INTERNATIONAL JOURNAL OF FUZZY SYSTEMS and ADVANCED APPLICATIONS
DOI: 10.46300/91017.2022.9.7 Volume 9, 2022

Applying Fuzzy Delphi Method and Fuzzy Analytic Hierarchy Process for Ranking Marine Casualties

Akbar Etebarian, Alireza Shirvani, Iraj Soltani, Ali Moradi
Department of Public Management Science and Research Azad University , Isfahan Branch, Shahraz Alley 1st Abshar St. Isfahan Iran

Abstract: Marine accidents, particularly those that involve pollution and large fatalities, bring into question the safety of shipping and the quality of ships and their crews. Whether or not such questions are justified, it is marine accidents that provide a poor image of the industry, which attract considerable attention. Incidents that particularly attract attention are those causing loss of life, pollution of the environment and the loss of ship and or cargo. Usually, People have a tendency to focus on the consequences of an accident rather than its root causes, so MCDM1 could improve to find the root cause elements by providing more precise decision parameters. Due to the complexity of Marine accident investigation, this study aims to provide a systematic approach to determine the degree of most influence parameters (cause and effect) in accident occurrence, in order to improve marine safety in direction of Good Governance; in the study two phase procedures are proposed. The first stage utilizes Fuzzy Delphi Method to obtain the critical factors of the Marine Accident Investigation by interviewing the related connoisseurs. In the second stage, Fuzzy Analytic Hierarchy Process is applied to pair fuzzy numbers as the measurable indices and finally to rank degree of each influence criterion within accident investigation. This study considers 1 Goal, 4 Aspects and 31 Criteria (Parameters), and establishes a ranking model that provides decision makers to assess the prior ordering of reasons and sorts by most effective parameter involved Marine Accident occurrence. The empirical study indicates that the " People, Working and living conditions, Effect " is the high ranking aspect and "Ability, Skills and knowledge of workers" is the most important evaluation criterion considered in overall experts view derived from Fuzzy Delphi Analytical Hierarchy Processing (FDAHP). The demonstration of how the prior order of accident maker parameters of connoisseurs is addressed as well. Therefore, ranking the priority of every influencing criterion (parameter), shall help the decision makers in marine transportation, to emphasize the area to improve and act accordingly to prevent future marine accidents.

Key-Words: Marine Accident, Accident Investigation, Good Governance, Analytic Hierarchy Process (AHP), Fuzzy Delphi Method (FDM), Fuzzy Analytic Hierarchy Process (FAHP),

I. INTRODUCTION

The efficient Marine Accidents Investigation is aimed to prevent the occurrence of same accident in the future. Accidents are rarely simple and almost never result from a single cause. Most accidents involve multiple, interrelated causal factors. Accidents can occur whenever significant deficiencies, oversights, errors, omissions, or unanticipated changes are present. Any one of these conditions can be a precursor for an accident; the only uncertainties are when the accident will occur and how severe its consequences will be. To conduct a complete accident investigation, the Parameters (factors) contributing to an accident, must be clearly understood. Management prevents or mitigates accidents by identifying and implementing the appropriate controls and barriers.

Parameters those involve in marine accident are as follow but not limited to them:

(A) Controls (e.g. rules/regulations, procedures, training, etc.) help to prevent errors or failures that could result in an accident; (B) Barriers (e.g. emergency systems onboard, contingency plans) help to mitigate the consequences of potential errors or failures. Barriers to protect targets against loss can be physical barriers, such as machine guards and railings, or management barriers, such as work procedures, hazard analysis, requirements management, line management oversight, and communications.

In a work environment, several barriers may be used in an effort to prevent accidents. Proper Marine Accident Analyzing could help reduce both the human loss and environmental pollution from ships, thus, creating a huge efficiency either from environmentally- friendly or economic levels.

This study tries to identify the influencing criteria by using expert's view who have wide knowledge and have been involved in Marine Accident Investigation in Iran.

According the SOLAS (74)[2] convention, each contracting government is responsible to carry proper Maine Accident Investigation process and keep recording for further use. The aim is to get advantage of worldwide Marine Accident Investigation findings to prevent future accidents and lessons can be learnt from each individual inspection.

So ranking the causal elements or reasons of a marine accidence will not only contribute in Good Governance process, but also to environmental protection.

This article introduces a model which takes advantage of expert idea to rank each parameter which are playing roles in the marine accident occurrence process. At present, the most important model for analyzing marine accident causations, which is recommended by IMO[3], is SHEL[4] model which analyzes the software, hardware, environment and life ware, surrounding a marine accident. But the model is not ranking the degree of effective of each parameter. FDAHP approach provides a scientific decision making in marine accident investigation by providing reliable decision factors for decision makers.

II. LITERATURE REVIW

A. Good Governance

Collely, John L, Doyle, Jacqueline L,(2003) and Osborne, (2009), mentioned the characteristics of Good Governance, which is now considered as a management paradigm , as follows:

A. ***Accountability*****:** is the key for good governance. Decision makers are accountable to those who are affected by the decision and implementation. Accountability cannot be enforced without transparency and the rule of law.

B. Responsiveness: is the concerns of those who are affected, those who implement, and those who integrate in the formulation of the decision.. To be responsive is also to provide feed back and address grievances spontaneously,

C. Transparency: means that the information is freely and directly accessible to those affected by the decision. It also means that the decisions are taken and enforced strictly within the established rules and regulations,

D. ***Citizenship Satisfaction*****:** this is most vital character and is the degree of satisfaction of people involved.

Therefore the MCDM is scientific approach to implement Good Governance as this study tries to high light it.

B. Marine Accident Investigation

B.1 Responsibilities of States

Each State shall cause an inquiry to be held by or before a suitably qualified person into every casualty or incident of navigation on the high seas involving a ship flying its flag and causing loss of life or serious injury to nationals of another State or serious damage to ships or installations or another State or to the marine environment. The flag State and the other State shall co-operate in the conduct of any inquiry held by other State into any such marine casualty or incident of navigation[5].

The objective of any marine casualty investigation is to prevent similar casualties in the future.

Investigations identify the circumstances of the casualty under investigation and establish the causes and Contributing factors, by gathering and analyzing information and drawing conclusions. Ideally, it is not the purpose of such investigations to determine liability, or apportion blame. However, the investigating authority should not refrain from fully reporting the causes because fault or liability may be inferred from the findings.

Over the years, and as a result of some major accidents, some of the existing international instruments have changed and some others specifically created to deal with various aspects of marine casualties. The most important ones are mentioned here and one in particular, (IMO Casualty Investigation Code), that is central to this course, will be covered in the next lesson. These are:

a) UN Convention on the Law of the Sea (UNCLOS)
b) IMO Conventions
c) IMO Assembly Resolutions
d) IMO MSC Circulars and Codes
e) International Labor Organization (ILO) Conventions

Marine Casualty Investigation Authorities' main objective of any marine casualty investigation is prevention of further similar cases by discovering the reasons behind the casualty and then promulgating actions, information and recommendations where appropriate, with a view to preventing similar casualties. Other benefits and reasons for investigations include:

1) Improved design
2) Improved operational and safety procedures
3) Improved work environment
4) Improved safety awareness

It is important that any recommendation arising from an investigation is based on sound analysis and is capable of practical implementation.

It follows from this that any casualty, from the simple to the major, can be the subject of a marine casualty investigation. A simple personnel incident, with the potential for learning something which could prevent recurrences, might be worth investigating thoroughly while a major collision resulting from a straightforward wrong application of the COLREGS[6] might not show anything new. Another different collision might indicate a need to look at fatigue, management procedures, training, certification and bridge design. The depth that each casualty which is reported needs to be investigated should be assessed on its merits.

B.2 What is a Marine Causality or Accident?

A marine Causality or Accident can be considered:

Marine casualty means an event that has resulted in any of the following:

a) the death of, or serious injury to, a person that is caused by, or in connection with, the
b) operations of a ship; or
c) the loss of a person from a ship that is caused by, or in connection with, the operations of a
    a. Ship; or
d) the loss, presumed loss or abandonment of a ship; or
e) material damage to a ship; or
f) the stranding or disabling of a ship, or the involvement of a ship in a collision; or
g) material damage being caused by, or in connection with, the operation of a ship; or
h) damage to the environment brought about by the damage of a ship or ships being caused by,
i) Or in connection with, the operations of a ship or ships. (IMO Resolution A.849 (20) adopted on 27 November 1997)

It was reported that 61 seafarers lost their lives on commercial vessels operating in and around EU waters in 2010 (compared with 52 in 2009 and 82 in both 2008 and 2007). The majority of these were in accidents involving fishing vessels (33%), while accidents on general cargo ships accounted for 28% of lives lost in 2010 (European Maritime Safety Agency Maritime Accident Review 2010,)

According to the Iranian maritime authorities only more than 100 vessels had accident during 2012 losing life, environmental impact and ship and cargo damages.(www.pmo.ir)

5 . Article 94, Duties of the flag State, provides, in paragraph 7 , United Nation Convention on Law Of Sea)

6 . Collision Regulation at Sea

C. Historical Overview of accident investigation

The sinking of the passenger liner SS[7] "Titanic" in 1912 made shipping safety a matter of public concern and issue, which later led to the development of the first SOLAS Convention in 1929 and formation of an international organization responsible for the safety of international shipping, now known as the International Maritime Organization (IMO). After then it was great importance to evaluate the reasons of each marine incident. IMO has provided codes and guidelines for effective marine accident investigation and data bank to collect information about accidents worldwide. So the marine accident investigation came to attention of all marine community especially governmental authorities.

III. VALIDITY AND RELIABILITY

Warwick and Linninger (1975) point out that there are two basic goals in questionnaire design.

1. To obtain information relevant to the purposes of the survey.

2. To collect this information with maximal reliability and validity.

How can a researcher be sure that the data gathering instrument being used will measure what it is supposed to measure and will do this in a consistent manner? This is a question that can only be answered by examining the definitions for and methods of establishing the validity and reliability of a research instrument. These two very important aspects of research design will be discussed in this module.

A. Validity

Validity can be defined as the degree to which a test measures what it is supposed to measure. There are three basic approaches to the validity of tests and measures as shown by Mason and Bramble (1989). The validity for questionnaire is obtained by **KMO and Bartlett's Test** by SPSS19 software.

B. Reliability

The reliability of a research instrument concerns the extent to which the instrument yields the same results on repeated trials. Although unreliability is always present to a certain extent, there will generally be a good deal of consistency in the results of a quality instrument gathered at different times. The tendency toward consistency found in repeated measurements is referred to as reliability (Carmines & Zeller, 1979). In scientific research, accuracy in measurement is of great importance. Scientific research normally measures physical attributes which can easily be assigned a precise value. Many times numerical assessments of the mental attributes of human beings are accepted as readily as numerical assessments of their physical attributes. Although we may understand that the values assigned to mental attributes can never be completely precise, the imprecision is often looked upon as being too small to be of any practical concern. However, the magnitude of the imprecision is much greater in the measurement of mental attributes than in that of physical attributes. This fact makes it very important that the researcher in the social sciences and humanities determine the reliability of the data gathering instrument to be used (Willmott & Nuttall, 1975). Reliability of questionnaire is obtained by Cronbach's Alpha Test by SPSS19 software.

IV. METHODOLOGY

The study contains two stages: the first stage is to establish the key parameters for evaluation of the marine accident analyzing, and use FDM by consulting experts from government sectors, academia and shipping industries to select a criterion, in order to find out the important factors to be conceded. We selected four organizations which are involved in marine activities, namely; PMO[8], IRISL[9], NIOTC[10]and two Universities[11]. The second stage is based on FAHP, and consults high level experts of various sections to find out the importance of various criteria, in order to obtain the measuring index for selecting the effective degree of each parameter on a marine accident occurrence. The survey methodology was used to gather the data and to build the marine accident causal criteria. Before designing the survey, we gathered the evaluation criteria from literature studies and some expert idea. Beside, according the literatures, we combined the criteria of accident causal elements and prior researches in related or other arenas, and generalized 43 factors of which 31 selected as important constructs under four important aspects.

A. Fuzzy Delphi Method

Fuzzy Delphi Method was proposed by Ishikawa et al. (1993), and it was derived from the traditional Delphi technique and fuzzy set theory. Noorderhaben (1995) indicated that applying the Fuzzy Delphi Method to group decision can solve the fuzziness of common understanding of expert opinions. As for the selection of fuzzy membership functions, previous researches were usually based on triangular fuzzy number, trapezoidal fuzzy number and Gaussian fuzzy number. This study applied the triangular membership functions and the fuzzy theory to solving the group decision. This study used FDM for the screening of alternate factors of the first stage. The fuzziness of common understanding of experts could be solved by using the fuzzy theory, and evaluated on a more flexible scale. The efficiency and quality of questionnaires could be improved. Thus, more objective evaluation factors could be screened through the statistical results.

The FDM steps are as follows:

1 . *Collect opinions of decision group*: Find the evaluation score of each alternate factor's significance given by each expert by using linguistic variables in questionnaires.

2 . *Set up triangular fuzzy numbers:* Calculate the evaluation value of triangular fuzzy number of each alternate factor given by experts, find out the significance triangular fuzzy number of the alternate factor. This study used the geometric mean model of mean general model proposed by Klir and Yuan (1995) for FDM to find out the common understanding of group decision. The computing formula is illustrated as follows:

Assuming the evaluation value of the significance of No. j element given by No. i expert of n experts is w_{ij} (a_{ij} , b_{ij} , c_{ij}), i =1, 2, ..., n; j =1, 2, ..., m. Then the fuzzy weighting w_j of No. j element is w_j (a_j , b_j , c_j), j =1,2, ..., m

7 . Steam Ship

8 . Ports and Maritime Organization (Maritime Authority in Iran)
9 . Islamic Republic of Iran Shipping Line
10 . National Iranian Oil Tanker Company
11 . Chabahar Nautical University and Khoramshar marine science and Technology University.

$a_j = \text{Min}_i(a_{ij})$, $b_j = \frac{1}{m}\sum_{i=1}^{m} bij$, $c_j = \text{Max}_i(c_{ij})$

3. Defuzzification: Use simple centre of gravity method to defuzzify the fuzzy weight w_j of each alternate element to definite value S_j , the followings are obtained:

$S_j = \frac{aj+bj+cj}{3}$ j=1, 2, ..., m

4. Screen evaluation indexes: Finally proper factors can be screened out from numerous factors by setting the threshold a. The principle of screening is as follows:

If $S_j \geq \alpha$, then No. j factor is the evaluation index.

If $S_j < \alpha$, then delete No. j factor. Schematic diagram of Fuzzy Delphi Method threshold is shown in Fig. 1.

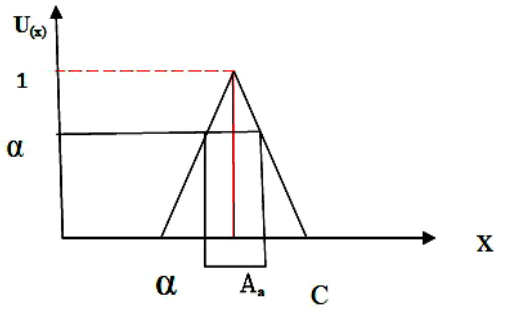

Fig. 1. Schematic diagram of Fuzzy Delphi Method threshold

B. Fuzzy Analytic Hierarchy Process

Laarhoven and Pedrycz (1983) proposed the Fuzzy Analytic Hierarchy Process in 1983, which was an application of the combination of Analytic Hierarchy Process (AHP) and Fuzzy Theory. The linguistic scale of traditional AHP method could express the fuzzy uncertainty when a decision maker is making a decision. Therefore, FAHP converts the opinions of experts from previous definite values to fuzzy numbers and membership functions, presents triangular fuzzy numbers in paired comparison of matrices to develop FAHP, thus the opinions of experts, approach human thinking model, therefore as to achieve more reasonable evaluation criteria.

As for the experts' opinions, this study adopted the Similarity Aggregation Method (SAM) proposed by Hsu and Chen (1996)[12] to integrate experts' weight values for various evaluation criteria, the fuzzy weight fraction of criterion of each hierarchy is obtained through the calculating mode of FAHP, and then the sequence of significance of each criterion is determined based on the hierarchy series connection and defuzzification mode.

Laarhoven and Pedrycz (1983) proposed the FAHP, which is to show that many concepts in the real world have fuzziness. Therefore, the opinions of decision makers are converted from previous definite values to fuzzy numbers and membership numbers in FAHP, so as to present in FAHP matrix.

The steps of this study based on FAHP method are as follows:

1.*Determine problems:* Determine the current decision problems to be solved, so as to ensure future analyses correct; this study discussed the ''evaluation criteria for Marine Accident Investigation".

2 . *Set up hierarchy architecture:* Determine the evaluation criteria having indexes to be the criteria layer of FAHP, for the selection of evaluation criteria, relevant criteria and feasible schemes can be found out through reading literatures and collective discussions. This study screened the important factors conforming to target problems through FDM investigating experts' opinions, to set up the hierarchy architecture (as shown in fig. 3).

3 . *Set up fuzzy paired comparison matrices:* Compare the relative importance between factors given by decision makers in pairs, set up paired comparison matrices, after the definite values are converted to fuzzy numbers according to the definition in Table 1 and Fig. 2, integrate the fuzzy evaluation values of experts based on the Similarity Aggregation Method SAM concept proposed by Hsu and Chen (1996).

4 .*Calculate fuzzy weight value*: Obtain the characteristic vector value of fuzzy matrix, namely the weight value of element. This study calculated these three positive and negative value matrices respectively by using the ''Column Vector Geometric Mean Method" proposed by Buckley (1985).

5. Hierarchy series connection: Connect all hierarchies in series, to obtain all factors' weights.

To collect the fuzzy numbers which have derived from directly from expert idea, In this study we have

used triangular method therefore a fuzzy number s defined according relations numbers (1) to (4):

(1) $\alpha_{ij}=(\alpha_{ij}, \mathbf{d}_{ij}, \mathbf{g}_{ij})$

(2) $\alpha_{ij}=\text{Min}(b_{ijk})$, k=1,….n

(3) $\mathbf{d}_{ij}=(\prod_{k=1}^{n} b_{ijk})^{1/n}$, k=1,….,n

(4) $\mathbf{g}_{ij}=\text{Max}(b_{ijk})$, k=1,….,n

Fig.2 shows a typical fuzzy number which we have used in this study:

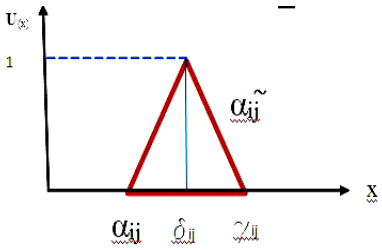

Fig. 2. Schematic diagram of Fuzzy Delphi Method threshold (*Liu and Chen, 2007*)

In which b_{ijk} is the relative preference parameter "i" to parameter "j" from expert "k" view, α_{ij} and g_{ij} are the lower and upper limits of expert view, respectively and d_{ij} is the geometric mean of experts views. Therefore parameters are so defined that: $\alpha_{ij} \leq d_{ij} \leq g_{ij}$

Then according to calculated fuzzy numbers as mentioned above, paired matrices between various parameters the inverted matrices are set up for fuzzy numbers according relation (5):

[12] . A similarity aggregation method (SAM) aggregates experts' opinions in a linguistic framework using a consensus weight factor for each expert that is based on the similarity of his or her opinion relative to the other experts to ensure that the experts' final decision is a result of common agreement Read More: http://ascelibrary.org/action/showAbstract?page=432

(5) $A_{ij}=[\alpha_{ij}], \alpha_{ij\times}\ \alpha_{ji}\approx 1$, $\forall$ i,j=1,2,3.....

To calculate the fuzzy relative weight we have used the following relations numbers (6), (7) and (8):

(6) $Z=[\alpha_{ij}\otimes \ldots\ldots\otimes \alpha_{ij}]$

(7) $Z_i=[\alpha_{ij}\otimes \ldots\ldots\otimes \alpha_{ij}]^{-1}$

(8) $W_{i=} Zi \otimes (Z_i\oplus\ldots\ldots\oplus Z_n)$

6. Defuzzification: Convert fuzzy numbers to easy-comprehended definite values, this study adopts the geometric mean method to solve fuzzy numbers proposed by *Liu and Chen, (2007), according to relation number :*

2. (9) $W_i=$

7. Sequencing: Sequence defuzzified criteria.

Table 1

The definition of every fuzzy number

Fuzzy number Definition

1= (1,1,1) Equally important

3=(2,3,4) Moderately more important

5=(4,5,6) Strongly more important

7=(6,7,8) Very strongly more important

9=(8,9,9) Extremely important

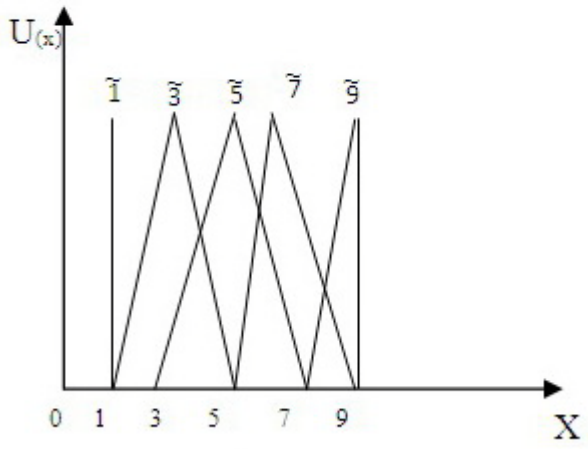

Fig.3. Scale of fuzzy numbers

V. EVALUATING MODEL APPLICATION AND RESULTS

A) *Reviewing relevant literature of Marine accident Investigation and proposing important criteria*:
More than 43 criteria (Parameter) for Marine Accident Investigation based on reviewing relevant literature (*Liu and Chen,2007*, Begum, Siwar, Pereira, & Jaafar, 2006; Emery, Davies, Grffths, & Williams, 2007; Finn -veden, 1999; International Maritime Organization (IMO) Resolution A.849(20) dopted on 27 November 1997 ,IMO Resolution A.884(21) adopted on 25 November 1999, Lin, Lin, & Jong,2007) and the current Marine Accident Investigation approach are proposed. A brief definition of evaluating criteria of Marine Accident Investigation is presented in Table 2.

B) *Screen important criteria (Parameters) by Fuzzy Delphi Method*. This stage includes three sections. Firstly, it lists Four main aspects and 43 items as the key evaluation items of Marine Accident Investigation, and a FDM interview framework is set up.The second section is the interview with twenty experts from national shipping company, the academic community, and competent government authority officers in Iran. Delphi Method mostly aims at easy common understanding of group opinions through twice provision of questionnaires. FDM formed by adding the fuzzy theory in, not only maintains the advantage of Delphi Method, but also reduces the provision times of questionnaires when using traditional Delphi Method as well as the cost.

For the third section, the opinions of experts in FDM questionnaires are converted to triangular fuzzy numbers, and defuzzified values can be figured out after calculation. This stage adopts elements with threshold above 6, and the key evaluation items with threshold below 6 are deleted. The important evaluation items after screening are listed in Table 3.

Table 2
Operational type for defining for 43 criteria

Aspects	Criteria (Parameters)	Short Operational Definition
Organization on board & Shore-side management (A)	Division of tasks and Responsibilities	Written job description, task analyzing, responsibility allocation, ...
	Composition of the crew	Mixture of nationality of crew and their competence and training.
	Working hours (planned)	Schedule duty, day or night time worker...
	Workload / Complexity of tasks	Amount of Paper work, Bureaucratic Activities etc.
	Rest hours (planned)	Including sleep duration and time for recreation.
	Procedures and standing orders	The way to implement the written current orders on board.
	Communication	Internal and external communication procedures.
	On-board management and supervision	Written mechanisms which make sure the works are going right direction.
	Organization of on-board training	Organizing practical on-board training to updated the workers.
	Organization of on-board drills	Written Procedures to carry out drills on-board.
	Voyage, cargo and maintenance ,planning	The procedure which a voyage or cargo or maintenance and etc, are planned.
	Policy on Recruitment	Written procedure on how the company select workers.
	Safety Policy and Philosophy	Written safety policy and training procedures including emergency drills
	Management Commitment to Safety	Written procedure from high level management indicating safety commitment.
	Amount of Logistic Support from Shore	Written policy of organizational logistic support
	Policy for workers motivation	Written policy of Management procedure for motivating the workers.
	Port Scheduling	Planning to leave or arrive on a port, stay at port...
	Contractual arrangements	Contractual, industrial arrangements and agreements for all crew members.
	Assignment of Duties	Assigning the duties to the involved workers.
	Ship-Shore Communication	Interaction with port, headquarter, emergency stations etc.
Ship factors (B)	Design of Ship and Equipment	Quality of Ship and Equipments Design....
	State of Maintenance	The Condition Which The Equipment Is Maintained...
	Equipment	The Availability, Reliability, Durability Performance Of Equipments….
	Cargo characteristics	Including Securing, Handling And Care Of Cargo ….
	Certificates	Certificates For Ship, Equipment, Machinery, …
	Ship type	Including Cargo Ship, Crude Oil Carrier, Ro-Ro Ship, Passenger Ship, …
Environment (C)	Weather and Sea Conditions	Internal And External Climate, Temperature. Visibility, Vibration, Noise ...
	Port and Transit Conditions	Including Vessel Traffic Service , Pilots, Port Facilities, Etc.
	Traffic Density	Number Of Coming And Going Vessels In The Area.
	Heavy Weather Conditions	Wind, Rain, Snow, Tifton, Cyclone...
	Representing Agencies	The Ship Owners And Seafarers Representatives And Agencies.
	Regulations, Surveys and Inspections	International, National, Port, Classification Societies, Etc.
	Shore side Interaction	Interaction With Stevedores, Port Officials, Security Measure In Port Area Etc.
People & Working and living conditions (D)	Ability, Skills, knowledge	The Outcome Of Training, Experience, Education, Professional, Certification…
	Personality	The Mental Condition, Emotional State,
	Physical condition	Including Sickness, Medical Fitness, Drugs And Alcohol, Fatigue…
	Sleep and its quality	Scheduled Sleep And The Area Which The Sleep Takes Place.
	Person Abilities	Assigned Duties Respect To Person Abilities
	Actual behavior at time of Accident	The Location, Task Performing, Attention, At Time Of Accident Occurrence
	Level of Automation	Taking Advantage Of Automatic Instruments To Perform Tasks And Duties.
	Ergonomic Design	Working, Living And Recreation Areas And Equipment Suitable For Human.
	Adequacy of Living Conditions	Opportunities For Recreation, Rest, Sleep…
	Adequacy of Food	The Quality And Quantity Of Food For Workers To Carry Out Their Duty.

Table 3
New evolution Criteria after Fuzzy Delphi Method

Aspects	Criteria(Parameters)- Code Number		Score			
			Min	Mean	Max	Defuzzification
Organization on board & Shore-side management (A)	Division of tasks and Responsibilities	A_1	5	7.4	9	7.1
	Working hours (planned)	A_2	5	6.5	9	6.8
	Workload / Complexity of tasks	A_3	3	6.4	9	6.1
	Rest hours (planned)	A_4	3	7.2	9	6.4
	Procedures and standing orders	A_5	3	6.2	9	6.1
	Communication	A_6	3	6.3	9	6.1
	On-board management and supervision	A_7	3	6.3	9	6.1
	Organization of on-board training	A_8	3	6.4	9	6.1
	Organization of on-board drills	A_9	3	7	9	6.3
	Policy on Recruitment	A_{10}	3	6.4	9	6.1
	Management Commitment to Safety	A_{11}	3	7.3	9	6.4
	Amount of Logistic Support from Shore	A_{12}	3	6.7	9	6.2
	Policy for workers motivation	A_{13}	3	6.4	9	6.1
	Assignment of Duties	A_{14}	3	6.7	9	6.2
Ship factors (B)	Design of Ship and Equipment	B_1	5	7	9	7.0
	State of Maintenance	B_2	5	7.4	9	7.1
	Equipment	B_3	5	7.2	9	7.1
	Cargo characteristics	B_4	3	6.5	9	6.2
Environment (C)	Weather and Sea Conditions	C_1	5	6.7	9	6.9
	Port and Transit Conditions	C_2	5	6.8	9	6.9
	Traffic Density	C_3	5	6.2	9	6.7
	Heavy Weather Conditions	C_4	5	6.6	9	6.9
	Regulations, Surveys and Inspections	C_5	5	6.5	9	6.8
People & Working and living conditions (D)	Ability, Skills, knowledge	D_1	7	8.4	9	8.1
	Personality	D_2	5	7	9	7.0
	Physical condition	D_3	5	7.1	9	7.0
	Sleep and its quality	D_4	5	7.6	9	7.2
	Person Abilities	D_5	5	7.5	9	7.2
	Actual behavior at time of Accident	D_6	5	7.5	9	7.2
	Ergonomic Design	D_7	5	6	9	6.7
	Adequacy of Living Conditions	D_8	3	6.5	9	6.2

C) *Establish a hierarchical framework:*

Based on the FDM, a general consensus among experts can be reached to establish a hierarchical structure. The Marine Accident Investigation can be evaluated based on four evaluation aspects and 31 evaluation criteria or Parameters (Fig. 2).

D) *Interview experts and integrate their opinions:* Subject to who fill in AHP questionnaires possess sufficient professional knowledge and at least 20 years of experience in marine activities either in shipping or authorising (government) field , so the interviewees are experts and from different concerned activities. The evaluation of each factor must go through consistency verification to ensure preferable credibility of results. In order to increase the objectivity of results, there are twenty experts to be interviewed. In the past, the integration of opinions from questionnaires adopted geometric mean method, but the unreasonable integration of group opinions therein would result in incorrect results. Therefore, this study adopts Similarity Aggregation Method (SAM) which was proposed by Hsu and Chen (1996), which can integrate group opinions more reasonably, so as to increase the credibility of questionnaires.

E) *Calculate the weights of evaluation criteria and weight result of evaluation criteria:* The weight values of various elements can be obtained through the opinions of experts resulted from SAM and the FAHP systematic steps. After sequencing, the evaluation criteria have higher significance, so decision makers can make correct judgments more quickly.

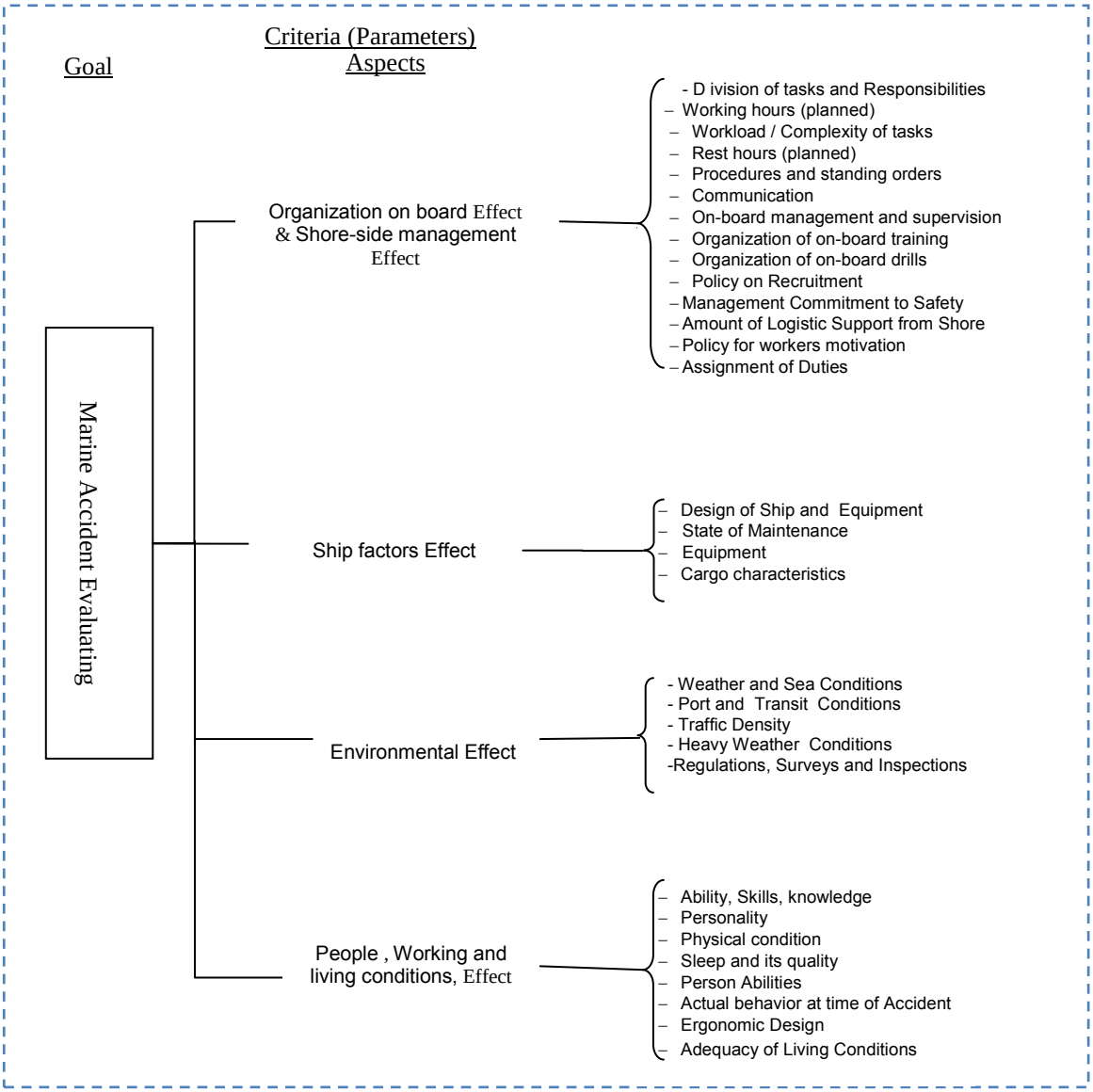

Fig. 4. The Hierarchy model of Marine Accident Investigation

Table 4 is the evaluation criteria weight by FAHP, the evaluation criteria weight is obtained based on FAHP questionnaire results of experts, finally the questionnaire results of all experts are integrated to become the overall weight.

Table 4
Evaluation Criteria Weight of connoisseurs

Aspects	Weights of Aspects	Criteria	Priority	Weights of Criteria			Defuzzification	Sort largest to smallest	Ranking	
				Fuzzy Weights W_i						
(A)	0.253	A_1	6	0.013	0.0353	0.1164	0.0376	0.0444	D_1	1
		A_2	16	0.012	0.0310	0.0997	0.0337	0.0389	D_4	2
		A_3	25	0.009	0.0297	0.1081	0.0306	0.0388	D_5	3
		A_4	14	0.011	0.0335	0.1167	0.0346	0.0380	B_2	4
		A_5	24	0.010	0.0291	0.0999	0.0308	0.0376	D_6	5
		A_6	29	0.009	0.0295	0.1008	0.0298	0.0376	A_1	6
		A_7	31	0.008	0.0294	0.0944	0.0287	0.0371	B_3	7
		A_8	26	0.009	0.0302	0.1000	0.0304	0.0361	B_1	8
		A_9	19	0.010	0.0330	0.1061	0.0330	0.0359	D_2	9
		A_{10}	30	0.009	0.0300	0.0942	0.0295	0.0359	D_3	10
		A_{11}	17	0.010	0.0342	0.1101	0.0332	0.0357	C_1	11
		A_{12}	27	0.009	0.0308	0.1034	0.0300	0.0352	C_4	12
		A_{13}	28	0.009	0.0297	0.1004	0.0298	0.0348	C_2	13
		A_{14}	22	0.010	0.0315	0.1010	0.0314	0.0346	A_4	14
(B)	0.230	B_1	8	0.013	0.0332	0.1076	0.0361	0.0343	C_5	15
		B_2	4	0.014	0.0354	0.1111	0.0380	0.0337	A_2	16
		B_3	7	0.013	0.0345	0.1097	0.0371	0.0332	A_{11}	17
		B_4	23	0.010	0.0305	0.1008	0.0310	0.0331	C_3	18
(C)	0.216	C_1	11	0.013	0.0319	0.1115	0.0357	0.0330	A_9	19
		C_2	13	0.012	0.0323	0.1056	0.0348	0.0320	D_7	20
		C_3	18	0.012	0.0294	0.1019	0.0331	0.0316	D_8	21
		C_4	12	0.013	0.0315	0.1100	0.0352	0.0314	A_{14}	22
		C_5	15	0.012	0.0307	0.1101	0.0343	0.0310	B_4	23
(D)	0.301	D_1	1	0.017	0.0405	0.1249	0.0444	0.0308	A_5	24
		D_2	9	0.013	0.0335	0.1030	0.0359	0.0306	A_3	25
		D_3	10	0.013	0.0340	0.1044	0.0359	0.0304	A_8	26
		D_4	2	0.014	0.0363	0.1158	0.0389	0.0300	A_{12}	27
		D_5	3	0.014	0.0355	0.1173	0.0388	0.0298	A_{13}	28
		D_6	5	0.013	0.0359	0.1100	0.0376	0.0298	A_6	29
		D_7	20	0.012	0.0286	0.0966	0.0320	0.0295	A_{10}	30
		D_8	21	0.010	0.0307	0.1005	0.0316	0.0287	A_7	31

For different aspects experts have selected aspect (D) “People , Working and living conditions, Effect” (0.301) , aspect (A) “The Organization on board & Shore-side management Effect” (0.253), aspect (B) . “Ship factors Effect”, aspect (0.230) and aspect “ Environmental Effect” (0.216) respectively.

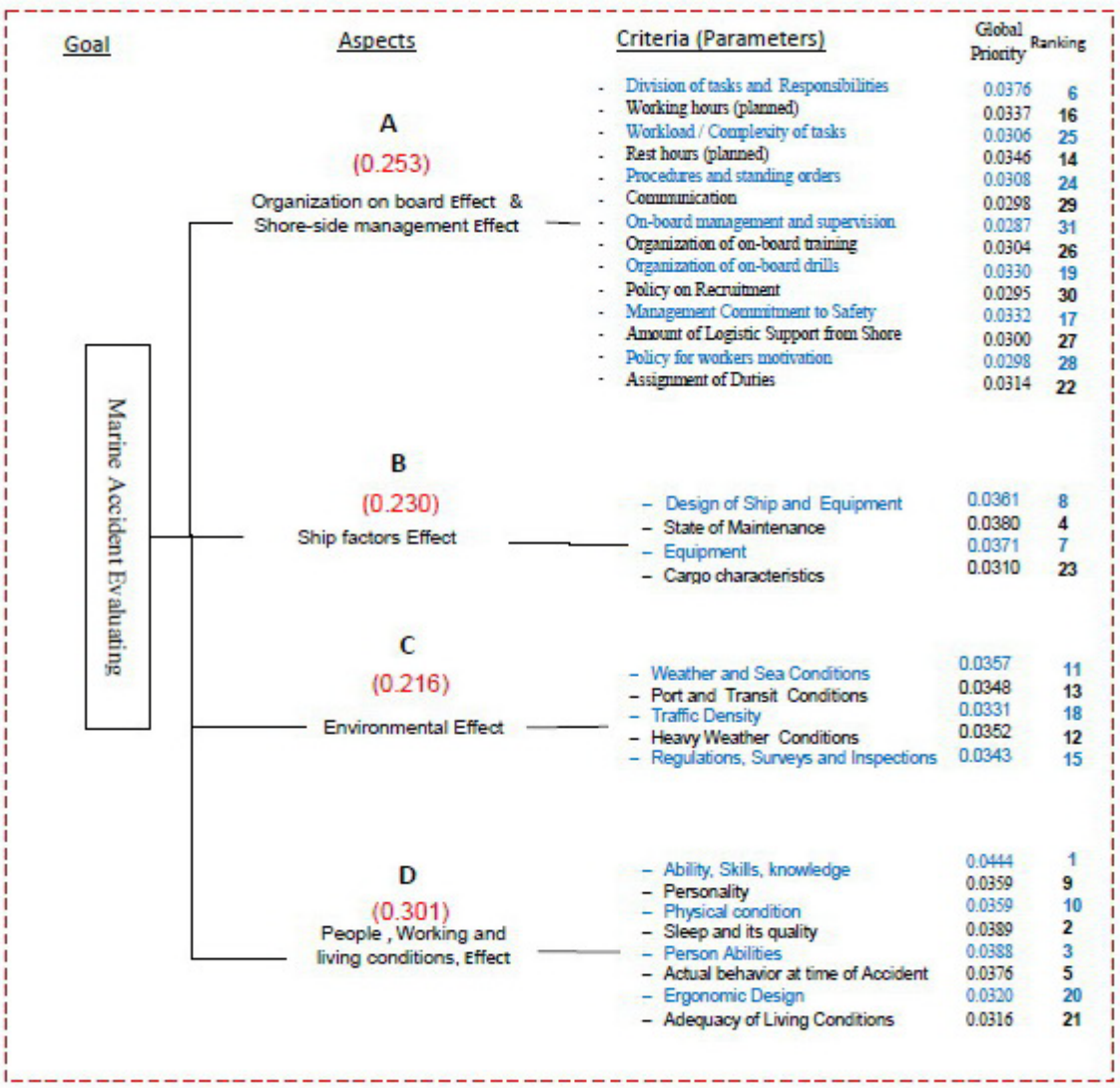

Fig.5. The weights of Marine Accident Investigation Hierarchy Model

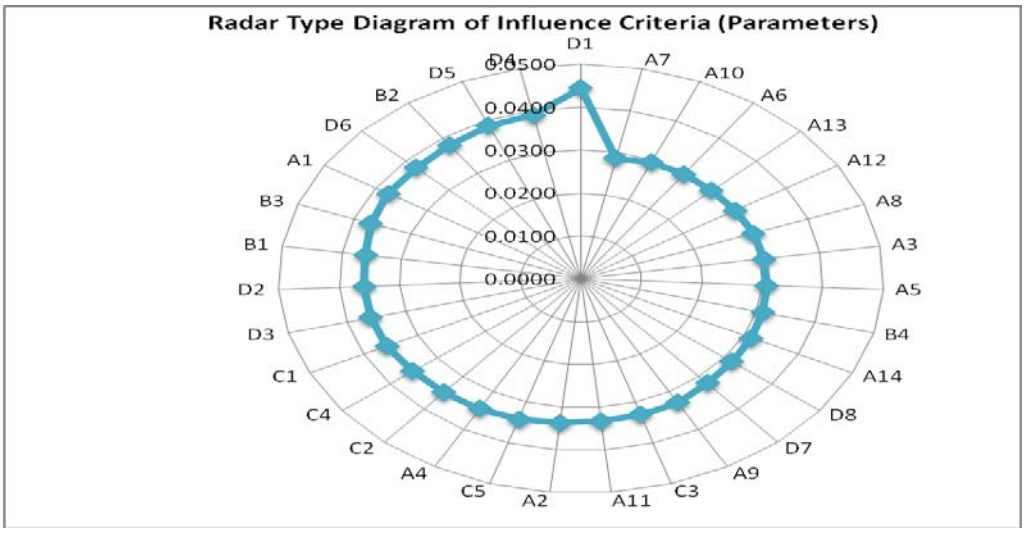

Fig. 6. Most to least, influence parameters (criteria, D_1 to A_7)

VI. CONCLUSIONS

This study investigates the key factors in marine accident investigation by combining FDM, and FAHP, and establishes objective and standardized references. A total of 43 factors influencing marine accident investigation are analyzed through FDM experts' opinions investigation, Experts of governmental

sectors, academia and shipping industry were interviewed, and 31 evaluation criteria were obtained as the key factors (parameters) by interviewed experts. SAM and FAHP were used to integrate experts' opinions to obtain the significance evaluation of various evaluation criteria given by experts in group decision. The results from experts were compared and analyzed to show the similarities and differences of various experts in marine accident investigation. Finally, the results of all experts were used as the evaluation index of marine accident investigation. The following conclusions were reached by analyzing the evaluation criteria stressed by experts when evaluating the marine accident investigation based on the demonstration of this study. The proposed method enables decision analysts to better understand the complete evaluation process. This approach provides a more accurate, effective, and systematic decision support tool.

The importance of the criteria is evaluated by experts, and the uncertainty of human decision making is taken into account through the fuzzy concept in fuzzy environment. From fuzzy AHP we find out that, thirty one criteria out of forty three for marine accident investigation are most important criteria and four aspects, (A) Organization on board Effect & Shore-side management Effect (B) Ship factors Effect (C) Environmental Effect and (D) People, Working and living conditions, Effect, are the most important as shown in Fig. 2.

In this study we highlighted the most important parameters which are assumed to cause a marine accident occurrence in marine accident investigation processing.

1. Emphasis on four main aspects:

The experts have different stress on four aspects; the aspect (D) has a higher weight (0.301), this is probably because the experts include those of People factors namely: (a) ability, skills, knowledge (b) personality (c) physical condition (d) activities prior to accident occurrence (e) assigned duties at time of accident occurrence (f) actual behavior at time of accident occurrence (h) attitude and so on, the experts thought. These are both outcome of training and experience, mental condition, emotional state, medical fitness, use of drugs and alcohol, fatigue etc.

2. Emphasis on over all criteria (five high ranking criteria):

Experts pay highly attention to evaluation criteria in (D)" People, Working and living conditions, Effect" aspect. Therefore the highest ranking criterion is "Ability, Skills, knowledge" (0.0444), the second "Sleep and its quality (0.0389) ", third "Person Abilities" (0.0388) criteria lied in aspect (D) and fifth "Actual behavior at time of Accident" (0.0376) but the forth highest ranking criterion lay in aspect (B) "State of Maintenance" (0.0380) Although the weight of aspect (B) "Ship factors" Effect " (0.230),is third among the four evaluation criteria in that experts make their opinions.

3. Mostly concerned issue:

As we demonstrated above the main parameter in marine accident causation is the criteria "Ability, Skills, knowledge" with weight of (0.0444) in overall expert opinions. Because this is the most important element which directly effect on overall activates. Actually ability, skill and knowledge are the outcomes of training and experience that workers collect over the time. Their definitions are:

ability: power or capacity to do or act physically, mentally, legally, morally, financially, competence in an activity or occupation because of one's skill, training, or other qualification,

Skill: the ability, coming from one's knowledge, practice, aptitude, etc., to do something well: Carpentry was one of his many skills, competent excellence in performance; expertness; dexterity and,

Knowledge: acquaintance with facts, truths, or principles, as from study or investigation; general erudition.

As we understand these are potential factors in every human activity in any field especially in marine transportation. So we suggest the decision makers to consider while planning, organizing, directing, training ..., and people for marine occupations.

REFERENCES

[1]American Bureau of Shipping. (2004). ABS Review and Analysis of Accident Databases: 1991 – 2002 technical Report Number 2003-01).

[2]Article 94,Duties of the flag State, , United Nation Convention on Law Of Sea (UNCLOS 1982)

[3]Ataei M, Fuzzy Multiple Criteria Decision making (FMCDM) (2010) 191-208

[4]Australian Transportation Safety Bureau. (2003). Retrieved Aug, 2003

[5]Cheng, Y. W., Lin, K. H., Chang, K. H., & Huang, W. R. The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative technology selection, Expert [6]Systems with Applications 37 (2010) 419–425Canadian Transportation Safety Board.(2003).Retrieved July16, 2003

[7]Clifford C. Baker , Ah Kuan Seah , Maritime Accidents and Human Performance: the Statistical Trail American Bureau of Shipping . Presented at MARTECH 2004, Singapore, September 22-24, 2004

[8]Collely,John L, Doyle, Jacqueline L, "Corporate Governance"(Tata McGraw-Hill Publishing Company Ltd., 2003)

Corporate Behaviour (http://en.wikipedia,org/wiki/corporate_behaviour)

[9]Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. Management Science, 9, 458–467.

[10]Houston, TX: American Bureau of Shipping. (Internal SAHF Report).

[11]Hsu, H. M., & Chen, C. T. (1996). Aggregation of fuzzy opinions under group decision making. Fuzzy Sets and System, 79, 279–285.

Http://dictionary.reference.com/browse/knowledge?s=t

[12]Hwang, C. L., & Lin, M. J. (1987). Group decision making under multiple criteria: Methods and applications. Springer-Verlag.

Iarossi, F. J. (2003). Marine Safety: Perception and Reality. 17th Annual Chua Chor Teck Memorial Lecture. Singapore. Retrieved May 12, 2003 from http://www.eagle.org/news /speeches/index.html.

[13]IMO Model Course on Marine Accident Investigation (2007)

[14]Iranian Ports and Maritime Organization reports on Marine Accident (2012) from http// www.pmo.ir

[15]Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., & Mieno, H. (1993).

[16]J.J. Buckley, (1985) Ranking alternatives using fuzzy numbers, Fuzzy Sets and Systems 15 (1) 21–31.

[17] JAO-HONG CHENG and et al ,An Application of Fuzzy Delphi and Fuzzy AHP on Evaluating Wafer Supplier in Semiconductor Industry ,Department of Information Management National Yunlin University of Science and Technology ,Taiwan

[18]Jones, M. (2002). Review and Analysis of Accident Incident and Near-Miss Databases.

Kahraman, C., Cebeci, U., & Ruan, D. (2004). Multi-attribute comparison of catering service companies using fuzzy AHP:

The case of Turkey. International Journal Production Economics, 87, 171–184.
[19]Klir, G. J., & Yuan, B. (1995). Fuzzy sets and fuzzy logic – Theory and application. New Jersey: Prentice-Hall Inc.
[20]Kristiansen Svein, (2005), Maritime Transportation Safety Management and Risk Analysis 523, Elsevier Butterworth-Heinemann, UK.
[21]Kuei-Yang Wu , Applying the Fuzzy Delphi Method to Analyze the Evaluation In for Service Quality after Railway Re-Opening Using the O Mountain Line Railway as an Example Department of Architecture National United University No. 1 Lien-Da, Kung-Ching Li, Miaoli 36003, Taiwan, ROC Taiwan, ROC kyw@nuu.edu.tw
Laarhoven, P. J. M., & Pedrycz, W. (1983). A fuzzy extension of Sati's priority theory. Fuzzy Sets and System, 11, 229–241.
Lin, B., Lin, C.-Y., & Jong, T.-C. (2007). Investigation of strategies to improve the recycling effectiveness of waste oil from fishing vessels. Marine Policy, 31(4), 415–420.
Linn, Johannes F, "Anticorruption in Transition" (World Bank Publications 2000) ODEC Principals of Corporate Governance
Liu YC, Chen CS (2007), A new approach for application of rock mass classification on rock slope stability assessment, engineering geology 89,pp 129-143
Maritime Accident Review 2010, , European Maritime Safety Agency Maritime Safety Committee (MSC).255(84) Resolution (adopted on 16 May 2008)
Murray, T. J., Pipino, L. L., & Gigch, J. P. (1985). A pilot study of fuzzy set modification of Delphi. Human Systems Management, 6–80.
Reza, K., & Vassilis, S. M. (1988). Delphi hierarchy process (DHP): A methodology for priority setting derived from the Delphi method and analytical hierarchy process. European Journal of Operational Research, 137, 347–354.
Teng, J. Y., & Tzeng, G. H. (1996). Fuzzy Multi Criteria Ranking of urban transportation investment alternative. Transportation Planning and Technology, 20,
The max–min Delphi method and fuzzy Delphi method via fuzzy integration. Fuzzy Sets and Systems,55,241–253.
UK Marine Accident Investigation Branch (MAIB),Annual Report 1999. Retrieved July 16,2003from http://www.maib.detr.gov.uk/ar1999/04.htm
United States Coast Guard Research and Development Center, (2001). United States Coast Guard guide for the management of crew endurance and risk factors (Report No. CG-D-13-01).
What is Good Governance Stephen P. Osborne The New Public Governance, Emerging Perspectives on the Theory and Practice of Public Governance Published In: United Kingdom, 21 December 2009
Zadeh, L. A. (1965). Fuzzy sets. Information Control, 8, 338–353.
Zhau, R., & Goving, R. (1991). Algebraic characteristics of extended fuzzy numbers. Information Science, 54, 103–130.