Risk Prioritization Based on Health, Safety and Environmental Factors by Using Fuzzy FMEA

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***Abstract*—**Failure Mode and Effects Analysis is assessing technique which relies to the rule of preventing failure, which is used to identify potential hazards. This method is used with minimum risks to predict the problems and deficits in design stage or development of the processes and services in organizations. The methods main principal is based on multiplying three main parameters: severity, occurrence, detection. This method with all the advantages still has minor disadvantages that in this paper attempts has been made to eliminate these deficiencies by fuzzification. Results show that fuzzy FMEA will enables us to evaluate situations correctly and precisely.

***Keywords*—** Failure Mode and Effects Analysis (FMEA), Fuzzy Method, Health, Safety and Environmental (HSE) Factors, Risk Prioritization.

I. Introduction

EVERY year a large number of accidents happen as a result of ignorance of warning signs on offshore Oil platforms that can cause injuries and even death likewise damages to the machinery and operational equipment's force managers and operatives to evaluate and calibrate these compensations that results in development of many methods in this field [1].

One of these methods used today is Failure Method and Effects Analysis [2]. This method is a systematic approach to identify and prevent potential in designing products, processes, etc. In this method first factor is Risk Priority Number the results of multiplying Severity, possibility of Occurrence and ability to Detect that cause hazardous events [3]. To perform this method a table has to be drawn for the variables and point given for each 1 to 10, 1 best and 10 worst. The results of multiplication of these numbers give us the Risk Priority Number RPN so that:

$$RPN = S \times O \times D \quad (1)$$

Where S= Severity, O= Occurrence, D= Detection.

Conditions with higher numbers have higher priority and must be dealt with and be corrected first. FMEA method as a one of the most important methods is an innovative prevention system that can be used during design, process and operation of a product. But unfortunately practice of this method without the use of Fuzzy system has been highly criticized [5, 6, 8, 10]. Including the possibility of pointing of S, O, D in calibration results in similar values and results in producing similar conditions but in fact their hidden risk levels are very different. As an example two different events with numbers 2, 3, 2 and 1, 3, 4 for O, S, D has the same RPN number of 12. Lots of data in this method are obtained orderly and their relative O, S, D parameter are considered unconnectedly and mostly estimated to their level of importance that results in similarity. Precise identification of

These numbers is very difficult and must be reordered in FMEA as "possible", "Important", "Very much" and "Soon".

Reaching an overall understanding in decision making can be difficult and complicated. But its human ability to take successful decisions based on reliable and unreliable data [3]. Fuzzy Theory first introduced by Zadeh (1965) is able to used unreliable data in decision making process. After introducing this theory, fuzzy logic is used present uncertainty and unreliability in and mathematical language to enable us to use these data in real life problems.

Advantages of using the method of prioritization with fuzzy logic can be rephrased as: In this method possibility of obtaining the similarity in results are greatly reduced. Achieved results in this method are far more accurate and practical for use in decision making and finally the mentioned system enables us to evaluate situations correctly. And this is why Fuzzy method has been used in this paper to evaluate the hazards in Oil and Gas industry with considering HSE parameters.

This paper is organized in five parts. The next section describes some background and history of using fuzzy FMEA and section three provides how we used the fuzzy method to evaluate the risk, next section we applied the mentioned method for Oil and Gas Company as case study. Finally, in section five conclusions are provided.

II. History Of Using Fuzzy FMEA

Fuzzy method first used by NASA in 1963[10], but by continuation of usage by Ford in 1977 better application of this method has been identified [11]. Fuzzy FMEA help to identify ambitious and inaccurate data and achieve an accurate answer [13]. When the relationships between data are unknown or the relationship cannot identify properly fuzzy theory becomes very useful. Fuzzy FMEA has been used in many researches to evaluate hazards. Yu and Eskinowski

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(2000) produced a system on the basis of Fuzzy in FMEA systems. Xu, Tang, Xie, Ho Zhu and Jia (2002) produced FMEA system on the basis of Fuzzy to tackle and evaluate motors. Guimaraes and Lapa (2004) proposed to use Fuzzy in FMEA to estimate the risk. Bukowski and Feliks (2005) introduced a new method by using Fuzzy to evaluate the risk in a system by combining FMEA and Failure mode, effects and criticality analysis (FMEACA) simultaneously to remove their disadvantageous. Their observations showed FMEA combined with Fuzzy on the basis of Failure mode and Effects Analysis is very practical in obtaining data and enable us to use these data in automated systems. Tay Teh and Bong developed and updated this method to use Fuzzy in FMEA systems. Tay and Lim (2006) in order to simplify the FMEA with Fuzzy, reduced the rules in the model to obtain Fuzzy Risk number (It is called FRPN) and evaluate this system in three divisions of scientific practicality. Chin, Chang and Yang (2008) an evaluating process in Fuzzy FMEA and been produced. In the model proposed by them they introduced an initial model that allows inexperienced user to use FMEA to improve the quality, reliability and evaluations of the designs and to help in decision making and cost reduction, this helps increase the ability in designing new products in design stage. Wang, Chin ,Poon and Yang (2009) analyzed risk FMEA by using Average Geometrical weight. Chang, cheng and chang (2010) calibrate the failure by using Fuzzy calibration. Yang, Xu , Chen, Hao, Zhu and Jia (2010) proposed a new system by Using Fuzzy FMEA in CNC machinery. The results produced in CNC machinery showed reliable and logical in production and could be used to produce a reliable model with the help of QC unit. Liu , Liu, Bian, Lin, Dong and Xu (2010) with the use of deduction analysis of fuzzy evidential reasoning improved the use of FMEA with a traditional approach.

III. Identifying And Evaluating Hazards

It is crucial to have a good understanding of what hazard is, otherwise it does not make a sense to speak about control or prevention [19]. Capital and time are two main assets managers struggle to control. Hence a good manager can predict hazards and have more control over these assets. Safety engineers and fire fighters visit the establishment and identify the hazards then analyze the risk in presence of the managerial team and compose a risk table form with the data from the visit. Completed form is confirmed by the head of HSE on platform. Analysis of the hazards by the parameters of O, S, D with the RPN equation is calculated. Level of hazard in the system is then prioritized and signed by the head of HSE. This method can be used in all section of offshore platform. Severity, Occurrence and Detection in the traditional approach is a basis of RPN in Fuzzy system. Functionality of these parameters is identified by lingual variables.

In Tables 1, 2 and 3 a few of these lingual variables are mentioned. The output of RPN number is divided into 5 groups, as an example “Low”, “Low to Medium”, “Medium”, “Medium to High” and “High”.

TABLE I
PROBABILITY OF OCCURRENCE WITHOUT FUZZY [5,6]

Grade	OCCURRENCE	Failur
9,10	Very High: Failure will happen	1-2>
7,8	High: Repetitious failure,	1-8 1-20
4,5,6	Medium: Often failure	1-80 1-400
2,3	Low: Rarely failure	1-1500
1	Very Low: Failure unlikely	<1-1500

TABLE II
GRADING OF LEVEL OF SEVERITY WITHOUT FUZZY [5]

Grade	EFFECT	Severity
10	Hazardous- Not Alarmed	Very high level of severity, effects and stops the safety and alarm systems
9	Hazardous-Alarmed	Very high level of severity, effects and stops the safety and alarm systems
8	Very High	Irreparable system, damage to equipment but the safety
7	High	Irreparable damage to equipment
6	Moderate	Irreparable damage to equipment
5	Low	Irreparable damage to equipment
4	Very Low	System Repairable with significant Effect on operation
3	Negligible	System Reparable with low effect on operation
2	Very Negligible	Repairable damage, insignificant interference with the system
1	None	Insignificant

In Tables 4, 5 and 6 functionality of these lingual variables are shown. Membership functions are used to transfer lingual variables into other functional variables.

TABLE III
GRADING OF DETECTION WITHOUT FUZZY [5,6]

Grade	EFFECT	Detection
10	Hazardous without Alarmed	Very high level of severity, effects and stops the safety and alarm systems
9	Hazardous with Alarmed	Very high level of severity, effects and stops the safety and alarm systems
8	Very High	Irreparable system, damage to equipment but the safety
7	High	Irreparable damage to equipment
6	Minor	Irreparable damage to equipment
5	Low	Irreparable damage to equipment
4	Very Low	System Repairable with significant Effect on operation
3	Minor	System Reparable with low effect on operation
2	Very Minor	Repairable damage, insignificant interference with the system
1	None	nsignificant

Lingual values of O, S, D which are inserted in the Table 10 are considered as input of the Fuzzy Tech. These lingual values are gathered with the help of HSE experts. In Table 11, the highest value in FRPN is similar to the 9th activity number in Table 9 and must be considered as a priority, but in this

table the FRPN results are not similar anymore and will not make problem in prioritizing.

TABLE IV
GRADING OF DETECTION IN FUZZY [5]

Grade	DETECTION	Fuzzy Number
Absolutely Uncertain	Hazardous- Not Alarmed	(9,10,10)
Very Remote	Hazardous- Alarmed	(8,9,10)
Remote	Very High	(7,8,9)
Very Low	High	(6,7,8)
Low	Moderate	(5,6,7)
Moderate	Low	(4,5,6)
Moderately high	Very Low	(3,4,5)
High	Remote	(2,3,4)
Very High	Very Remote	(1,2,3)
Absolutely Certain	None	(1,1,2)

TABLE V
FUZZY GRADING OF SEVERITY [5]

Grade	SEVERITY	Fuzzy Number
Hazardous without Alarmed	Hazardous- Not Alarmed	(9,10,10)
Hazardous with Alarmed	Hazardous- Alarmed	(8,9,10)
Very High	Very High	(7,8,9)
High	High	(6,7,8)
Moderate	Moderate	(5,6,7)
Low	Low	(4,5,6)
Very Low	Very Low	(3,4,5)
Minor	Remote	(2,3,4)
Very Minor	Very Remote	(1,2,3)
None	None	(1,1,2)

TABLE VI
GRADING OF OCCURRENCE IN FUZZY [5]

Grade	OCCURRENCE	Fuzzy Number
Very High	Very High: Failure will happen	(8,9,10,10)
High	High: Repetitious failure	(6,7,8,9)
Medium	Medium: Often failure	(3,4,6,7)
Low	Low: Rarely failure	(1,2,3,4)
Unlikely	Very Low: Failure unlikely	(1,1,2)

TABLE VII
DEFINITIONS OF FUZZY TO EVALUATE RISK [5]

Linguistics	Fuzzy Number
Very Low	(0,0,0.25)
Low	(0,0.25,0.5)
Medium	(0.25,0.5,0.75)
High	(0.5,0.75,1)
Very High	(0.75,1,1)

As an example in Table 9, the 6th and 7th activity has the same priority number of 2 that makes problem in decision making but in Table 10, activity of 7 has Priority 2 and activity of 6 has priority 3.

IV. ANALYSIS OF AN OFFSHORE OIL PLATFORM AND COMPARING RPN AND FRPN

After sufficient observation and with the help of Oil Company's IOOC possible hazards to an operator has been observed and analyzed and the RPN number with the help of HSE team has been calculated. As mentioned before to calculate RPN equation 1 must be used, for example for the first activity RPN= 5×2×7=70, then the RPN number for all activity has been calculated and written in Table 8.

After obtaining the value for RPN table activities, it needed to identify the priority number which has been organized and added as descending order of RPN, result are shown in the Table 9.

In the next step for qualifying the factors, problem has been tackled with Fuzzy logic. For doing so, computer software program Fuzzy Tech is used which calculate the RPN number using Fuzzy logic. In this software three parameters of O, S, D as input and FRPN as output are set. Then, 500 rules are set in execution of program to get the most accurate results.

V. CONCLUSION

FMEA is an important technique to identify and remove the causes of failure and to increase the level of confidence and safety in a complex system. The main goal of using this technique is to obtain data and to help making the best decisions for risk managers. In fact parameters of O, S and D are used as Fuzzy variables and the output results are FRPN (Fuzzy Risk Priority numbers). So FRPN proposed to priorities the unknown and uncertain situations. As result shows there has been a lot of difference in prioritizing numerically in Fuzzy.

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TABLE VIII
RPN RESULTS OF AN OPERATOR ON AN OIL PLATFORM

No	**Activity**	**Hazard**	**Cause**	**Effect**	**D**	**O**	**S**	**RPN**
1	Daily activities	Contact with H2S gas & inhalation	Corrosion in pipeworks, High pressure, deliberate	Gas poisoning	5	2	7	70
2	Operations	Contact with H2S gas & inhalation	Corrosion in pipeworks, High pressure, deliberate	Death	5	2	4	40
3	Cleaning	Contact with Naphta & inhalation	Ignorance of PPE inappropriate use	Skin and eye erosion	6	2	7	84
4	Daily activity	Feet stock in gratings	Ignorance, Corrosion in Gratings	Injuries	2	4	4	32
5	Daily activity	Heavy objects drops	Ignorance of PPE inappropriate use	Injury, Bone breakage	1	6	7	42
6	Daily activity	Loud noise	Problem in Design, Corrosion, High pressure, Ignorance to PPE	Deaf, injury to hearing	5	6	8	240
7	Daily activity	High magnetic fields	Ignorance, Corrosion in insulation	Level 3 burn	6	5	8	240
8	Climbing ladders, stairs in case of fire	Drop from the stairs in case of fire	Ignorance, Corrosion in Gratings	Injury, Bone breakage	4	3	7	84
9	Daily activities	High magnetic fields	Ignorance, Corrosion in insulation	High magnetic fields	6	5	9	270

TABLE IX
GRADING OF HAZARD PRODUCED BY AN OPERATOR ON PLATFORM

Priority	RPN	Activity	Fuzzy Number
3	**70**	**1**	(9,10,10)
5	**40**	**2**	(8,9,10)
3	**70**	**3**	(7,8,9)
6	**32**	**4**	(6,7,8)
4	**42**	**5**	(5,6,7)
2	**240**	**6**	(4,5,6)
2	**240**	**7**	(3,4,5)
3	**70**	**8**	(2,3,4)
1	**270**	**9**	(1,2,3)

TABLE X
FUZZY PRODUCED OUTPUT

Output	Fuzzy FMEA	Detection	Occurrence	Severity	Hazard
0.49384	Medium	Low	Low	High	In contact, Inhalation of H2S from Oil and Gas Pipes
0.29764	Low	Low	Low	Very low	In contact and inhalation of H2S
0.49414	Medium	Medium	Low	High	In contact and Inhalation of Naphtha
0.21458	Low	Insignificant	Medium	Very low	Feet stock in Gratings
0.41982	Medium	None	Medium	High	Fall of items and suspended objects on personnel's head
0.65004	High	Low	Medium	Very High	Very loud noise of oil and gas pipes
0.74490	High	Medium	Medium	Very High	Stock in very high magnetic fields
0.49782	Medium	Very Low	Low	High	Drop and Fall from stairs during fire
0.74510	Very High	Medium	Medium	Dangerous	Stock in very high magnetic fields

TABLE XI
GRADING OF FUZZY SYSTEM

Priority	RPN	Activity	Fuzzy Number
6	0.49384	1	(9,10,10)
8	0.29764	2	(8,9,10)
5	0.49414	3	(7,8,9)
9	0.21458	4	(6,7,8)
7	0.41982	5	(5,6,7)
3	0.65004	6	(4,5,6)
2	0.74490	7	(3,4,5)
4	0.49782	8	(2,3,4)
1	0.74510	9	(1,2,3)