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Environmental risk management associated with the development one of oil fields in southwestern Iran using AHP and FMEA methods

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Abstract: Nowadays risk management is intended to be a solution in project management to deal with the risks and events that may occur in an industrial project. The risk management is a process that is able to identify, analyze risks and determine strategies to reduce the effects of that. Also, most managers are challenged, especially when they are supposed to choose between multiple solutions to a problem. In this project we have tried to use the FMEA and AHP techniques to evaluate the environmental risk posed by Ahvaz oil field development as well. List of aspects and environmental impacts of completed construction and operation phases and the scoring were based on the criteria mentioned methods. The level of risks were at three levels: low, medium and high, respectively. For the construction phase from all 35 rated risks 5 were high-level, 19 were medium-level, and 11 showed a low level of risk. Operation phase from all 29 risks 4 were high-level risk, 15 were medium risk and 10 were low-level. In the end, strategies for reducing environmental pollutants in construction, operation and management phase and in the framework of manpower, vehicles, materials and operations are provided.

Keywords: Risk management. Ahvaz oil field. FMEA. AHP.

1. Introduction:

Considering the increasing requirement of industries and the present economic situation of the country from the aspect of developing more income resources based on export, exploiting oil as one of the most important resources of energy in the 21th century on one hand, and reducing the cost of discovery, new harvest technologies, taking advantage of new technologies and economizing of the production on the other hand has encouraged oil producers to work in this field. Oil field is called to a geographical area where we can drill several wells and extract oil from them. The study area is in the Ahvaz of research fields. The field is located in southwestern of Iran (Ahvaz in Khuzestan province. The Ahvaz oil field was discovered by geophysical operations by digging wells in the area and was established in 1295. The researches on this field is now in process by National Iranian South oil fields Company and development activities are underway. The oil reserves of Ahvaz oilfield is not estimated yet, but it's expected to produce around 10 thousand barrels of oil from fields in early production stage.

Considering the complexity of technology and equipment for oil and gas resources in the country and existence of a large number of working force, identifying risks in control stage is the most important step(Josie and Farokhi,2012). Nowadays a project confronts with many different risks that if faced with each of them the results have to be reviewed. This risk leads to various problems such as the increasing environmental problems that it causes more attention to the topic of environmental risk assessment (Allen et al, 2009). Risk management is the systematic process of identifying, analyzing and responding to project risk. This management ensures maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives (Afkhami et al,2013) Analysis of failure modes and effects on the environment is a qualitative evaluation of environmental impacts that its purpose is to provide a tool to facilitate the development of production by companies with regard to environmental considerations (Abrahim and Parker,2008). Hierarchical decision-making process (AHP; Analytic Hierarchy Process) is one of the most used multi-criteria tools. This method may be used when facing with few options and decision criteria. This criteria can be qualitative or quantitative. The baseline of this decision- making method lies on pairwise comparisons (karbassi et al,2008; Hosseinzadeh et al., 2017)

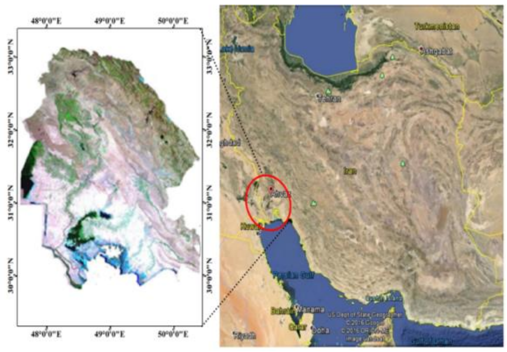


Fig 1: Geographical position of study area in the Iran

2. Research method

1.2 Study area

The study area is the Ahvaz oil field. The field is located in Khuzestan province in southwestern of Iran. The studied area is located in Khuzestan Province, west/southwest of Iran, between latitudes 40´ 47° to 33´ 55° east and longitudes 57´ 29° to 00´ 33° north (Fig.1). One of the most important geological features of Khuzestan is the presence of several oil fields in its mountainous and plain areas. Because of the abundance of oil fields, in addition to geological studies, there has been a special focus on contamination studies in this province. The studied area is part of the Zagros fold-and-thrust

belt ranging in age from Cambrian to present era and most of the exposed formations in the oil fields and related to groundwater resources can be classified as calcareous formations (Asmari formation), gypsum-marne formations (Gachsaran formation), Bakhtiari conglomerate formations and present era sediments Management process of environmental risks resulting from the development of Ahvaz using analytic hierarchy process (AHP) and analyzing the causes of failure and its consequences (FMEA) is stated as figure 2.

2.2 Approaches and materials

This research method was performed based on field visits from all functional and process units and interviews with experts, review past events, past results of audits and inspections, including collecting details of the process to determine the potential risks, the effects of any risk to determine the causes risk, determine the extent of occurrence (probability of occurrence of the deterioration rate).

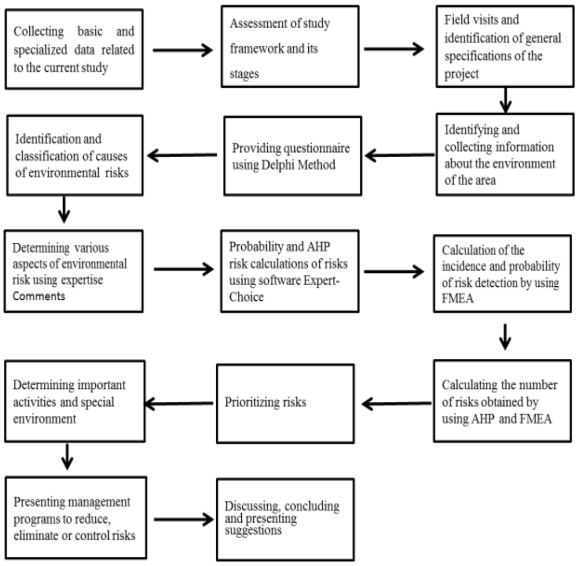
2.2.1 Potential failure modes and effects analysis(FMEA)

Like all methods for risk assessment, Failure Modes and Effects Analysis (FMEA) has its own its identification and analysis capabilities. The most important achievement of this method is vulnerable elements of the process as well as critical system areas. Taking into account the quantitative index of any destruction, this method has significant impact on reducing the risks and costs of failure of the operational and maintenance units. The proposed research method was conducted according to the following steps:

A) The potential failure modes (aspect)
B) The potential effects of downtime (the outcomes).
C) The intensity (S).

Assigning a number between 1- 4 in accordance to the figure 2 and tables 1-3, the environmental risks are ranked:

Fig. 2. framework Processing Method



D) Detection

A scale of 1 to 3 is used to determine the detection rate of the proposed table 1.

E) Safety level or risk index

The arithmetic mean is calculated data using the following formula:

$$x = \frac{1}{N}\sum_{i=1}^{N} x = \frac{xi + x2 + \cdots + xn}{N}$$

x = arithmetic mean
N = the number of data
Xi = data (RPN)

Then the number of data standard deviation was calculated by the formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(xi - x)^{2}}$$

σ = standard deviation

Table 1. The intensity of outcome / environmental risk

Class	Rank	Description
Disastrous	4	Irreversible degradation of resources and lack of effective measures to reduce and control the widespread contamination inside and outside the region, repeated complaints from interested parties, irreversible damage to the environment (destruction of natural monuments and mortality of Antiquities and disturbance of the balance of life in the region)
Critical	3	Severe damage to the environment (mortality beneficial organisms, poisoning humans), emissions within the region, together with the effects of the accident on environment, natural resources
Average	2	Consumption of natural resources with little savings, moderate damage to the environment (reversible pollution and unseemly sights)
Weak	1	Natural resource consumption and emissions to the not-so-noticeable impact on the surrounding area

Xi = data (RPN)
X = average data

In order to determine the risk level (high, medium and low), to prioritize corrective actions and control of the following formula is used:

σ + X = high risk
σ - X = low Risk

And the risks between high and low levels are medium level risk.

Table 2. Chance Discovery (identifying) impact / environmental risk

Class	Rank	Description
unrecognizable	3	There is no operating system, there is no awareness of the risks, inconsistencies and contradictions can be seen in environmental and ecological parameters and decisions are entirely based on personal opinions
Detected by 50-50 probability	2	Identifying and assessing the risks and environmental aspects have been done, but still are not operational and there is no review of this assessment, there are some controls on the environment
Recognizable	1	Review system is very effective in risk assessment, environmental control mechanisms work well and are quite powerful identification and declaration of contamination

3. Discussion

3.1.Analytic Hierarchy Process method (AHP)

This process involves different possible options in making decisions and has the ability of sensitivity analysis on its criteria and sub criteria. In addition, the above- mentioned process is based on pair-wise comparison which facilitates judgment and calculations. It also shows the compatibility and incompatibility decision that is one of the benefits of this technique in multi-criteria decision making (Dinmohammadi and Shafiee,2013)

3.2.Fundamentals of Analytical Hierarchy Process

* principle 1: reverse condition (Reciprocal Condition)
* principle 2: homogeneity (Homogeneity)
* principle 3: dependence (Dependency)
* principle 4: expectations (Expectation)

3.3.Calculating the weight

In the hierarchy process, the elements of each level is compared pair-wise to their respective elements in the higher level and their weights would be calculated. These are called relative weights. Then by combining the relative weights, the final weight of each option is determined which is called absolute weight. In these comparisons, decision makers will use the oral judgment in such a way that if the elements i and j are compared with the each other, the decision-maker says that importance of i to j will be one of the following scenarios:

Table 3. preferred values for comparing (Asgharpour, 2008)

Comparing the relative index i to j (in relation to the target)	The relative importance level (score)
Equal importance	1
Low importance of i on j	3
High importance of i on j	5
Very high importance of i on j	7
Absolute importance of I on j	9
Preferences between intervals i to j	2, 4, 6, 8

3.4.Calculating the relative weight

In general, a pair comparison matrix is shown below where aij is the preference of ith element to jth element.

$$A=\begin{vmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{vmatrix}$$

$$A=[a_{ij}] \qquad I, j=1,2,\dots,n$$

In this study, Special Vector method is used to calculate the weight of which its usage has been much easier by software EC.

3.5.EXPERT CHOICE software (EC) EC, which is based on the Special Vector method, has been developed to analyze the multi-criteria decision problems using the Analytic Hierarchy Process. The software has many capabilities and in addition to designing hierarchical structure, decision-making and designing preferences questions and calculating the final weight, it also has the ability to evaluate the sensitivity to changes in problem parameters (Qudsi Pour, 2009).

After completing the questionnaires, the geometric mean were computed from resulted values and the corresponding number were entered in EXPERT CHOICE software and the pairwise comparisons matrix. Finally, weight and values of the occurrence of any of the risks emerged were taken from the output of the application which are as decimals and less than 1. Probabilities that have won more weight have a higher degree of importance than other possibilities are. Now attempt has been done to obtain the intensity values of the occurrence of environment risk resulted from Ahvaz oilfield development by using factor analysis of failure and its effects on the environment (EFMEA) which is one of the methods of FMEA. In this regard, questionnaires were prepared and grading was done through expertise and severity of risk was calculated in different environments. The values of the intensity of the incident was ranked by assigning a number from 1 to 10 in the table (1-2). Then the calculation of risk was started. In this regard, the probability obtained from AHP multiplied in intensity value obtained from EFMEA and the value and number of risk were calculated.

Risk= risk of danger calculated by AHP * the severity and magnitude of the incident calculated by FMEA

4- Results

4-1: A questionnaire has been prepared to determine the causes of risks in the Ahvaz oilfield development project using Delphi method. The questionnaire was distributed among environmental experts associated with the project such as National Iranian South Oil Company personnel, experts of Ahvaz oilfield development project, and etc. and identifying and prioritizing risk factors in the current project was performed based on forms completed and technical comments collected**.**

4-2: Results of questionnaire

The results of the questionnaire are presented on the priority basis in Table 4.

Table 4. The results of the questionnaire are presented on the priority basis.

Factor	Importance Level					Total sum	Average
	Very high importance (5)	High importance (4)	Medium (3)	Low importance (2)	Very low importance (1)		
Construction of camp and workshop	6	8	6			80	4
Cutting bushes		7	8	5		62	3.1
Handling equipment		5	11	4		61	3.05
Sand planning and road construction		7	10	3		64	3.3
Deployment of personnel at camp	7	9	4			83	4.15
Bitumen spray	2	8	10			75	3.6
Asphalt planning		7	9	4		63	3.15
Installation of wellhead	11	5	4			87	4.35
Daily traffic personnel	9	10	1			88	4.4
Oil spill in the area	13	7				93	4.65
Welding	12	7	1			91	4.55
Failure of cooling equipment containing gas cfc	5	12	3			82	4.1
Maintenance and replacement of parts	8	9	3			85	4.25
Insulation of pipes	4	5	11			73	3.65
Construction activities	5	5	10			75	3.75
Turning on the fellers of utilization units	5	6	6	3		73	3.65
Pigging operations	8	5	5	2		79	3.95
Welding test	10	7	3			87	4.35
Piping the casing well	9	9	2			87	4.35
Acid dipping operation	12	8				92	4.6
Desalination process	10	10				90	4.5
Fracture of pipelines	11	9				91	4.55
Leaks in pipelines	10	11				94	4.7
Fire in the pipeline	9	9	2			87	4.35
Pipeline pressure test	4	5	9	2		71	3.55
Replacement oil filters and generators fuel	7	10	3			84	4.2
Replacement oil filters of machinery	8	11	1			87	4.35
Kitchen, bathroom and office wastewaters	9	11				89	4.45
Industrial wastes	4	5	9	2		71	3.55
Food wastes	4	5	9	2		71	3.55
Cutting	7	8	5			82	4.1
Radiography (logging, imaging inside the well)	9	8	3			86	4.3
Gas H2s	11	6	3			88	4.4

Table 5. Weighting to aspects of the construction phase

aspects of the construction phase	
Construction debris caused by the construction of camps and workshops	**J1**
Water consumption caused by the construction of the camp and workshop	**J2**
Electricity consumption caused by the construction of the camp and workshop	**J3**
Removal of vegetation caused by cutting bushes	**J4**
Dust emissions caused by movement of equipment	**J5**
Production of particle debris caused by sand and road planning	**J6**
Water consumption caused by sand and road planning	**J7**
Fuel consumption caused by sand and road planning	**J8**
Energy consumption resulting from the deployment of personnel at camp	**J9**
Water consumption resulting from the deployment of personnel at camp	**J10**
Noise making resulting from the deployment of personnel at camp	**J11**
Wastewater generated by the deployment of personnel at camp	**J12**
Dangerous gas emissions caused by bitumen spray	**J13**
Smoke emission resulting from bitumen warming-up	**J14**
Dust particles emission in the air from asphalt planning	**J15**
The noise caused by the installation of wellhead equipment	**J16**
Dust emissions due to the installation of wellhead equipment	**J17**
Noise pollution caused by daily traffic personnel	**J18**
Noise caused by the welding	**J19**
Waste electrodes caused by welding	**J20**
Polluting materials emission caused by welding	**J21**
Cfc gas emissions resulting from the repair and replacement of parts containing cfc	**J22**
Non-hazardous waste resulting from the repair and maintenance parts	**J23**
Dust emissions arising from repair and replacement parts	**J24**
Noise caused by the repair and replacement parts	**J25**

Table 6. Weighting to aspects of the operation phase

aspects of the operation phase	
Dust emissions caused by movement of equipment	**J1**
Noise pollution caused by daily traffic personnel	**J2**
Releasing oil into the environment due to fuel consumption	**J3**
Non-hazardous waste resulting from the repair and maintenance parts	**J4**
Dust emissions arising from repair and replacement parts	**J5**
Noise caused by the repair and replacement parts	**J6**
Greenhouse gas emission caused by turning on the operation units' fellers	**J7**
Water consumption caused by pigging process	**J8**
Release of waste water in the flowing waters caused by pigging process	**J9**
Waste water caused by piping of casing well	**J10**
Production of hazardous wasted caused by acid- induced work	**J11**
Wastes resulting from desalination process	**J12**
Hazardous waste waters resulting from desalination process	**J13**
Production of fluids from the tube pressure test	**J14**
Water consumption due to tube pressure test	**J15**
Release oil and diesel fuel due to replacing oil and diesel filters of generators	**J16**
Wastewater generated by the deployment of personnel at camp	**J17**
Water consumption to deploy of personnel at camp	**J18**
Solid waste resulting from the deployment of personnel	**J19**

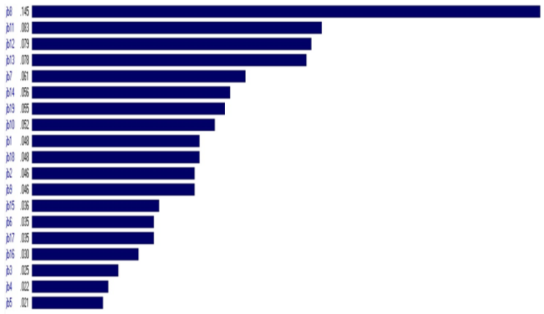


Fig. 3. Prioritizing aspects of the construction phase using the software EXPERT CHOICE

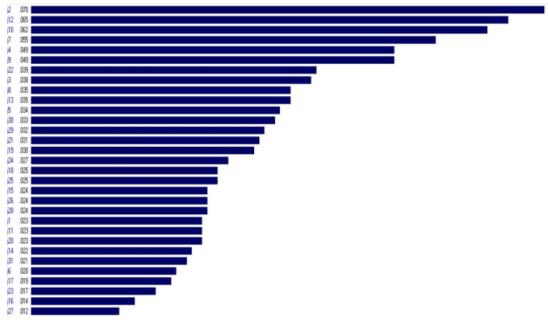


Fig. 4. Prioritizing aspects of the operation phase using the software EXPERT CHOICE

5.Conclusion

Since the method EFMEA has no RPN basis to compare the values of risk obtained and determine their level to determine the level of risk, methods such as statistical analysis risk index, and high and low risk are appointed and risks are prioritized based on them. For this purpose, through the venture level or priority number, the risk index was calculated using the frequency distribution. It should be noted that all calculations were performed using SPSS software. Then the average rating was calculated and finally the venture level was calculated based on the average of the rating with the highest frequency. Then, based on the degree of risk-taking, the ranking of the number of categories was calculated by the following formula and the length of the category was obtained from difference between the smallest and largest amount of risk priority number on the number of classes (categories).

Number of classes =1+3.3LogN

$$\text{Length of class} = \frac{\text{Smallest RPN} - \text{Largest RPN}}{\text{Number of classes}}$$

The aspects which their number of priority was higher than the degree of risk- taking were considered to be as critical activities (which are in need of corrective measures). Also, calculations and data analysis was performed using EXCEL software and the results were analyzed.

Construction phase calculations

Number of classes = 1+ 3.3 LogN

1+3.3 LOG35 = 6.09

$$\text{Length of class} = \frac{\text{Smallest RPN} - \text{Largest RPN}}{\text{Number of classes}}$$

$$\frac{0.068 - 0.002}{1.06} = 0.010$$

Table 7. Results of the initial construction phase RPN

Number of data	35
Number of classes	6.09
The smallest risk priority number	0.002
The largest risk priority number	0.068
Length of the class	0.010

Table 8.Class limit of construction phase

Calculation of class limit	
0.002+0.010= 0.012	L1= 0.002 – 0.012
0.012+0.010= 0.022	L1= 0.012 – 0.022
0.022+0.010= 0.032	L1= 0.022 – 0.032
0.032+0.010= 0.042	L1= 0.032 – 0.042
0.042+0.010= 0.052	L1= 0.042 – 0.052
0.052+0.010= 0.062	L1= 0.052 – 0.062
0.062+0.010= 0.072	L1= 0.062 – 0.072

Table 9.The frequency category of construction phase

Class	Frequency
L1= 0.002 – 0.012	20
L1= 0.012 – 0.022	5
L1= 0.022 – 0.032	6
L1= 0.032 – 0.042	0
L1= 0.042 – 0.052	2
L1= 0.052 – 0.062	0
L1= 0.062 – 0.072	2

Average= 0.018
SD (Standard Deviation) = 0.011
σ + X = High Risk 0.029 = 0.011 + 0.018
σ - X = Low Risk 0.007 = 0.011 - 0.018

Table 10.Classification of risks in the EFMEA

Risk level	Risk range
High risk	0.007 RPN<
Medium risk	0.007 RPN< <0.029
Low risk	RPN <0.029

Finally in the construction phase, from all 35 risks there are 5 high, 19 medium and 11 low. And in operation phase, from all 29 risks there are 4 high, 15 medium and 10 low.

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