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Evaluating Safety Control Criteria in Maritime Traffic Using Formal Safety Assessment. Case Study: Iranian Port of Bushehr

M. Fallahzadeh[1,*], M. Kiani[2], H. Talebnezhad[3]

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ABSTRACT

The maritime safety improvement and the reduction of the loss of the life, property and environmental pollution are critical for maintain the role of ports in the national economy, reducing investment risks in the maritime and shipping industry and reaching sustainable development of the marine economy. This study aims at to provide a systematic approach towards the Formal Safety Assessment (FSA) of maritime traffic, in which four phase procedures, is proposed.

The first step in FSA model (Hazard Identification) is to utilize the Delphi method to obtain the main vessel traffic risk factors in Bushehr port by considering four main criteria, notably 'vessels', 'traffic', 'navigation' and 'anchorage & waterway conditions'. The second step of FSA model (Risk Analysis) comprises risk index values of operational hazards and identification of high risk areas need to be addressed. The third step of FSA model the Risk Control Options (RCOs) comprises a range of RCOs which are assessed for their effectiveness in reducing the risks involved. The fourth step of FSA model (Recommendations for Decision-Making) comprises feedback information to review the results generated in the previous steps.

Subsequently five control options 'enforce existing rules / policies', 'improve a vessel traffic service', 'improve the ability to communicate bridge to bridge or ship to shore', 'establish / refine rules, regulations, policies or procedures', 'waterway changes' are prioritized and recommended to improve the safety of maritime traffic management.

1. Introduction

Shipping industry as one of the most important components of maritime transport has gone through many risks because of the environment and its international situation. Today, by growing process of global economy and thereby growth of transportation of cargo and ingredients by sea, importance and attention toward safety and security issues in vessel traffic have gone through a fundamental change. On the other hand, the ports are considered as sensitive areas and even strategic points of the countries because of their role in the connections of maritime transport, and other kinds of transportation such as road transit, rail and air transport, and also the existence of valuable human and material capital.

Technology development has caused people to benefit from more and faster services at lower costs. In line with this development, the need to enhance the safety level has increased. Therefore, special attention to safety needs inevitable, and the most basic tool to enhance the safety level is assessing it continuously.

In most of the marine operations, safety is considered as an important issue. Senior managers need the relevant information in decision-making process, in order to achieve safety management. Planning necessary measures, announcing orders, and executing them are the required information to identify prob-

[1]MSc in maritime transportation. Chabahar Maritime University, Iran.

[2]Head of Chabahar maritime university deputy of researches, PhD in Marine Transportation Technology. Lecturer in Chabahar Maritime University. http://www.cmu.ac.ir/find.php?item=1.219.224.fa.. E-mail address: mansoorkiani@googlemail.com.

[3]MSc in maritime transportation. Chabahar Maritime University. E-mail address:hossein_talebnezhad@yahoo.com

*Corresponding author:fallahzadeh2010@gmail.com

lems. An effective safety management system must reveal the state and changes of safety range to its users. Organizing the traffic of a waterway in order to utilize the waterway capacity logically, reducing the delay time of vessels by laws, and performing related activities to navigation controller, are expressed due to the safety level.

Traffic organization of a specific waterway or part of it is related to the following items (Bukurov and Backalic 2011):

- The type of exploitation and waterway technical characteristics and its expected objectives;
- The type of exploitation and technical characteristics of Fleet Owner (Operator);
- The volume of traffic;
- The number and the type of vessels in the Fleet Owner (Operator);
- The priority for special vessels;
- The climate and the hydrological region.

In 1972, the International Regulations for Preventing Collisions at Sea were published by IMO, and maritime regulations, which must be followed by ships in order to prevent collisions between vessels, were launched. In this regulations, special political lines segregated domestic waterways and coastal ones, and has restricted the range of application of international navigation rules to coast waterways. As might be expected, the possibility of different navigation rules in domestic waterways has been emphasized, although it should be in line with international rules as much as possible (IMO 1972).

Ports and Maritime Organization of Islamic Republic of Iran as a representative of the international Maritime Organization and, in accordance to above-mentioned rules has established coastal maritime communication and traffic control stations. In addition, by developing the management on these centers in order to promote maritime safety and perform their authority duties by of the department of maritime communications, the department of Maritime Affairs has taken steps.

Providing the safety of waterway, and coasts are considered as sovereign duties of Ports and Maritime Organization; Codifying strategies and proper monitoring of maritime traffic control will also have a direct impact on maritime safety factor and productivity of shipping industry. As a result this fact will be challenging in a near future due to the ports expansion plans, and the growth of maritime traffic.

The port of Bushehr is located in 28, 58 N and 50, 50 E in the north end of a peninsula on the coast of the Persian Gulf. This peninsula is 14 km long. The outer anchorage of this port is located in 58,28 N latitude and 43, 50 E longitude,. The depth of water is near to 10.8 m in the external anchorage leading to internal anchorage by the external channel 9200 m in length, and from the internal anchorage to Khowr Soltani, Bushehr berth and then to Khowr Booder by internal channel 3900 m in length. The external anchorage is 150 m in width, and the internal one is 140 m in width. Table No.1 shows the number of berths in the port of Bushehr and their description, length, draft and DWT ("As of July 16, 2014, the Bushehr port listed on its website `http://bushehrport.pmo.ir/`").

By the completion of construction project of dredging Bushehr access channel by a Dutch company of Bockalis Westminister in 2008, the depth of access channel in Bushehr Port increased from 6.5 m to 10.8 m (in external channel) and so forth to 10.3 (in internal channel), and also the bottom depth of external channel were switched to 150 m, and the internal channel to 140 meters. In addition to above-mentioned changes, new turning basin of ships has been constructed in 400 meters in diameter and 10 meters in depth; and also the central radius of turn was switched to 800 meters (Port and Maritime Administration of Bushehr Province 2012).

Currently, the new turn of access channel switched to its maximum width up to 250 meters, and enjoys the minimum depth of 10.8. This section the channel, which is designed to connect the external channel to the internal one, before the new dredging, had a less width than 10 meters, and a less depth of 7 meters. With the change of 2 degrees in internal channel of the port to the east, the channel's central radius of turn has switched from 500 meters, in 1975, to 800 meters. It is obvious that, widening the channel up to 250 meters, deepening it up to 10.8, and increasing its central radius to 800 meters, have facilitated the most critical part of the channel for safe ship rotation. Turning basin of ships was designed in the extreme south side of Negin Island, in front of launch berth (number 7) and a part of multi-purpose berths (number 8 to 13), in order to provide a safe rotation of entrance ships for controlling to multi-purpose berths (number 4, 5, & 6), special berth of oil productions (number 1), and containers (number 3 & 4). Currently, this turning basin enjoys the depth of 10 meters and turning radius of 400 meters (Port and Maritime Administration of Bushehr Province 2012).

This study examines the safety status of trade vessels traffic (including tankers, containers, general cargo, bulk carrier, lighterage, barge, tugboat, fishing vessels, and passenger ships (cruise ships)) in Bushehr Port, with the consideration of environmental dangers and risks in operational area including the external anchorages, external access channel, internal anchorage, internal channel and Soltani, Lashkar, and Poodre Khowrs (creeks).

The purpose of this study is to evaluate terms of maritime traffic in the operational range of the case study port (Bushehr), identifying risky factors of the safety of maritime traffic, and offering appropriate policies toward managing and controlling maritime traffic.

1.1. Review of Literature

Concerning different approaches of maritime traffic management and appropriate solution for maritime traffic control, we can say not much study have been done. In this section some of them have been introduced briefly.

Kurada et al (1982) presented a mathematical model in order to estimate the probability of collision of passing ships through a consistent waterway. This model considered some

Table 1: Bushehr port berths.

NO of Berths	Description	Length (m)	Draft (m)	DWT (tons)
1	Liquid Bulk	250	9.5	25000
2	Reefer & Container	194	9.5	30000
3	Reefer & Container	194	9.5	30000
4	Reefer & general cargo	174	9	15000
5	Reefer & general cargo	174	9	15000
6	Reefer & general cargo	155	9	15000
7	General cargo (Dhow)	286	4	500
8	General cargo	103	7.5	5000
9	General cargo	103	7.5	5000
10	General cargo	103	6.5	5000
11	General cargo	103	6.5	5000
12	General cargo	103	6.5	5000
13	General cargo	103	6.5	5000
14	Ro-Ro	70	4	-
Total	**2230**			

Source: Bushehr port portal 2014

traffic characteristics such as: traffic volume, passing ship dimensions, vessels speed, and also the channel characteristics like: width, length, and its central line. In this study, the suggested model were examined with the collision of some of the Japans' straits and waterways, and showed that the mentioned model provided an appropriate estimation for the risk of collision in a waterway.

In a research done by the Dutch maritime institute research center, Tak Vender & Spaans (1976) explained the access to creator factors of maritime risks in a marine range. The main purpose of this study is to calculate the digression variable of different ways of traffic in a specific area to find the best supervisory control solution of the general traffic condition.

In another study, Roeleven et al (1995) explain some methods, which consider the designing of anticipator model of collision probability on the basis of features and conditions of waterways. The authors used the generalized linear Models with the assumption of the probability of the collision without a normal distribution and they concluded that some conditions such as visibility status, and wind speed are more important than waterways characteristic, in the process of calculating the probability of the collisions.

Yurtoren et al (2008) examined the environmental effects of construction of new container terminal, on the safety maneuver (exercises) vessels. A comprehension risk analysis of maritime traffic was performed to establish a container terminal on the Izmit Bay by a team of the stimulation of guiding the vessels. As a result of above-mentioned research, quantitative analysis of maritime traffic risks were introduced as a very important part in the required emergency plans of the waterways.

Ulusçu et al (2009) researched about "Risk Analysis of the Vessel Traffic in the Strait of Istanbul". "Results show that current operations at the Strait of Istanbul have reached a critical level beyond which both risks and vessel delays are unacceptable. Results further indicate that scheduling changes to allow more vessels into the Strait will increase risks to extreme levels. Conversely, scheduling policy changes that are opted to reduce risks may cause major increases in average vessel waiting times". Shayun (2010) presented vessel traffic control safety evaluation model based on the analytic hierarch process with the regard to four main criteria and 14 sub-criteria for utilizing China ports:

- Vessel criteria including the structure and technical condition of (body/hull) and the cargo;
- The criteria of used area for pilotage of the vessels including, weather, maritime route, and fishing boats;
- The criteria of present crew in the vessel including the crew skill level, their awareness of the safety issues, mental condition, way of task division, and present passengers on the vessel;
- Management criteria including, chief management, related company management, and the Owner management.

In a study, Harrall and Merrick (2000) presented a decision-making tool about the evaluation of the requirements of the vessel traffic management in the United States of America ports. The mentioned tool is based on innovative presumption methods and extracting the judgments of experts working in the ports, which means analytic hierarchy process and also existing quantitative data, present the current safety level of studied ports and utilization of appropriate traffic management to reduce the offer of risks. For this purpose, the ports will be evaluated in terms of traffic, situation, weather, waterway construction, potential impacts and possible effects. On the other hand six traffic management levels have been defined, which the specialists will select among them, considering the existing risks in each port. Finally, special type of Vessel Traffic Management (VTM) has been suggested due to the gained weight for five studied ports.

Kujala et al (2009) in article of "Analysis of the marine traffic safety in the Gulf of Finland" resulted that the grounding is the dominating accident type in these waters and typically about 11 groundings take place annually. The main causes of collision are passenger ships/RoPax ships traffic between Helsinki and Tallinn.

2. Methodology and Results

In the mid1990s' the International Maritime Organization approved the Formal Safety Assessment (FSA) in order to improve and enhance the maritime safety. The mentioned process was first presented by Maritime and Coast Guard Agency in the maritime safety committee No. 62 in order to be used in maritime industry, and also the IMO members were asked to use it in the vessel safety research (Fang et al, 2004). Zhang and Hu (2009) examined the vessel traffic risk in the coastal waters and ports by using FSA model in China's Fujian port. In another study, Hu et al (2007) examined the FSA model by using the ship navigation risk model. In the study of "Application of the FSA methodology to intact stability criteria", Kobylinski (2004) have considered the drawbacks related to vessel stability by using FSA model and suggested some solutions.

This study used the second type of FSA to evaluate the maritime traffic control on Bushehr Port. The second type of FSA stages includes: identifying dangers, analysis of risk factors, identifying the possible control methods, recommendations to make decisions.

2.1. FSA First Stage: Risk Identification

Due to the purposes of this study, existing types of natural and operational dangers about the entry waterway to the ports have been extracted from the guideline 1018 of risk management published by International Association of Marine Aids to Navigation and lighthouse Authorities (IALA 2000). After the required reforms and review with regard to Bushehr port, four main factors (which each of them have sub-factors) were considered as follows:

1. 1) The vessels condition, which evaluates the quality of incoming and outgoing vessels to/ from the port, in terms of longevity and safety management system. This factor includes the following sub-factors:

(a) The quality of ships with high draft
(b) The quality of ships with low draft
(c) The quality of fishing ships
(d) The quality of passenger ships

2. The traffic condition, in which importance of different passing vessels will be evaluated. This factor includes the following sub-factors:

(a) The amount of traffic of trade vessels
(b) The amount of traffic of small and traditional vessels
(c) The amount of traffic of barges and tugboats
(d) The combination of vessel traffic
(e) Density of vessels

3. Navigation condition, in which the effective environmental terms for guiding vessels will be evaluated. This factor includes the following sub-factors:

(a) Local winds, and possible storms
(b) The status of tides and streams
(c) Visibility limits (dust- mist)
(d) Route barriers
(e) Light Pink Mechanisms (berth lights, sunlight)

4. The waterway and anchorage condition, in which the physical characters of port channel and anchorage will be evaluated. This factor includes the following sub-factors:

(a) Visual barriers
(b) The access channel dimensions
(c) The seabed type in the waterway and anchorage
(d) The general form of the channel
(e) The dredging quality, and navigation aid signs.

To ensure the validity of data collection instruments, based on the published guideline factors by authorities international experts, as well as a survey from related experts and specialists in Bushehr port (due to the limitation of respondents to the survey form of this study); at first, all survey forms were given to the above-mentioned people, and after removing the defects the final survey was prepared. In addition, in the present study the Test-Retest method have been used in order to determine the reliability of the survey forms. Noting that all correlation coefficients of all mentioned factors were more than 0.7 (Pearson R ¿ 0.7), the reliability of the present study was confirmed. The survey form contains questions about each of the mentioned subfactors with closed responses including: trivial, insignificant, important, very important, and too much important. Screening (sieve) for identified risk factors by Delphi method leaded to the determination o mentioned values in table 2.

After screening risk factors by using Delphi method, all the defined factors gained the required minimum of significance percentage and degree except "the quality of the fishing vessel", at the first stage. In continue, in order to focus on the effective factors and sub-factors on the maritime safety traffic of Bushehr port, eight sub-factors which all have higher rates of significance degree than other factors, are selected as follows:

- The vessel condition criterion:
  - The quality of ships with high draft
- The traffic condition criterion:
  - Traffic of trade vessels
  - Traffic of barges and tugboats
  - The combination of vessel traffic
- The navigation condition criterion:
  - Local winds and storms
  - The status of tides on streams
  - Visibility limits
- The waterway and anchorage condition criterion:
  - The access channel dimensions

2.2. *FSA Second Stage: Risk Analysis*

In this study, the SPE (Severity, Probability, Exposure) model have been used in order to analyze risks, this method is actually a qualitative one, but its results are expressed as numerical ones, and easily shows the risk priorities. This method is developed by the United States Coastal Guard, and is used to identify risks. By using three components of severity, probability, exposure the risk can be calculated numerically (U.S. Department of Transport 1999). In order to accurately evaluate the operational risks, the study area -Bushehr port and harbor- was divided to four zones.

- Zone 1, including outer harbor
- Zone 2, including outer channel
- Zone 3, including channel turn and inner harbor
- Zone 4, including local channel, estuaries berth area

Examining the environmental conditions of Bushehr port, and consulting maritime and port experts, we got to this point that four types of possible accidents threatens the safety of passing vessels, in navigation and maritime traffic area of Bushehr port, which are as follows:

- Vessel grounding
- Stranding West Coasts
- Impact with ocean surface and subsurface objects and equipment
- Collision with other vessels

Table 2: The Results of Using the Delphi Method.

Criterion	Significance Percentage	Significance Degree	Normalized Value	Significance Coefficient
Ships with high draft quality	3.4	8.52	0.29	0.077
Ships with low draft quality	2.3	5.88	0.13	0.037
Fishing ships quality	1.6	4.2	0.07	0.018
Small and traditional ships quality	2.2	5.6	0.12	0.034
Passenger ships quality	2.4	6.2	0.15	0.041
Traffic of trade vessels amount	3	7.5	0.22	0.061
Traffic of small and traditional vessels amount	2.5	6.2	0.15	0.042
Traffic of barges and tugboats amount	3.1	7.8	0.24	0.066
Vessel traffic combination	2.9	7.3	0.21	0.34
Density of vessels	2.6	6.9	0.29	0.057
Local winds, and possible storms	2.9	7.3	0.21	0.34
The status of tides and streams	2.9	6.9	0.29	0.057
Visibility limits (dust-mist)	2.8	7.2	0.21	0.056
Route barriers	2.7	6.8	0.15	0.041
Light Pink Mechanisms (berth lights, sunlight)	2.5	6.2	0.15	0.041
Visual barriers	2.2	5.5	0.12	0.032
The access channel dimensions	3.3	8.2	0.27	0.072
The seabed type in the waterway and anchorage	2.4	5.5	0.27	0.34
The general form of the channel	2.8	8.2	0.29	0.072
The dredging quality, and navigation aid signs.	2.7	7.2	0.2	0.052
Total			3.7262	1.00

Source: Authors

The mentioned operational risks were presented to experts for completion in the survey form number two. Identifying three components of severity, probability, and exposure for each risk, and multiplying the three numbers together, the risk indicators for each defined zone will be obtained separately. The validity and reliability of this stage were confirmed just like the previous stage. Risk index for each probable event will be obtained by scalar multiplication of the amount of factors –"severity", "probability", and "exposure". Exposure includes, duration, number of events, the crew number, the vessel number or the facilities in danger; probability includes the possibility of occurring the possible events; and severity shows dimensions of an event according to the degree of damage to properties and infrastructure, casualties (loss of life), environmental damages, and traffic impacts (U. S. Department of Transport 1990). The obtained risk indexes will be examined in table 3.

Table 4 shows the significance of calculated risk index for mentioned 4 zones. These indexes are the results of multiplying severity, probability, and exposure, which are obtained from the survey form number 2.

Table 5 shows the determination of risk level in all 4 zones by SPE model based on tables3 and 4. In terms of risk factors, zone number 4 has the most significance in index of grounding risk, hitting the port equipment risk, and collision to other vessels, because of the limitation of waterway width range, which is among coastal walls and berths. Zone number 3 has the most significance in risk index of hitting the sea substrate.

2.3. FSA Third Stage: Identification of Possible Control Methods

The purpose of this stage is to present a scientific method for prioritizing appropriate control strategies for risks and identified dangers in the initial stages in order to help the managers upon deciding the best strategy. Identifying the status of Bushehr Port, and examining the existing risks and the significance of each risk index in the studied zones, five control strategies were identified and determined by the suggestion of experts in order to reduce and control of the mentioned zones maritime traffic.

- Proper implementation of existing laws;
- New legislation;
- Improvement of communication;
- Providing vessel traffic services (VTS);
- The required changes in waterway.

According to the studied environmental factors and the impact of some conditions such as weather, arrival of vessels with different flags, and managing marine transportation companies with different qualities, the suggested strategies by experts and related specialties were selected in order to control the conditions and reduce the possible losses.

One of the most powerful tools to examine such conditions is the Analytical Hierarchy Process (AHP). The mentioned technique was presented in the late seventies by Professor L. Saaty Thomas. The main application of this method is when there may be different factors or sometimes conflicting ones in the time of selecting the best choice or prioritizing them. Extent Fuzzy AHP method, which is a new branch for classical AHP model, was first proposed by Chang (1996) and it was reformed by Wang et al (1999). In this method, the main factors, sub indicators and main objectives will be drawn in a graph.

Available options in the second level are compared by comparison matrices in one-to-one way of comparing. In the third level sub indicators of each factor are evaluated by comparison matrices. In the fourth level, also, comparison matrices will compare each of the options one by one with the each of the sub indicators. From each obtained comparison matrices, relative weight for sub indicators, main factors and finally the comparing options will be evaluated.

In this section, the methods and possible strategies of controlling risk factors were examined by consultation of experts and specialists. As a result the hierarchical process tree were provided in order to obtain the best suggested strategies. Then the survey form number three –which reliability and validity were confirmed like two previous stages– was prepared and presented to experts in order to investigate their opinion. The purpose of this survey is to gather the experts' opinions about the priority of strategies. In order to use Fuzzy-AHP method, after defining the goal, identifying the criterion and sub factors, and control measure, the mentioned hierarchical process of elements were sketched.

After experts' ratings and performing matrix operation, which is related to AHP Fuzzy –which is not, mentioned here to its length– the decision-making tree of relative weight of main factors were obtained. By examining the relative weights presented in table 9, the vessel condition criterion is the most important criteria to improve the vessel safety traffic.

According to the results obtained from matrix operation, table 10 shows the relative weight of sub-factors in the Fuzzy tree.

In order to improve the safety level of marine traffic in Bushehr Port, five control methods were proposed, which were evaluated and ranked by the opinion of experts and specialist. Table 11 shows the mentioned results.

2.4. FSA Fourth Stage: Analysis and Suggestions for Making Decisions

Using the results of the previous stages, we can examine and analyze the marine traffic safety condition very accurately. At this stage by holding expert meetings, and specialists' attendance, and presenting the obtained results, all the solutions for implementation of preferred suggested strategies will be evaluated again by brain storm method, and in result the best control method of risk factors will be determined. It should be mentioned that, in this stage, the experience and activity record of experts and maritime specialist and proposing applicable and practical solutions are really important, in order to improve the maritime traffic safety level by mentioned recommendations.

As it was shown in table 11, three methods namely, right implementation of laws, vessel traffic services, and improving radio communication and giving information, has approximately

Table 3: Different risk levels and the way of reacting to them.

Action	Risk Level	Risk Index
Stop activity and attempt to reduce risk	Very high	80 100
Modification of activity as soon as possible	High	60 79
Modification of activity is required	Substantial	40 59
Attention and supervision is required	Possible	20 39
The acceptable level of risk index	Slight	1 19

Source: U. S. Department of Transport 1990

Table 4: The significance of calculated risk index for zone 1.

Risk factors	Zone 1 calculated risk	Zone 2 calculated risk	Zone 3 calculated risk	Zone 4 calculated risk
Grounding	8	36	36	48
Hitting the wrecks & substrate	12	36	48	36
Hitting the signs & equipment	6	48	60	80
Collision	30	36	48	60

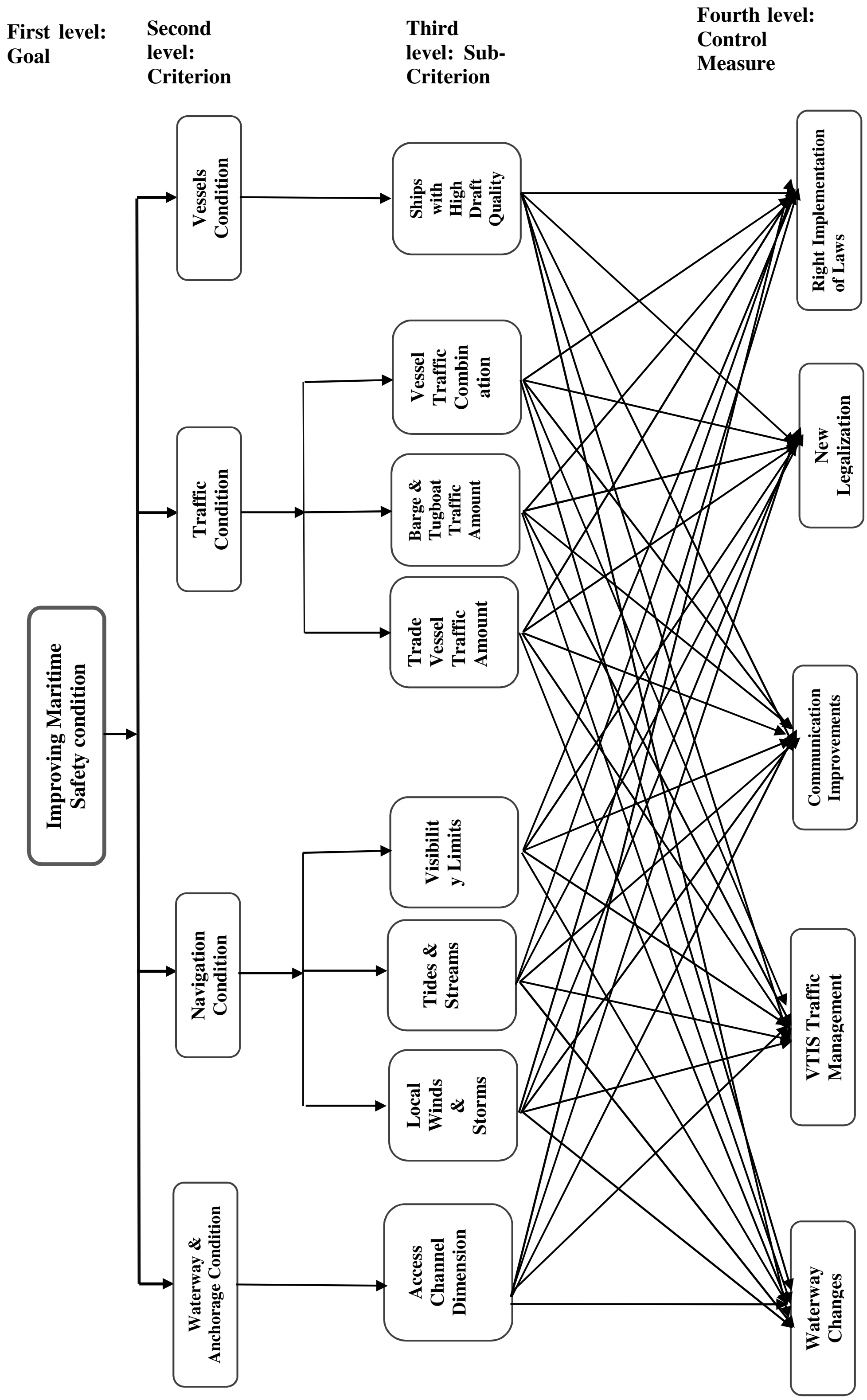
Source: Authors

Table 5: Determination of risk level* in the 4 mentioned maritime zones.
* Very High= VH, High=H, Substantial=SB, Possible=P, Slight=S

Risk factors	Zone 1 calculated risk	Zone 2 calculated risk	Zone 3 calculated risk	Zone 4 calculated risk
Grounding	S	P	P	SB
Hitting the wrecks & substrate	S	P	SB	P
Hitting the signs & equipment	S	SB	H	VH
Collision	P	P	SB	H

Source: Authors

Figure 1: Hierarchical process tree of goal criterion, sub-criterion, control measure for controlling the marine traffic of Bushehr port.



Source: Authors

Table 9: Relative weight of main factors in fuzzy tree.

Rank	Main Factors	Relative Weight
1	Vessel Condition	0.271
2	Traffic Condition	0.250
3	Navigation Condition	0.228
4	Waterway and Anchorage Condition	0.250

Source: Authors

Table 10: Relative weights of sub-factors.

Rank	Main factor	Sub-factors	Relative Weight of Sub-factors
1	Vessel Condition	Ships with High Draft Quality	1
2	Traffic Condition	Trade Vessel Traffic	0.419
		Barge & Tugboat Traffic	0.239
		Vessel Traffic Combination	0.342
3	Navigation Condition	Local winds and Storm	0.331
		Tides and Stream	0.369
		Visibility Limits	0.300
4	Waterway & Anchorage Condition	Channel Access Condition	1

Source: Authors

Table 11: Possible absolute weight of control methods in fuzzy tree.

Absolute Weight	Possible Control Methods	Rank
0.235	Right Implementation of Laws	1
0.219	Vessel Traffic Services	2
0.205	Improving Communication & way of Information	3
0.187	New Legalisation & Improving Methods	4
0.162	Waterway Required changes	5

Source: Authors

the same importance, and they can be considered as the best methods of controlling.

Control method of right implementation of existing laws, as a superior method, suggests the need for accurate monitoring of vessel traffic and ensuring of the legality of all traffics. At the same time, offering vessel traffic services, gives managers a useful tool for controlling and monitoring of vessel traffic.

Improving radio communication and way of informing the vessels, which got the third place among strategies, is used for guiding and informing personnel of vessels about local laws, traffic condition, weather condition and other required information.

Legalization of new laws and improving methods got the fourth place among strategies, and show that in experts' opinion in case of right implementation of existing laws, there is no need for new legalization, and the processes will be reformed.

Changes of forms or access channel dimension to port got the least among strategies, in experts' opinion, this issue reflects that current problems in the physical structure of waterway has less importance than the way of management and monitoring of vessel traffic. However, it should be noted that the mentioned strategies or controlling methods, are comprehensive and in continue management suggestions and proposals will be presented in order to explain each of the above methods in detail.

3. Conclusion

This study examined the marine traffic safety criteria of Bushehr port, using second type of formal safety assessment model. After extracting marine traffic safety criteria from IALA 1018 guideline, and localizing them due to prevailing conditions in Bushehr, existing risks in maritime traffic, and screening them by Delphi model, some of these factors have been chosen as the most effective ones, which are as follows:

1. Vessel condition criterion with the sub-criterion of ships with high draft quality;

2. Traffic condition criterion with the sub-criteria of trade vessels traffic, barge and tugboat traffic, and different vessel traffic combination;

3. Navigation condition criterion with the sub-criterion of access channel dimensions to port.

The results of examination of risk indicators by using SPE model showed that in terms of risk factors, some factors such as grounding risk, impacting port equipment risks, and collision to other vessels risk are more significant than others in internal channels, estuaries, and berth's range due to the limitation of waterway width to the coastal walls and berths.

In order to improve the safety level of maritime traffic in Bushehr port, five strategies were suggested, which were evaluated and ranked by related experts and specialists. After drawing the hierarchical graph and using AHP Fuzzy model three strategies got the higher priority, which are namely right implementation of existing laws, vessel traffic services and improving radio communication and way of informing, and two strategies got the lower priority, which are namely new legalization and improving methods strategy, and form change or access channel dimensions. Considering the mentioned strategies and presented discussion in brainstorm meetings, the following suggestions have been offered to improve the condition of maritime traffic safety of studied port.

- Right implementation of laws:
  1. Carful inspection of safety of vessels by control and monitor officers (PSC, FSC) prior to arrival and departure of vessels especially vessels with low quality (vessels with high lifetime or vessels under the management of invalid shipping companies) can prevent the occurrence of a lot of possible accidents.
  2. According to the port requirements and limitations, providing a comprehensive instruction on management of the vessel traffic in port, enjoys a special important and it can prevent individual preferences in different decision-making satiations.
  3. With regard to the importance of environmental factors evaluation and assessing safety and existing risk factors in order to sustain the marine operations, the necessity of performing studies on safety assessment of marine operations by the applicants and employers prior to offering justification projects of construction and development of ports, coastal and offshore facilities is inevitable.
- Vessel traffic service:
  1. Designing s suitable system for environmental conditions of Bushehr port in order to control the traffic of vessels seems inevitable, but in this regard studies of the evaluation of cost benefit are necessary.
  2. Currently, despite of using Automatic Identification System (AIS) in traffic control center of Bushehr port, the mentioned system's data is not available and there is no useful database about the vessel traffic amount, therefore establishing of suitable mechanism for taking advantage of these data is required.
- Improving radio communication and way of informing:
  1. Noting that currently, information about weather are reported by available stations in airports, and are only declared to vessels as weather forecasting information and safety wringing by VHF radio station and NAVTEX system; in case of establishing Physical Oceanographic Real-Time System (PORTS) in the port, marine characteristics can be accessible to mariners and leaders momentarily and carefully.
  2. According to the focus of docks and active marine industries in Bushehr port, providing a special mechanism in order to prevent the interference of radio communication between vessels, local radio stations, and center of port traffic control.

- New legalization and improving methods:

  1. Exploitation of standard safety assessment models, which were approved by International Organizations should be the agenda of all marine organs of the country particularly "Ports and Maritime Organization" as the naval and maritime affairs.
  2. Preparing plans and methods of facing emergency situations in waterways and port access channel have important role in controlling maritime accidents and collisions.
  3. Barge and tugboat traffic in Bushehr, which usually are engaged with carrying minerals, should be done with more sensitivity and accuracy because in this case the ability of maneuvers and tugboats faces multiple problems.

- Required changes of waterways:

  1. During the external channel route of the harbor, vessels with the destination to Khark Island or other northern areas of Persian Gulf, which also relatively have a low draft to other vessels, usually leave this route after passing buoy No. 6. In this regard a sub-channel can be designed in order to make such movements safe and legalize.
  2. Dredging and hydrographic operations in Bushehr port do not enjoy a good quality, therefore it affects the port policy about the permissible amount of draft for input vessels and the interval of substrates to the bottom of the vessels (UKC), and it can have negative effect on the safety traffic of vessels with high drafts and also economic position of the port.

The above-mentioned results provides the last objective of this study, which includes appropriate strategies of controlling and managing the maritime traffic.

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