from the investor, where the port or port structures under the project stage are evaluated in terms of ship manoeuvres. The project investor applies to the authorized institution and ensures the preparation of this report. With this modeling report, which ships are suitable for manoeuvring in a port and under which environmental conditions ship can manoeuvre is determined. Moreover, the Ministry wants the manoeuvres in the port area to be evaluated by using a risk analysis method in the modeling report prepared.

In this study, risk analysis studies on the ship handling manoeuvres in port area were examined. In the literature review, with the "ES Model" as the leading model, "PARK Model", "IWRAP Model" and "Risk Matrix Method" were seen as the most used methods. When considering the modeling reports prepared by the institutions in our country, it was found that the ES Model and Risk Matrix Method are generally used as risk analysis methods. Consequently, It has been determined that the risk analysis methods used in the studies are insufficient for the evaluation of the port manoeuvres. In this study, a model to be used in modeling reports was created to evaluate port manoeuvres. With this model, how to prepare a modeling report was explained step by step. Also, by using new risk analysis methods in the model, a more accurate assessment of port manoeuvres in terms of risk analysis has been provided.

In the study, two different risk analysis methods, which have not been used in this field before, were used in order to be used in modeling reports. These methods are Fine-

Kinney and Fuzzy Fine-Kinney methods. The results of these two risk analysis methods applied in the study were compared. As a result of the evaluations made with the experts, it was determined that when the risk levels of both methods were compared, they gave similar and consistent results. However, it has been evaluated by experts that the risk score calculations of the Fuzzy Fine-Kinney are generally higher than the Fine-Kinney and give more precise results. Therefore, the application of the Fuzzy Fine-Kinney method was recommended by experts in the studies.

During the scenario implementations, it has been understood that simulation systems make a significant contribution to the risk analysis studies conducted on the evaluation of ship manoeuvres. In addition, it has been observed that the experts participating in the simulation studies have an important place in performing an accurate risk analysis. Finally, it was understood that a consistent risk analysis study to be carried out with an accurate risk analysis method applied.

As a result of this study, a risk analysis model has been created for institutions to benefit in their modeling reports. At the same time, it was contributed to the literature review by using two different risk analysis methods in the study, which have not been used in this field before.

In further research, the model created in the study is considered to be applied in various port projects. Additionally, it is planned to identify the risk analysis method that gives the most consistent results by comparing the risk analysis methods used in the study and the different risk analysis methods used before.

REFERENCES

American Bureau of Shipping. (2000). Guidance Notes on Risk Assessment: Applications for the Marine and Offshore Oil and Gas Industries. New York: American Bureau of Shipping.

Baykal, R. ve Dikili, A. C. (2002). Gemilerin Direnci ve Makine Gücü. *İstanbul: İTÜ Yayınları*.

Behrooz, F., Mariun, N., Marhaban, M. H., Radzi, M., Amran, M., & Ramli, A. R. (2018). Review of Control Techniques for HVAC Systems: Nonlinearity Approaches Based on Fuzzy Cognitive Maps. *Energies*, 11(3), 495.

Bekdemir, E. (2019). Bina İnşaatında Fine-Kinney Ve 5x5 Matris Risk Analizi Yöntemlerinin Uygulanması (Doctoral dissertation, İstanbul Aydın Üniversitesi Fen Bilimleri Ensitütüsü).

Board, M., & National Research Council. (1992). Ship handling simulation: Application to waterway design. *National Academies Press*.

Board, M. (1996). Simulated Voyages: Using Simulation Technology to Train and License Mariners. *National Academies Press*.

Boran, S., Yılmaz, D., Ürük, Z. F., & Gökler, S. H. (2018). Evaluation of Spatial Risks of Nursing Homes by Fuzzy Risk Analysis Method. *The International Symposium for Production Research* (pp. 800-810). Springer, Cham.

Cotter, C. H. (1963). The Apprentice and His Ship. London : The Maritime Press Limited.

Çokluk, Ö., Yılmaz, K., & Oğuz, E. (2011). Nitel Bir Görüşme Yöntemi: Odak Grup Görüşmesi. *Kuramsal Eğitim Bilim Dergisi*, 4(1), 95-107.

Eke, A. B. (2010). Römorkör İşletmeciliği Uygulama Yöntemlerine Göre Çekme Kuvveti Hesaplamaları (Doctoral dissertation, Fen Bilimleri Enstitüsü).

Elmontsri, M. (2013). Review of the Strengths and Weaknesses of Risk Matrices. *Journal of Risk Analysis and Crisis Response*, 4(1), 49-57.

Erdebilli, B., Gür, L. (2020). Bulanık Fine-Kinney Yöntemiyle Risk Değerlendirmesi Uygulaması. *Journal of Industrial Engineering* (Turkish Chamber of Mechanical Engineers), 31(1).

Falah, Z. (2018). Types of Membership Function. Retrieved January 29, 2020, from www.uobabylon.edu.iq/eprints/pubdoc_11_6921_1712.docx

Fine, W. T. 1971. Mathematical evaluations for controlling hazards (No. NOLTR-71-31).Naval Ordnance Lab. Whıte OAK MD.

Ghosh, S. (2019). Understanding Different Types of Manoeuvres of a Vessel. Retrieved August 26, 2019, from https://www.marineinsight.com/naval-architecture/different-types-of-manoeuvres-of-a-vessel/

Gucma, L. (2004). General Models of Ship Risk During Port Manoeuvres. *WIT Transactions on Ecology and the Environment*, 77.

Gug, S. G., Fukuda, G., Cho, A. R., & Park, H. R. (2014). Collision Risk Analysis in Busan Harbour. *2013 Joint Conference KINPR Proceedings* (Republic of Korea Naval Academy pp.169-171).

Hu, H., Chen, X., & Sun, Z. (2017). Effect of Water Flows on Ship Traffic in Narrow Water Channels Based on Cellular Automata. *Polish Maritime Research*, 24(S3), 130–135. https://doi.org/10.1515/pomr-2017-0115

IALA. (2009). Meteorological Visibility. Retrieved November 10, 2019, from https://www.ialaaism.org/wiki/dictionary/index.php/Meteorological_Visibility

IALA. (2010). Navguide 2010: *Aids to Navigation Manual* (6th ed.). Saint-Germain en Laye: IALA.

ICS. (2016). Bridge Procedure Guide (5th Ed.). London / U.K. Marisec Publications.

IMO. (1968). Resolution A.159(ES. IV): Recommendation on Pilotage. London: IMO.

IMO. (1972). Convention on the International Regulations for Preventing Collisions at Sea (COLREGs).

IMO. (1974a). SOLAS Conv. Chp.5 Safety of Navigation. London: IMO.

IMO. (1974b). SOLAS Conv. Chp.5 Reg.13: Establishment and Operation of Aids to Navigation. London: IMO

IMO. (1974c). SOLAS Conv. Chp.5 Reg. 12: Vessel Traffic Services. London: IMO

IMO. (1974d). SOLAS Conv. Chp.5 Reg. 10: Ships' Routeing. London: IMO

IMO. (1987). Resolution A.601(15): Provision and Display of Manoeuvring Information On Board Ships. London: IMO.

IMO. (2002). Resolution MSC. 137(76): Standards for Ship Manoeuvrability. London: IMO

IMO. (2003). Resolution A.960(23): Recommendations on Training and Certification and on Operational Procedures for Maritime Pilots Other Than Deep-Sea Pilots. London: IMO.

IMO. (2011). Resolution A.1045(27): Pilot Transfer Arrangements. London: IMO

IMO. (2012). MSC.1/Circ.1428: Pilot Transfer Arrangements. London: IMO.

IMO. (2013). Resolution MSC-MEPC.2/Circ.12/Rev.2 : Revised Guidelines for Formal Safety Assessment (FSA) for Use in the IMO Rule-Making Process. London : IMO

IMO. (n.d.). Vessel Traffic Services. Retrieved July 15, 2019, from http://www.imo.org/en/OurWork/Safety/Navigation/Pages/VesselTrafficServices.aspx

Inoue, K. (2000). Evaluation Method of Ship Handling Difficulty for Navigation in Restricted and Congested Waterways. *The Journal of Navigation*, 53(1), 167-180.

Inoue, T., Kenjo, H., Hayashi, Y., & Murai, K. (2011). Evaluation of Difficulties and Risks of Ship Handling in Case of Entering Port. *6th International Conference on System of Systems Engineering* (pp. 77-82). IEEE.

Isikli, S. (2008). Bulanık Mantık Ve Bulanık Teknolojiler. Ankara Üniversitesi, DTCF, Felsefe Bölümü, Doktora Öğrencisi Tezi, 1-19.

ISO. (2019). ISO 14971: Medical devices—Application of Risk Management to Medical Devices.

Kaftan, İ., Balkan, E., & Şalk, M. (2013). Bulanık Mantık (Fuzzy Logıc) ve Jeofizikte Kullanım Alanları: Sismoloji Örneği. *DEÜ Mühendislik Fakültesi Mühendislik Bilimleri Dergisi*, 15(2), 15-29.

Kan, E., & Kişi, H. (2016). Ergonomic Analysis of Navigation Bridge Design: A Qualitative Study on User Perception. *Journal of ETA Maritime Science*, 4(2), 113-133.

Kaya, H., & Askerbeyli, İ. D. (2018). Akciğer Hastalıkları Teşhisinde Sınıflandırma ve Bulanık Mantık Yöntemlerinin Uygulanması. (Doctoral dissertation, Ankara Üniversitesi Fen Bilimleri Enstitüsü).

Khaled, M. E., & Kawamura, Y. (2015, July). Collision Risk Analysis of Chittagong Port in Bangladesh by Using Collision Frequency Calculation Models with Modified BBN Model. *Twenty-fifth International Ocean and Polar Engineering Conference. International Society of Offshore and Polar Engineers*.

Kim, D. W., Park, J. S., & Park, Y. S. (2011). Comparison Analysis between the IWRAP and the ES Model in Ulsan Waterway. *Journal of Navigation and Port Research International Edition*, 35(4), 281-287.

Kinney, G. F., & Wiruth, A. D. (1976). Practical risk analysis for safety management (No. NWC-TP-5865). Naval Weapons Center China Lake Ca.

Mathworks. (2020). Fuzzy Logic Toolbox : User's Guide (R2020). Retrieved February 16, 2020, from https://www.mathworks.com/products/fuzzy-logic.html

Marcjan, K., & Gucma, L. (2018). Determination of the Risk of Location the Quay for Large Steel Components Handling in Vicinity of the Fairway Using the Fast-Time Simulation Method. *Annual of Navigation*, 25(1), 93-108.

Mikail, R. (2007). Tuzlu Toprakların Islahı İçin Bir Bulanık Uzman Sistem Tasarımı (Doctoral Dissertation, Selçuk Üniversitesi Fen Bilimleri Enstitüsü).

Ministry of National Education. (2011). Gemi Yapımı: Gemi Balast Tesisatı. Retrieved November 2, 2019, from http://www.megep.meb.gov.tr/mte_program_modul/moduller_pdf/Gemi%20Balast%20Tesisat%C4%B1.pdf

Ministry of National Education. (2013). Gemi Yapımı: Gemi Pervane Donanımı. Retrieved July 5, 2019, from http://www.megep.meb.gov.tr/mte_program_modul/moduller_pdf/Gemi%20Pervane%20Donan%C4%B1m%C4%B1.pdf

Misra, K. B. (2008). Risk Analysis and Management: An Introduction. *Handbook of Performability Engineering* (pp. 667-681). Springer, London.

Mousavi, M., Ghazi, I., & Omaraee, B. (2016). Risk assessment in the maritime industry. *Engineering, Technology & Applied Science Research*, 7(1), 1377-1381.

Mousavi, M., & Jafari, M. (2017). Marine Accidents İnvestigation Methods Based on the Role of Human Factors in Accidents. *International Journal of Scientific Study*, 5(6), 264.

Nas, S. (2008). Enhancement of Safety Culture in Harbour Pilotage and Towage Organizations. *International Maritime Lecturers Association 16th Conference on MET* 14th-17th October 2008. Izmir /Turkey.

Nas, S , Zorba, Y . (2011). İzmir Alsancak Limanı Gemi Manevraları Risk Değerlendirmesi . *Dokuz Eylül Üniversitesi Denizcilik Fakültesi Dergisi*, 3(1), 35-47. Retrieved from https://dergipark.org.tr/tr/pub/deudfd/issue/4584/62757

NOAA. (2018). Why does the Ocean Have Waves? Retrieved September 15, 2019, from https://oceanservice.noaa.gov/facts/wavesinocean.html

Official Gazette. (2009a). Kıyı Tesisi Yapım Taleplerinin Değerlendirilmesine Dair Tebliğ (Tebliğ No: 2009/2). Resmî Gazete Tarihi: 15.03.2009 Resmî Gazete Sayısı: 27170. Retrieved June 4, 2020, from https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=12930&MevzuatTur=9&MevzuatTertip=5

Official Gazette. (2009b). Seyir Yardımcıları Yönetmeliği. Resmî Gazete Tarihi: 25.05.2009 Resmî Gazete Sayısı: 27238. Retrieved September 12, 2019, from https://www.resmigazete.gov.tr/eskiler/2009/05/20090525-3.htm

Official Gazette. (2012). Limanlar Yönetmeliği. Resmî Gazete Tarihi: 31.10.2012 Resmî Gazete Sayısı: 28453. Retrieved September 24, 2019, from https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=16726&MevzuatTur=7&MevzuatTertip=5

Official Gazette. (2020). Kılavuzluk ve Römorkörcülük Hizmetleri Hakkında Yönetmelik. Resmî Gazete Tarihi: 08.01.2020 Resmî Gazete Sayısı: 31002. Retrieved October 23, 2019, from https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=34175&MevzuatTur=7&MevzuatTertip=5

Okumuş, D., & Barlas, B. (2016). Gemi İnşaatı Sektöründe 5x5 Analiz Matrisi ve Fine-Kinney Yöntemlerinin Uygulamalı Bir Karşılaştırması. *GMO Journal Of Shıp And Marine Technology*, 22(Supp: 204-205), 95-106.

Oral, E. Z., Coşar, Y., Danacı, A., & Esmer, S. (n.d.) Kruvaziyer Limanlarında Yer Seçimi. *8. Kıyı Mühendisliği Sempozyumu*, İstanbul.

Otoi, O. S., Park, Y. S., & Park, J. S. (2016). A Basic Study on Marine Traffic Assessment in Mombasa Approach Channel-I. *Journal of Korean Navigation and Port Research*, 40(5), 257-263.

Oturakçı, M., & Dağsuyu, C. (2017). Risk Değerlendirmesinde Bulanık Fine-Kinney Yöntemi ve Uygulaması. *Karaelmas İş Sağlığı ve Güvenliği Dergisi*, 1(1), 17-25.

Ozbas, B. (2013). Safety Risk Analysis of Maritime Transportation: Review of the Literature. *Transportation Research Record*, 2326(1), 32-38.

Özbek, C., (2017). Bulanık Mantık (Fuzzy Logic). Retrieved December 20, 2019, from https://www.slideshare.net/cihanzbek/bulanik-mantikfuzzy-logic

Ölçücü, H, Ersöz Kaya, İ. (2019). Tehlikeli Atık Bertaraf Tesislerinde Meslek Hastalığı ve Biyolojik Faktörler Açısından Risk Değerlendirmesi. *Avrupa Bilim ve Teknoloji Dergisi* , (17) , 1375-1382. DOI: 10.31590/ejosat.668653.

Özdemir, A., Alaybeyoglu, A., & Balbal, K. F. (2019). Bulanık Mantığın Eğitim Alanındaki Uygulamaları. *Bilim Eğitim Sanat ve Teknoloji Dergisi*, 3(1), 45-50.

Özkan, E. D., & Nas, S. (2016). Sımulatıon Modellıng-assısted Traınıng in the Marıtıme Educatıon: An Example in Deu Marıtıme Faculty. *Proceedıngs Book*, 441.

Park, Y. S., Kim, J. S., & Aydogdu, V. (2013). A Study on the Development the Maritime Safety Assessment Model in Korea Waterway. *Journal of Korean Navigation and Port Reserch*, 37(6), 567-574.

PIANC. (1997). Approach Channels A Guide for Design. Report of Working Group II-30., 95, 14-28. Brussels.

PIANC. (2014). Report No 121: Harbour Approach Channels Design Guidelines.PIANC, Brussels.

Rameesha, T. V., & Krishnankutty, P. (2019). Numerical Study on the Manoeuvring of a Container Ship in Regular Waves. *Ships and Offshore Structures*, 14(2), 141-152.

Ross, T. J. (2010). Fuzzy Logic with Engineering Applications. (3rd ed.). John Wiley & Sons. https://doi.org/10.1002/9781119994374.

Rouse, M. (2020). Risk Analysis. Retrieved April 8, 2020, from https://searchsecurity.techtarget.com/definition/risk-analysis

Şahin, O. A. (2016). İzmit Körfezi Deniz Trafiğinin IWRAP Model Kullanılarak İncelenmesi (Doctoral dissertation, Fen Bilimleri Enstitüsü).

Senol, Y. E., & Sahin, B. (2016). A Novel Real-Time Continuous Fuzzy Fault Tree Analysis (RC-FFTA) Model for Dynamic Environment. *Ocean Engineering*, 127, 70-81.

Sukas, Ö. F., Kınacı, Ö. K., & Bal, Ş. (2017). Gemilerin Manevra Performans Tahminleri için Genel Bir Değerlendirme-II. *GMO Journal Of Ship And Marine Technology*, 23, 76-105.

Taha, A. (2016). Coupled Motions in Turning and Sea Trials. Retrieved October 11, 2019, from https://www.slideshare.net/AhmedTaha67/coupled-motions-in-turning-and-sea-trials

Talay, A. A. (2012). Liman Bölgelerindeki Seyir Güvenliğini Geliştirmek İçin Oluşturulan Bir Karar Destek Modelinin Haydarpaşa Liman Bölgesi Uygulaması (Doctoral dissertation, Fen Bilimleri Enstitüsü).

Transas. (2014). NAVI-TRAINER 5000. *Navigational Bridge Manual*,(version 5.35).

Ungureanu, O. (2015). Entering and Departure Maneuvers. Retrieved June 12, 2019, from http://travellingoncontainervessels.com/entering-and-departure-maneuvers-general-info/

URL-1. (n.d.). Marine Accident Investigation Branch reports. Retrieved June 15, 2020, from https://www.gov.uk/maib-reports?keywords=mooring

URL-2. (n.d.). Breadth of the Ship. Retrieved August 12, 2019, from https://www.wartsila.com/encyclopedia/term/breadth-of-the-ship

URL-3. (2017). Measures and Criteria of Manoeuvrability. Retrieved August 8, 2019, from https://shipsnow.com/wiki/measures-and-criteria-of-manoeuvrability/

URL-4. (n.d.). Free Floating Body Motions. Retrieved October 14, 2019, from https://s815.photobucket.com/user/applemung/media/9625jkh03_zpsdepv189r.gif.html

URL-5. (2013). Types of Sailing Ships :Tugboat and Its Uses. Retrieved September 18, 2019, from https://www.brighthubengineering.com/naval-architecture/35004-how-can-a-tugboat-pull-a-large-ship/

URL-6. (n.d.).What is Fuzzy Logic System: Operation, Examples, Advantages & Applications. Retrieved January 10, 2020, from https://www.electricaltechnology.org/2018/02/fuzzy-logic-system.html

URL-7. (n.d.).Fuzzy Membership Functions and its Features. Retrieved January 11, 2020, from https://www.tech-wonders.com/2010/08/membership-functions-and-its-features.html

Usanmaz, D , Köse, E . (2020). Kimyasal Araştırma Laboratuvarı Risk Değerlendirmesi İçin İki Farklı Metodun İstatistiksel Analizi. *International Journal of Engineering Research and Development* , 12 (2) , 337-348 . DOI: 10.29137/umagd.606402.

Usluer, H. B., & Alkan, G. B. (2015). Liman Planlama ve Geliştirmede Deniz Bilimlerinin Önemi. *II. Ulusal Liman Kongresi*, İzmir.

Wynn, T., Howarth, P. A., & Kunze, B. R. (2012). Night-time Lookout Duty: The Role of Ambient Light Levels and Dark Adaptation. *The Journal of Navigation*, 65(4), 589-602.

Yegin, C. (2019). Tekstil Sektöründe Ergonomik Riskleri Esas Alan Sürdürülebilirlik Modeli ve Uygulaması (Master's thesis, Pamukkale Üniversitesi Fen Bilimleri Enstitüsü).

Yurtören, C., Duru, O., & Satir, T. (2008). The Environmental Effects of Projected Container Terminal to the Safely Manoeuvring. *TransNav, International Journal on Marine Navigation and Safety of Sea Transportation*, 2(1).

Zaloğlu, D. I. (2019). İş Sağlığı ve Güvenliği Kapsamında Fosil Lokalitisinde Fine-Kinney Metodu ile Risk Değerlendirilmesi (Master's thesis, Başkent Üniversitesi Fen Bilimleri Enstitüsü).

Zaman, I. G., Toma, A., & Pascu, L. G. (2015). The Influence of Squat on The Maneuverability Of" Musca" Classminesweeper. *"Mircea cel Batran" Naval Academy Scientific Bulletin*, 19(2), 128-134.

Zorba, Y. (2007). Ship Handling. Retrieved June 25, 2019, from http://yusufzorba.com/images/GemiManevras%C4%B1_v0207.pdf

Zoroğlu, C. (2015). Bulanık Uzman Sistem Kullanarak Tıkayıcı Uyku Apne Hipopne Sendromunun Ciddiyet Seviyesinin Tahmini (Doctoral dissertation, Fen Bilimleri Enstitüsü).

APPENDIX-A

EVALUATION SURVEY

This risk analysis form is prepared for use in my dissertation which is entitled "A Model on Risk Analysis Methods in Ship Handling During Port Manoeuvres"

With this study, it will be determined under which conditions the pier is suitable for ship manoevres. After each manoeuvre you perform in bridge simulators, you are asked to evaluate the manoeuvre performed by considering the environmental conditions too.

The fine-Kinney method was used in the study as a risk analysis method. The risk score of the pier will be determined by specifying the probability, frequency, and consequence parameters in the Fine-Kinney method. Below are the parameters of the Fine-Kinney method and the values of these parameters are given in the table.

P Value	Probability (P)
10	Might well be expected
6	Quite possible
3	Unusual but possible
1	Only remotely possible
0.5	Conceivable but very unlikely
0.2	Practically impossible
0.1	Virtually impossible

F Value	Frequency (F)
10	Continuous
6	Frequently (daily)
3	Occasional (weekly)
2	Unusual (monthly)
1	Rare (a few per year)
0.5	Very rare (yearly)

C Value	Consequences(C)
100	Catastrophic (many fatalities, or > $\$10^7$ damage)
40	Disaster (few fatality, or > $\$10^6$ damage)
15	Very serious (fatality, or > $\$10^5$ damage)
7	Serious (serious injury, or > $\$10^4$ damage)
3	Important (disability, or > $\$10^3$ damage)
1	Noticeable (minor first aid accident, or > $\$10^2$ damage)

Please determine the parameters below by taking into account the manoeuvre you have performed.

Probability (P) Value	Frequency (F) Value	Consequence (C) Value

Scenario No		**Evaluator's Name Surname**	

Thank you for your participation.

Kind regards.

APPENDIX-B

ONE-YEAR DAILY AVERAGE WIND SPEED AND WIND DIRECTION OF THE PORT REGION

T.C.
Tarım ve Orman Bakanlığı
Meteoroloji Genel Müdürlüğü

Station Name : TUZLA AYDINLI LİMAN FENERİ **Station No** 17437

Date : 04/2019 - 03/2020

1-Year Daily Average Wind Speed (m / sec) and Direction

Day	04/2019	05/2019	06/2019	07/2019	08/2019	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020	03/2020
1	NNE 4.0	W 4.5	NE 5.5	NE 4.0	NE 4.9	NE 4.5	NNE 2.7	NE 6.3	N 4.9	N 4.2	W 4.1	NNW 2.4
2	NE 4.6	WSW 3.7	NNE 4.4	NE 5.1	NE 3.6	NE 6.0	NE 4.6	NE 4.7	SSE 3.1	NE 4.9	W 3.2	NNW 2.3
3	NE 5.9	SSW 2.2	W 3.3	NE 4.6	W 3.2	ENE 6.7	W 2.3	NE 2.5	NE 4.5	NNE 4.4	WSW 7.4	N 2.2
4	NE 5.8	W 3.0	WSW 3.7	NE 5.9	NNE 4.4	NE 6.3	SE 3.7	SE 3.2	NE 6.7	W 5.8	SW 3.0	NW 2.2
5	NNE 4.8	SE 3.6	NE 3.9	NE 5.4	NE 5.0	NE 5.9	NNE 5.3	WSW 3.2	NE 4.7	NNE 3.0	S 3.5	WNW 2.9
6	NNE 7.4	W 3.3	N 3.9	ENE 3.6	NE 5.6	NE 6.8	NNE 4.1	SSW 3.4	ENE 3.4	NE 5.7	NW 4.5	SSW 2.6
7	N 3.8	W 6.5	NE 3.3	NE 4.7	NE 6.1	NE 4.4	NE 4.7	ESE 1.5	SSE 2.8	NNE 12.0	N 5.2	SE 2.2
8	N 2.6	NNW 4.1	NE 4.4	N 3.4	NE 5.1	NE 5.6	NE 5.6	ENE 2.0	SE 3.4	NNE 5.8	NNW 4.6	N 2.6
9	NW 4.4	S 2.8	NE 5.8	NNE 4.0	NE 5.5	NE 4.1	NE 3.8	N 1.5	ENE 2.2	NE 3.6	W 3.8	NNE 5.5
10	NW 1.7	ESE 2.2	NE 6.2	NE 5.4	NE 5.5	NE 5.2	NNW 3.2	N 1.6	ENE 3.0	ENE 2.4	SSE 4.0	WSW 3.4
11	S 2.4	WSW 2.2	NNE 4.5	NNE 4.3	NE 6.4	NE 7.0	NNE 3.1	NE 1.7	NE 3.7	N 2.1	SW 3.9	W 1.6
12	SSE 3.1	N 2.9	W 2.6	NNE 2.7	ENE 7.3	NE 5.9	NE 6.1	NNE 3.4	NE 4.0	NE 3.5	SSW 2.4	NNE 4.1
13	NW 3.2	NE 7.4	WNW 3.1	NNE 2.9	NE 6.3	NE 6.4	NE 4.8	NE 2.3	SE 1.6	NE 4.9	SE 2.2	NE 5.6
14	N 4.0	NE 5.8	W 3.9	NNW 3.3	NNW 3.8	NE 5.7	NE 4.5	SE 1.8	E 3.3	NNE 3.2	ESE 3.0	NNE 4.9
15	NNE 5.0	NE 4.1	NE 3.4	WNW 4.9	NE 4.1	NE 5.7	NE 4.6	NE 2.4	NNE 2.4	NE 4.5	NE 4.1	NE 7.8
16	NE 6.4	NE 4.9	NNE 4.0	NE 3.7	NE 5.1	NNE 4.4	NE 3.6	NE 4.1	N 1.7	NE 5.4	NE 5.3	NE 8.0
17	N 2.8	NNE 6.6	NE 4.0	NE 6.4	NE 4.6	NW 2.3	NNE 3.8	NNE 5.6	ENE 1.4	NE 6.4	NE 4.4	NE 4.4
18	NNE 4.1	W 2.7	NNE 4.8	NE 3.7	ENE 2.5	NNW 2.0	NNE 3.1	NNE 2.7	S 2.8	NE 6.5	NW 2.7	NE 5.7
19	NNE 5.1	W 2.2	SE 3.4	NE 6.5	NE 4.0	NE 6.5	NNE 3.5	N 2.6	NE 1.7	NE 4.4	ENE 3.5	NE 5.0
20	N 4.9	WNW 2.0	S 1.5	NE 7.2	NE 4.6	NNE 4.6	NE 4.2	NNE 4.5	SE 2.0	N 5.7	NE 4.3	E 2.9
21	N 4.3	W 2.3	SSW 1.8	NE 6.3	W 2.4	NE 4.8	NE 5.1	NE 4.6	SSW 3.6	N 4.2	NNE 5.8	NNW 2.3
22	NNE 3.8	WSW 2.9	WNW 2.4	NE 5.8	WNW 3.3	NE 5.1	NE 5.7	ENE 5.4	SSW 4.6	WSW 3.0	NNE 4.9	N 4.5
23	NE 4.6	SE 2.4	NE 3.0	NE 5.5	NNE 3.6	NNW 2.9	NE 5.7	NE 4.0	N 4.3	NNW 6.6	NW 3.9	NE 5.0
24	NE 3.6	NNE 5.8	NE 4.0	ENE 4.5	ENE 3.7	N 2.3	NE 4.9	NE 2.9	N 2.8	E 2.5	SW 5.1	NE 7.5
25	N 3.8	WSW 3.9	NE 6.0	NE 3.2	NE 4.4	WNW 3.8	NE 4.6	NE 4.7	N 3.3	SSW 4.1	E 3.2	NE 6.1
26	NNE 5.5	W 2.5	NE 6.5	NE 4.3	ENE 6.1	SSW 2.3	NNE 5.8	S 3.2	N 4.4	SSE 3.0	W 5.6	ENE 6.9
27	NNW 3.9	NE 4.7	NE 6.8	NE 5.8	NE 6.1	WNW 3.6	NE 4.5	NNE 4.2	NE 2.9	SE 2.0	WSW 5.7	NE 4.2
28	WNW 2.2	WNW 3.6	NE 4.4	NNE 4.3	NE 6.9	NE 3.2	NE 3.9	SE 2.9	NNE 3.9	W 2.1	WSW 2.5	WNW 4.7
29	WSW 2.0	W 2.1	NE 6.4	N 4.3	NE 6.9	N 2.7	N 3.3	S 5.5	NE 4.3	S 4.0	NNE 5.1	WSW 7.8
30	WSW 2.7	WSW 2.7	NE 4.2	N 4.5	NE 5.3	NNW 2.4	NNE 3.1	SW 3.1	NE 8.1	N 3.5		SW 2.7
31		N 2.9		NNE 4.3	NE 5.9		NNE 3.6		NNE 8.0	SW 3.8		NE 6.6

CURRICULUM VITAE

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EDUCATION

2017 – 2020	Pîrî Reis University, MSc Maritime Transportation & Management Engineering
2009 – 2014	Pîrî Reis University, BSc Maritime Transportation & Management Engineering

ACADEMIC EXPERIENCE

03/2018 – Present	Research Assistant at Pîrî Reis University

PROFESSIONAL EXPERIENCE

07/2018 – 08/2018	Second Officer, Pîrî Reis University
02/2016 – 07/2017	Second Officer, IDC Shipping
10/2014 – 05/2014	Third Officer, MedkonLines