ISSN: 2148-9173 Vol: 8 Issue:4 December 2021

International Journal of Environment and Geoinformatics (IJEGEO) is an international, multidisciplinary, peer reviewed, open access journal.

Evaluation of Ship Manoeuvres in Port by Using Fuzzy Fine Kinney Method

Ferdi ÇINAR, Murat Selçuk SOLMAZ, Emre ÇAKMAK

Abstracting and Indexing: TR DIZIN, DOAJ, Index Copernicus, OAJI, Scientific Indexing Services, International Scientific Indexing, Journal Factor, Google Scholar, Ulrich's Periodicals Directory, WorldCat, DRJI, ResearchBib, SOBIAD

International Journal of Environment and Geoinformatics 8(4):537-548 (2021)

Research Article

Evaluation of Ship Manoeuvres in Port by Using Fuzzy Fine Kinney Method

Ferdi Çınar[1], * , **Murat Selçuk Solmaz**[2] , **Emre Çakmak**[2]

[1] Department of Marine Engineering, Maritime Faculty, Pîrî Reis University, İstanbul / Turkey
[2] Department of Industrial Engineering, Faculty of Engineering, Pîrî Reis University, İstanbul / Turkey

* Corresponding author: Ferdi Çınar
E-mail: fcinar@pirireis.edu.tr

Received 18.05.2021
Accepted 22.09.2021

How to cite: Çınar et al. (2021). Evaluation of Ship Manoeuvres in Port by Using Fuzzy Fine Kinney Method. *International Journal of Environment and Geoinformatics (IJEGEO)*,8(4): 537-548, doi. 10.30897/ijegeo.938973

Abstract

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 analysed. The purpose of this study is to create a risk analysis model to be used in the ship manoeuvres and to determine which ships are suitable for manoeuvring in a port and under which environmental conditions ship can manoeuvre. Fuzzy Fine-Kinney method was chosen as the main risk analysis methodology for this study, which has 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 experts in the maritime domain. According to results obtained from the risk analysis method applied in the study, it was determined which ships with which characteristics are suitable for manoeuvring and under which environmental conditions.

Keywords: Ship Manoeuvres, Risk Analysis, Fuzzy Fine-Kinney, Ship Management, Port.

Introduction

A ship can face many dangers during 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 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 the human factor (Permanent International Association of Navigation Congress [PIANC], 2014). 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 suitability for ship manoeuvres (Zghyer and Ostnes, 2019). 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. The high emission values of ship manoeuvres put pressure on the environmental conditions in the port area. It is expected that the manoeuvres in the port area, which is located within the settlement, will be reduced in terms of both quality and quantity (Bayırhan et al., 2019; Mersin et al., 2019; Ülker et al., 2020).

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 modelling report before the construction of the above mentioned coastal facilities. The modelling report is prepared only by ministry-authorized institutions. With this modelling report, it is determined which ships are suitable for manoeuvring to a coastal facility under various environmental condition. In the modelling 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 modelling 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 identify a proper risk analysis method that can be used in the modelling reports. Fuzzy Fine-Kinney was used as risk analysis methods in the study. In the application part of the study, a pier in a port is situated in the İstanbul area was modelled 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 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 was evaluated using Fuzzy Fine-Kinney risk analysis method and was 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 proper risk analysis method has been created to be used in modelling reports.

Risk Analysis Studies in Maritime Area

The International Maritime Organization (IMO) 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, 2018). 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, 2018).

Risk analysis is the process that defines the potential hazards in any given situation, finds out and analyses the probability of occurrence for the hazards defined and makes sure that the available information is used systematically (ISO, 2018; Rouse, 2020). The purpose of risk analysis is to identify the risk that may arise and to analyse 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.

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, and 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 guidelines for the correct interpretation of maritime risks. 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; Özbaş, 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.

Literature Review on Ship Manoeuvres

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.

When the studies within the literature are considered, the lack of adequate retrospective data is often mentioned. It is also seen that the 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 automatic identification system (AIS) is used as a source in some studies.

When the risk analysis studies on ship manoeuvres around port limits are examined, the "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 to 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. With simulation studies, 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 modelling reports. Yurtören et al. (2008) applied the "ES Model" developed by Inoue to determine the effects of a container port to be established in İzmit Bay on the surrounding port traffic. 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.

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 modelled using "Monte Carlo Simulation". In the study, it was concluded that the "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.

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". 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 analyses were made and the risk preventive precautions to be taken are determined.

Nas and 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. Bridge simulators were used to evaluate and test the situations evaluated by the experts. 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) analysed the hardships of ship handling in Hanshin Port area in Kobe using bridge simulators. 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 analysed 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.

The "Potential Assessment of Risk" (PARK) model was developed in Korea by Park et al. (2013) to create a domestic evaluation model. The model calculates the elements of a ship that may affect marine traffic safety by regression analysis. In the study, 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 harbour, 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. Additionally, an application was made with ship bridge simulation and the PARK Model and the ES Model were compared in the study and it was seen that the PARK Model gave more realistic results.

Gug et al. (2014), in their study, used a method called the "gas molecular collision calculation model". 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 analysed with the study.

In the study conducted by Khaled and Kawamura (2015), collisions in Chittagong Port were evaluated. While "Collision risk" was analysed with the IWRAP Model recommended by IALA, "causation probability" was analysed 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.

Şenol and Şahin (2016) created a dynamic risk assessment model named "Real-Time Continuous Fuzzy Fault Tree Analysis". 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 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. In the study, the frequencies of the risks caused by local traffic in the region were determined by applying three different models.

Yücel and 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. With this study, the root causes of the risks obtained from the ES model have been analysed and these root causes have been evaluated. It is also mentioned that this study may contribute to the use of this method in the modelling reports requested by the Ministry of Transport and Infrastructure in the construction of coastal facilities.

When studies on the risks caused by the use of ships in port manoeuvres are examined, 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.

Materials and Methods

Fuzzy Logic Method

The fuzzy logic theorem was first suggested by the Azerbaijani-American scientist Lotfi A. Zadeh (Zadeh et al., 1996). 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 (Özdemir, 2019). The first commercial use of it was in 1980 for controlling the furnace of a cement factory (Işıklı, 2008).

Fuzzy logic is generally used to model decisions specified verbally, that is 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 cannot get certain results but can draw limits locally. The purpose of fuzzy logic applications is then to get 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 to 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. In the following section fuzzy sets, membership functions of fuzzy sets, and structure of fuzzy systems are mentioned in the order.

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, information on to what extent a member can belong to a set is reached. In Figure 1, a graphical representation of classic and fuzzy sets is shown.

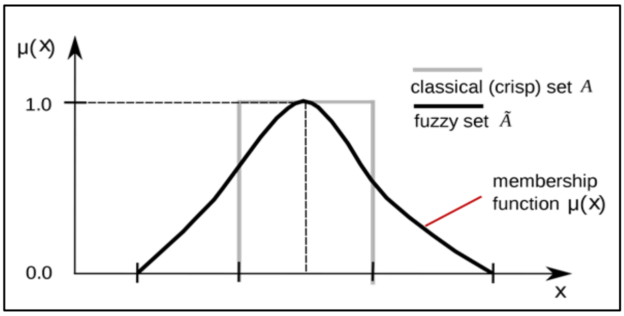

Figure 1. Graphic representation of a fuzzy set with a classic set (URL-1)

In Figure 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. When Figure 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.

Membership Functions of Fuzzy Sets

Functions that equate the members of a fuzzy set to a defined interval of numbers are named "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 below;

$$\mu A(x) = \begin{cases} 1;\ x \in A \\ 0;\ x \notin A \end{cases} \qquad \text{(Eq. 1)}$$

Fuzzy logic membership function is defined as shown in below;

$$\mu A(x) = E\,[0,1] \qquad \text{(Eq. 2)}$$

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

Structure of Fuzzy Systems

Fuzzy sets and systems made up of graded membership systems are defined as fuzzy systems. In Figure 2, a simple fuzzy system structure is shown. Also, processes that take place in a fuzzy system structure are explained below.

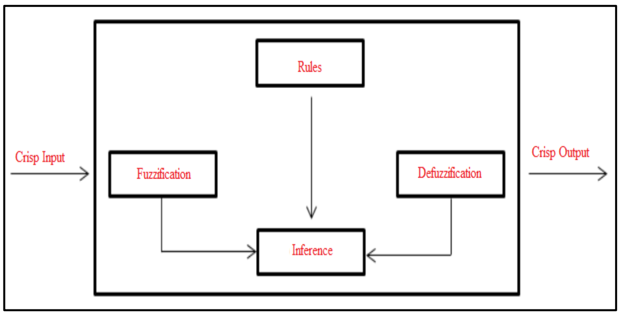

Figure 2. Basic fuzzy system (Zoroğlu, 2015)

Fuzzification: The process of converting numerical variable inputs into verbal statements is called fuzzification. In 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).

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.

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. The Sugeno inference method is generally preferred in control problems. It is used in problems that 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.

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. Max-membership principle, centroid method, weighted average method, mean–max membership, the centre of sums, the centre of the largest area, first of maxima or last of maxima are commonly used defuzzification methods (Kaya and Askerbeyli, 2018).

Fine-Kinney Method

Fine-Kinney 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 and 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 and Wiruth, 1976):

Probability (P) is defined as the possibility of exposure to a dangerous event. Ratings and classifications of probability are presented in Table 1.

Table 1. Value and classifications of probability (Kinney and 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 *Exposure (E)* is the frequency of occurrence of the hazard event (the undesired event which could start the accident sequence). Ratings and classifications of frequency are presented in Table 2.

Table 2. Value and classifications of frequency (Kinney and 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 consequences are presented in Table 3.

Table 3. Value and classifications of consequences (Kinney and 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 levels of risk present in the risk score are divided into 5 categories (in Table 4.). This categorization helps us understand the level of the risk. The Fine-Kinney risk score is calculated as shown below.

$$\text{Risk (R)} = \text{Probability x Freq. x Conseq.} \quad \text{(eq. 3)}$$

Table 4. Risk scores and action plan (Kinney and Wiruth, 1976)

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

Fuzzy Fine-Kinney Method

In the methodology part of the study, the Fuzzy Fine-Kinney method was applied in order to eliminate the uncertainties that occur during the grading of the parameters (Erdebilli and 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 3). In the Fuzzy Inference System, the "Mandani Min Max" method was utilized. "Centroid" was chosen as the defuzzification method.

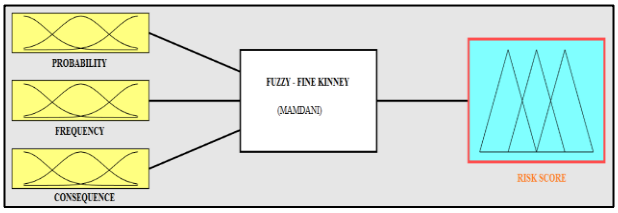

Figure 3. Inputs and output in FIS

The membership function was chosen as the "triangular membership function". This function was chosen due to its ease of use and it is 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 parameters were used. For example, while determining the fuzzy value of "Might well be expected (MWE)" in the first row of Table 5; From the probability parameters in Table 1, the value of 6 for "quite possible", the value of 10 for "might well be expected" and the maximum value for the final fuzzy value is assigned as 10. The same process has been applied for other input parameters as well. The fuzzy values of the probability scale are shown in Table 5.

The fuzzy values of the consequence scale are shown in Table 7. The fuzzy values of the frequency scale are shown in Table 6.

Table 5. 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)

Table 6. 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. 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. The fuzzy values of the risk score scale are given in Table8.

Table 8. 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)

Application of Ship Manoeuvres on Ship Bridge Simulators

In this study, the aim was 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. The studies performed during the simulation process were explained in this section. These processes consisted of six steps and explained below:

1. *Modelling of Port Area:* Firstly, the port area where the manoeuvres will be performed was modelled. The software of the simulation system was used to model the port area. With this software, it was 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 modelling the port area, different documents and resources such as layout plans, bathymetry charts,

photographs of the port area and satellite images were utilized. By loading the prepared port model to the simulation system, the modelling process of the port area was completed. 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 4.

Figure 4. 3D general view of the port

2. *Creation of Scenarios*: After modelling the port, details of the scenarios to be applied were determined. These details were explained below.

   Creation of environmental conditions: While creating scenarios, environmental conditions of the manoeuvred area were taken into consideration. The factors affecting the manoeuvre such as wind, visibility condition, wave, current, tide, day/night vision of the region were 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 was 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 manoeuvres were determined by considering the port characteristics.

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

3. *Determination of Experts:* It is important that the designated experts have maritime experience in terms of manoeuvring practices and the application of risk analysis. Experts that continue their careers in different fields in the maritime industry contribute to making the correct evaluations. 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 centre coordinator at the maritime faculty and one of them is a training coordinator at a maritime firm.

4. *Determination of Details of Manoeuvre Scenarios*: Scenarios for the manoeuvres to be implemented were determined by taking the opinions of the experts into account. 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 (Çokluk et al., 2011). A focus group was created by the experts involved in the study. With this group, details of the scenarios to be implemented were determined. The details of scenarios that were simulated are presented in Table 10. 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 were determined.

With a focus group study, hazards that may occur during the coming alongside the process of the model ship used in the scenarios were determined. The experts, as a result of the focus group study, identified the hazards that may occur in the manoeuvring area. These hazards were categorized into 5 categories. Types of hazards that may be encountered during the process of the model ship boarding a pier are shown in Table 9.

Table 9. 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 5, the regional distribution of the hazard types within the manoeuvring area is shown. When Figure 5 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 neighbouring dolphin, hard contact of the model ship with the neighbouring dolphin was defined as a hazard.
- In region number 3, a 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 the 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 this area determined as shallow water, grounding of the model ship was defined as a hazard.
- *Application of Scenarios*: The determined manoeuvring scenarios were carried out by experts. After each scenario applied, the evaluation survey prepared was filled out by the experts performing the manoeuvre. These evaluation surveys were used in the risk analysis study.
- *Application of Risk Analysis Methods:* After the scenarios were completed, the risk analysis method was applied by using the data obtained from the evaluation survey. In the study, the Fuzzy Fine-Kinney method was applied as the risk analysis method.

Table 10. Details of scenarios applied in simulation

Scenario No.	Wind Direction	Wind Force	Beaufort Scale	Berthed Neighbouring Dolphin	Current Information	Wave Height (meter)	Visibility	Number of Tug Used
1	0	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	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

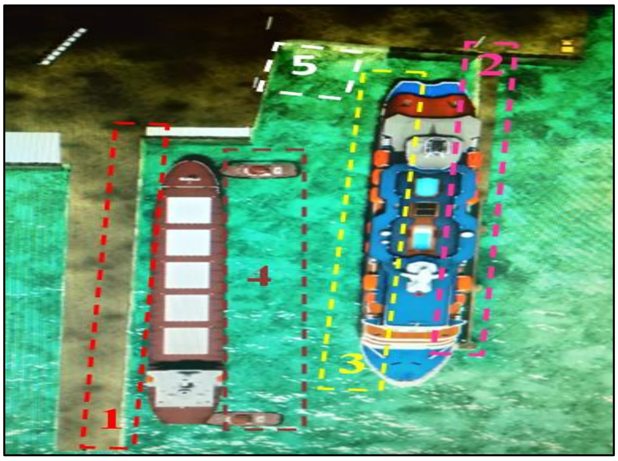

Figure 5. Regional distribution of hazard types that can occur during the model ship is coming alongside to the pier.

Results

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 neighbouring 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 neighbouring dolphin was supplied from the port managers. Lastly, information about the frequency of a ship similar to the chosen model ship mooring to the chosen pier was supplied from the people in charge of the port's operations. With this 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 Fuzzy 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 10 was used and defined hazard types are specified in Table 11.

With the parameters acquired, the Fine-Kinney risk scores of all scenarios were determined. Scenarios applied and probability, frequency, and consequence values of these scenarios were given in Table 11. The risk scores and the risk levels 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.

Table 11. Risk score results of Fuzzy Fine-Kinney Method

Scenario	Wind Direction	Wind Force	Beaufort Scale	Berthed Ship	P	F	C	Risk Score	Fuzzy Fine-Kinney Risk Level	Defined Hazard Type Codes
1	0	0	0	0	0,2	0,5	1	18,8	Risk (Perhaps acceptable)	
2	NE	3	1	0	0,2	1	1	18,8	Risk (Perhaps acceptable)	
3	NE	7	2	0	0,2	6	1	18,8	Risk (Perhaps acceptable)	
4	NE	10	3	0	0,5	10	3	18,8	Risk (Perhaps acceptable)	
5	NE	16	4	0	1	10	3	63,6	Possible risk (Attention indicated)	
6	NE	21	5	0	3	3	7	63,6	Possible risk (Attention indicated)	
7	NE	27	6	0	10	2	15	362,0	High risk (Immediate correction required)	1
8	W	3	1	0	0,2	0,5	1	18,8	Risk (Perhaps acceptable)	
9	W	7	2	0	0,2	3	1	18,8	Risk (Perhaps acceptable)	
10	W	10	3	0	0,2	3	3	18,8	Risk (Perhaps acceptable)	
11	W	16	4	0	3	2	3	18,8	Risk (Perhaps acceptable)	
12	W	21	5	0	6	2	7	160,0	Substantial risk (Correction needed)	2
13	W	27	6	0	10	0,5	40	362,0	High risk (Immediate correction required)	1,2
14	0	0	0	1	0,2	0,5	1	18,8	Risk (Perhaps acceptable)	
15	NE	3	1	1	0,5	0,5	3	18,8	Risk (Perhaps acceptable)	
16	NE	7	2	1	3	3	3	63,6	Possible risk (Attention indicated)	
17	NE	10	3	1	3	6	3	63,6	Possible risk (Attention indicated)	
18	NE	16	4	1	3	6	15	362,0	High risk (Immediate correction required)	1,4
19	NE	21	5	1	10	2	40	650,0	Very high risk (Consider discontinuing opr.)	1,3,4
20	NE	27	6	1	10	1	100	650,0	Very high risk (Consider discontinuing opr.)	1,3,4
21	W	3	1	1	1	0,5	3	18,8	Risk (Perhaps acceptable)	
22	W	7	2	1	1	2	3	18,8	Risk (Perhaps acceptable)	
23	W	10	3	1	6	3	3	63,6	Possible risk (Attention indicated)	
24	W	16	4	1	10	1	15	160,0	Substantial risk (Correction needed)	3,4
25	W	21	5	1	10	1	40	362,0	High risk (Immediate correction required)	1,3,4
26	W	27	6	1	10	0,5	100	650,0	Very high risk (Consider discontinuing opr.)	1,3,4

The below results were achieved by analysing scenarios applied and results from Table 11:

It was understood that the direction of the wind is an important factor with the force of the wind. Types of hazards varied 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 neighbouring pier, it was seen that the hazard "hard contact of the model ship with the neighbouring dolphin" was encountered. If there is a ship present at the neighbouring dolphin, especially the hazards "collision between the model ship and ship at the boarding the neighbouring 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 neighbouring 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.

Finally, the results acquired from Fuzzy Fine-Kinney was analysed by the experts. The experts have stated that the method gives precise and consistent results. Additionally, the experts have advised similar studies to be conducted with different scenarios in order to expand the study.

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 modelling 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 modelling 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 modelling report prepared.
In this study, risk analysis studies on the ship handling manoeuvres in the 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 modelling reports prepared by the institutions in Turkey, 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, by using a new risk analysis method, a more accurate assessment of port manoeuvres in terms of risk analysis has been provided.

In the study, the Fuzzy Fine-Kinney method risk analysis method, which has not been used in this field before, was used in order to be used in modelling reports. As a result of the evaluations made with the experts, it was determined that Fuzzy Fine-Kinney Method gave consistent and 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 method that has not been used in this field before is created for institutions to benefit in their modelling reports. In further research, it is planned to identify the risk analysis method that gives the most consistent results by comparing the risk analysis method used in the study and the different risk analysis methods used before.

Acknowledgements

This article was produced from Ferdi Çınar's master's thesis titled "A Model on Risk Analysis Methods in Ship Handling During Port Manoeuvres" written at Pîrî Reis University, Institute of Science and Engineering. The authors acknowledge with grateful thanks the cooperation and supports of Anadoluport and Pîrî Reis University.

References

Bayırhan, I., Mersin, K., Tokuslu, A., Gazioglu, C. (2019). Modelling of Ship Originated Exhaust Gas Emissions in the Istanbul Strait. *International Journal of Environment and Geoinformatics (IJEGEO),* 6(3): 238-243. doi.10.30897 /ijegeo.641397

Çokluk, Ö., Yılmaz, K., Oğuz, E. (2011). A qualitative interview method: Focus group interview (Nitel bir görüşme yöntemi: Odak grup görüşmesi). Kuramsal Eğitim Bilim Dergisi, 4(1), 95-107.

Erdebilli, B., Gür, L. (2020). Risk assessment application with Fuzzy Fine-Kinney method (Bulanık Fine-Kinney Yöntemi İle risk değerlendirmesi uygulaması). Journal of Industrial Engineering (Turkish Chamber of Mechanical Engineers), 31(1).

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

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

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.

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.

Işıklı, S. (2008). Fuzzy logic and fuzzy technologies (Bulanık mantık ve bulanık teknolojiler). Ankara Üniversitesi, DTCF, Felsefe Bölümü, Doktora Öğrencisi Tezi, 1-19.

ISO. (2018). ISO 31000:2018 Risk Management-Guidelines. International Organization for Standardization (2018).

Kaftan, İ., Balkan, E., Şalk, M. (2013). Fuzzy logic and it's uses in geophysics: The case of seismology (Bulanık mantık ve jeofizikte kullanım alanları: sismoloji örneği). DEÜ Mühendislik Fakültesi Mühendislik Bilimleri Dergisi, 15(2), 15-29.

Kaya, H., Askerbeyli, İ. D. (2018). Classification and application of fuzzy logic methods in the diagnosis of lung diseases (Akciğer hastalıkları teşhisinde sınıflandırma ve bulanık mantık yöntemlerinin uygulanması). (Doctoral dissertation, Ankara Üniversitesi Fen Bilimleri Enstitüsü).

Khaled, M. E., and 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., and 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).

Mersin, K., Bayırhan, İ., Gazioğlu, C. (2019). Review of C02 Emission and Reducing Methods in Maritime Transportation, *Thermal Science,* 23(6).73-79. doi.org/10.2298/TSCI190722372M.

Mikail, R. (2007). Design of a fuzzy expert system for saline soils remediation (Tuzlu toprakların islahı için bir bulanık uzman sistem tasarımı). (Doctoral Dissertation, Selçuk Üniversitesi Fen Bilimleri Enstitüsü).

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). Izmir Alsancak Port ship maneuvers risk assessment (İzmir Alsancak Limanı gemi manevraları risk değerlendirmesi). Dokuz Eylül Üniversitesi Denizcilik Fakültesi Dergisi, 3(1), 35-47.

Official Gazette. (2009a). Communiqué on Assessment of Coastal Facility Construction Requests (Kıyı Tesisi Yapım Taleplerinin Değerlendirilmesine Dair Tebliğ) (Tebliğ No: 2009/2). Official Gazette Date: 15.03.2009 Official Gazette Number: 27170.

Official Gazette. (2012). Ports Regulation (Limanlar Yönetmeliği). Official Gazette Date: 31.10.2012 Official Gazette Number: 28453.

Otoi, O. S., Park, Y. S., and 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.

Özbaş, B. (2013). Safety risk analysis of maritime transportation: Review of the literature. Transportation Research Record, 2326(1), 32-38.

Özdemir, A., Alaybeyoğlu, A., Balbal, K. F. (2019). Applications of fuzzy logic in education area (Bulanık mantığın eğitim alanındaki uygulamaları). Bilim Eğitim Sanat ve Teknoloji Dergisi, 3(1), 45-50.

Park, Y. S., Kim, J. S., and Aydogdu, V. (2013). A study on the development the maritime safety assessment model in Korea Waterway. Journal of Korean Navigation and Port Research, 37(6), 567-574.

PIANC. (2014). Report No 121: Harbour approach channels design guidelines. Permanent International Association of Navigation Congress, Brussels.

Rouse, M. (2020). Risk Analysis.

Şenol, Y. E., Şahin, B. (2016). A novel real-time continuous fuzzy fault tree analysis (RC-FFTA) model for dynamic environment. Ocean Engineering, 127, 70-81.

Talay, A. A. (2012). Haydarpaşa Port Area application of a decision support model created to improve navigation safety in port areas (Liman bölgelerindeki seyir güvenliğini geliştirmek için oluşturulan bir karar destek modelinin Haydarpaşa Liman Bölgesi uygulaması). (Doctoral dissertation, Fen Bilimleri Enstitüsü).

URL-1. (n.d.). Breadth of the ship. Retrieved August 12, 2019, from https://www.wartsila.com/encyclopedia

Ülker, D., Bayırhan, İ., Mersin, K., Gazioğlu, C. (2021). A comparative CO_2 emissions analysis and mitigation strategies of short-sea shipping and road transport in the Marmara Region, Carbon Management, 12(1):1-12.

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).

Yücel, M., Yurtören, C. (2019). Determination of risk factors caused by ships in port planning. International Journal of Environment and Geoinformatics, 6 (3), 254-263. DOI: 10.30897/ijegeo.641434.

Zadeh, L. A., Klir, G. J., and Yuan, B. (1996). Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers (Vol. 6). World Scientific.

Zghyer, R., Ostnes, R. (2019). Opportunities and challenges in using ship-bridge simulators in maritime research.

Zoroğlu, C. (2015). Estimation of severity of obstructive sleep apnea-hypopnea syndrome using fuzzy expert system (Bulanık uzman sistem kullanarak tıkayıcı uyku apne hipopne sendromunun ciddiyet seviyesinin tahmini). (Doctoral dissertation, Fen Bilimleri Enstitüsü).