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A Hybrid Approach Based on AHP and FMEA Approaches for Risk Assessment of Refinery Construction Projects

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ABSTRACT

Through risk assessment, very valuable data was provided for decision making about risk reduction, improvement of the surrounding environment of hazardous installations, planning for emergency conditions, acceptable risk level, inspection and maintenance policies in industrial installations, and other cases. The gas and petrochemical industries have always been considered by the safety and environment experts and professionals, because of their numerous and widespread hazards. The purpose of this research was to assess the risk ratio of the phases of 17 and 18 refineries of Asaluyeh. The research method used in this research was descriptive-analytical, and multi-criteria models (hierarchy analysis) and FMEA risk assessment model were used. The results of this research indicated that the risk of oil and gas installations infrastructure in the phases of 17 and 18 refinery, for a hard and special threat meant that the occurrence probability of air and missile attacks and cyber attacks and bombing in such installations were located at the primary degree of threats.

Keywords: *Threat, Risk Assessment, Hierarchy Analysis, Construction Project.*

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1. INTRODUCTION

During the recent several decades, the occurrence of horrific events such as Bhopal in India, Chernobyl in Ukraine, Flixborough in England, and Suso in Italy have attracted the public's attention to the chemical industries and various risks existing in them and, consequently, have increased the necessity of a systematic analysis of the safety of various processes in the chemical industries (Eskandari, M, et al., 2015: 19).

Considering that oil, gas and petrochemical storing reservoirs are regarded as important and basic infrastructures, this industry has always been considered by the safety and environment experts and professionals (Bashiri Nasab, 2009: 1-11). In gas refineries, operational units deal with high temperature and pressure, and consequently, there is a probability of occurring events (Josie A, et al., 2013: 1-13). In the case of war occurrence and bombardment in cities, in a very short time, the functional system of infrastructural installations gets damaged (Hakim Panah, 2009: 103). These installations are created and exploited at a high cost that damaging them causes the pause of production and delivering services to the citizens, and the economic and social losses (JICA, 2000: 63). More than two thirds of threats are nowadays focusing on infrastructures and vital arteries, and the important role of vital arteries in the comprehensive management of urban crisis and the close link between these networks with each other on the one hand, and their economic value on the other hand makes us pay special attention to them (Lee et al., 2007: 29). Therefore, defending the vital infrastructures of every community is one of the determinant presuppositions for the survival of that community. Non-passive defense in vital arteries is a set of measures that protect such centers against deliberate man-made threats. Assessing the vulnerability and risk of vital arteries, and observing the non-passive defense principles is the only guarantee for their salvation against threats.

Risk assessment is a logical method to investigate risks that identifies the hazards and their potential consequences on individuals, materials, equipment and environment. In fact, in this way, very valuable data is provided for decision making about risk reduction, improvement of the surrounding environment of hazardous installations, planning for emergency conditions, acceptable risk level, inspection and maintenance policies in industrial installations, and other cases (Nivolianitou, 2002). Risk assessment can be done by two qualitative and quantitative methods. A quantitative assessment focuses on risk factors and taking preventive measures, and is performed to control, eliminate or prevent hazards. In this regard, a scientific approach for decision making is required for the justification of costs, prevention and reduction of risk, and the necessity of rapid risk control programs. Accordingly, the purpose of this research was to evaluate the refineries construction projects based on the passive defense perspective, and the question that the researcher analyzed and investigated was how the risk assessment of the South Pars phases 17 and 18 assets is on the basis of human-made threats.

2. RESEARCH HISTORY

Nouri et al. (2010) investigated the gas stations in order to assess the fire occurrence risk, and eventually, by combining the William Fine and FMEA methods, determined fire intensity at the stations (Nouri J, et al. 2010, 143-152).

Ebrahimzadeh et al. (2011) concluded in a research that the highest level of RPN score in the activities of transporting and replacing objects and the section of scraping external surfaces preceded and followed by corrective measures were (200, and 210), (72, and 84); respectively, while the priority score of risk in the welding and external drilling activities before and after the corrective measures was the RPN score of (144 and 120) and (24 and 36); respectively. In a research, Adl et al. (2013) concluded that the implementation of preventive repairs of a unit, the preparation and accurate implementation of these repairs can be the most important suggestion that can lead to the risk reduction by decreasing the probability of occurrence.

Eskandari et al. (2015), in a research by introducing water and electricity arteries and by using two models of graph theory and the Leontief model, counted 240 scenarios to assess the vulnerability and risk of these arteries, and among the single-variable scenarios, the explosion scenario in the purification unit, and among the combination scenarios, two purification units and an electricity station had the highest probability of occurrence (Eskandari et al., 2015: 19).

Mohammad Ataee (2014) in a research, evaluated airport key assets, airport threats, and airport vulnerability (Ataee, 2014: 22). Wang et al. (2013) in a research showed that the use of insulating layer in the interior and exterior walls of the design of reservoirs reduced their potential vulnerability during the earthquake (Wang D et al., 2013, 110).

Chang & Chang (2011) studied the incident in the industrial installations storing reservoirs in the last 40 years. Their results showed that 74 percent of the incidents occurred in oil refineries, oil terminals and their storage (Chang & Chang, 2011: 51). Millazzo and Maschio conducted a study in Italy in 2008 that considered most of the transportation systems of hazardous materials (Millazzo and Maschio, 2008: 37). Catalina and Cioaca (2013) in a research investigated the event probability of threats in the airport, especially passenger terminals, and offered solutions to neutralize or reduce the effects of terrorist threat on terminals (Cioaca, 2013: 82)

3. RESEARCH METHOD

This research has been of analytical-evaluation type. To investigate the research question, the Vulnerability Assessment Model and the Federal Risk Management of Emergency Management Agency (FMEA[1]) and also in the section of valuating and weighing the research criteria, L. Saaty Network Analysis Model were used. In order to validate the results, in the first step, assets, threats, and vulnerability indicators were weighed. In order to weigh the indicators after setting the questionnaire, they were distributed, and their results were extracted by using the Analytical Hierarchy Process (AHP) technique in Expert Choice software. After weighing the assets of the phases of 17 and 18 refineries of South Pars Site One, in the next step, based on the FMEA risk assessment model, the researchers obtained the weights of each asset that were extracted in the previous stage among the threats that endangered the equipment of the region. In the following part, the table of threats has been represented.

Table 1: Probability of Threat Occurrence (Research Findings)

No.	Threat type	Type	Implemented Threat Method	Occurrence Probability
1	Hard	Tool oriented	Air and missile attacks	
			Chemical, microbial, nuclear attacks	
		Method oriented	Marine attacks, regular ground attacks	
2	Semi-hard		Attacks by electromagnetic, graphite, sound bombs	
3	Soft threat	Security	Spy and human influence and so on	
			Unsafe demonstration, chaos and turbulence	
		Non-security	Economic sanction, cultural invasion, psychological operation and so on	
4	Special threats	Modern terrorist	Cyber terrorism and so on	
			Bioterrorism	
		Classical terrorism	Threat to bombing and its implementation	
			Suicide attacks and remote control explosive shipments and so on	
			Urban punitive attacks and so on	
			Hostage taking , kidnapping and so on	
			Murder, assassination and so on	

Having prioritized the threats of the equipment of the region, in the next step, the vulnerability assessment of the region's assets against potential threats based on the confrontation weakness, defensive and protective weakness, access possibility, and the possibility to discover and identify were determined.

Hence, for each asset, a risk matrix was formed. In the risk matrix, having the numbers of assets, threat and vulnerability obtained from the previous sections, the final number of risk was obtained. In the assets, risk matrix of the region, in one dimension of matrix, the numbers related to risk components and in another dimension, the screened threats were located, so that ultimately the risk ratio of each asset against each threat was clearly specified. The obtained risk numbers carried useful conceptual outcomes, but it must have been specified what is the meaning of highness or lowness of risk numbers, that here, there was a need for the existence of a scale for the interpretation of the numbers, as have been shown in the table below (Table 2).

[1] Failure Mode and Effects Analysis

Table 2: Final Scale of Risk Degree (Jalali, 2013: 87)

Scale	Score	Commentary	Grouping
Too high	600-1000	The asset is severely prone to risk	Group 1
High	250-600	The asset is highly prone to risk	
Medium and upward	200-250	The asset is very prone to risk	Group 2
Medium	150-200	The asset is relatively prone to risk	
Medium downward	100-150	The asset is a little prone to risk	
Low	50-100	The asset is very little prone to risk	Group 3
Very low	1-50	The asset is rarely prone to risk and is not worth to be invaded	

4. RESEARCH FINDINGS

For risk assessment of the infrastructure of the phases 17 and 18 of refinery, the indicators of this section of the macro objectives of the project were used. On this basis, the following indicators have been considered for this step of studies (Table 3).

Table 3: Infrastructures of the Phase 17 band 18 of Refinery

	Installations and assets
Administrative-service installations	Administrative buildings
	Firefighting unit
Oil and gas installations	Clotting
	Desulphurization and Dehumidification unit
	Bhutan Reservoirs
	Liquid gas reservoirs
	Unit of injecting Methane to the main line
	Methane, Ethan, Propane and Bhutan separation unit and making them cool
	Cooling Tower unit

In the second stage, after recognizing and forming the tree structure of hierarchical analysis model, two components of administrative-service installations, and oil and gas installations were entered into the Expert Choice software for the formation of paired matrix, which its stages have been addressed below. In the first step of the hierarchical analysis model, the formation of hierarchical structure related to the subject has been addressed (Table 4).

Table 4: Infrastructures of the Phase 17 and 18 of Refinery

	Installations and assets
Administrative-service installations	Administrative buildings
	Firefighting unit
Oil and gas installations	Clotting
	Desulphurization and Dehumidification unit
	Bhutan Reservoirs
	Liquid gas reservoirs
	Unit of injecting Methane to the main line
	Methane, Ethan, Propane and Bhutan separation unit and making them cool
	Cooling Tower unit

At this stage of the hierarchical analysis model, the formation of a paired matrix between the criteria was addressed. According to the extracted results, it was specified that the criterion of oil and gas installations with the weight equal to 0.667 value has allocated the highest score ratio to itself, and in the second rank, the criterion of administrative-service installations was located with the weight equal to 0.33. The importance coefficient of the criteria has been shown in the diagram below.

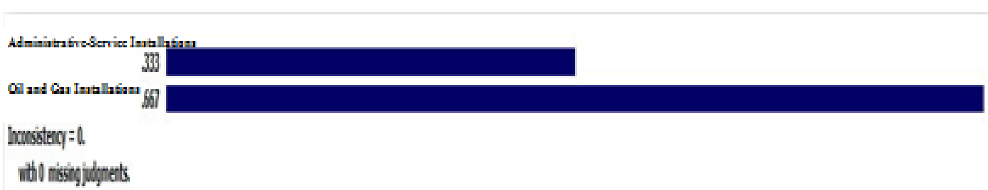

Diagram 1: Determining the Importance Coefficient of the Criteria

In this stage of the model, the importance coefficient (weight) of the sub-criteria was determined, and the sub-criteria of each of the criteria were compared in pair. The results showed that the sub-criterion of "administrative buildings" with the weigh equal to 0.66 value has allocated the highest weight, and the sub-criterion of "firefighting unit" with the weight equal to 0.33 has allocated the second rank to itself.

Diagram 2: Determining the Importance Coefficient of the Sub-Criteria of Administrative-Service Infrastructure

The results extracted from the determination of the importance coefficient of the sub-criteria of oil and gas installations indicated that the "liquid gas reservoirs" sub-criterion with the weight of 0.24 values has allocated the highest weight to itself. Also, the sub-criterion of "Bhutan reservoirs" with the weight equal to 0.22 has allocated the second rank to itself.

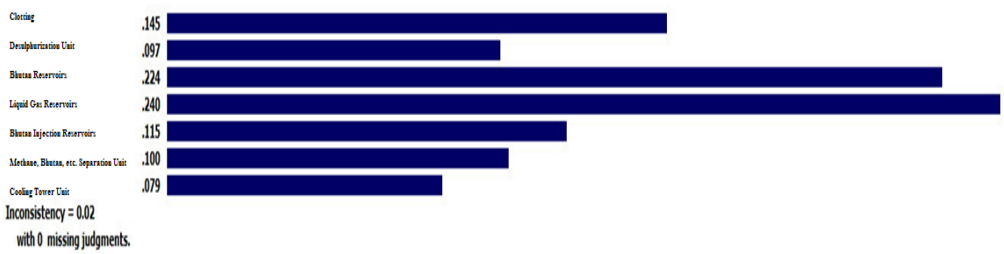

Diagram 3: Determining the Importance Coefficient of the Sub-Criteria of Oil and Gas Infrastructure

After determining the importance coefficient of the criteria and sub-criteria, the importance coefficient of the options has been determined. The results extracted from the hierarchical analysis model showed that the functional value with the score equal to 0.525 has allocated the first rank among the options to itself. In the second rank, the replacement value with the score equal to 0.27 and, finally, the economic value with the score equal to 0.2 was located. The diagram below shows the final score matrix of assets value indicators.

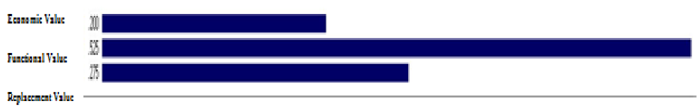

Diagram 4: Determining the Importance Coefficient of the Options

In the following, in order to accurately investigate the results of asset value, threat and vulnerability in the first step, the assets, threats and vulnerability assessment indicators that were weighted in the previous stage should be implemented in the assets of the phases of 17 and 18 of refinery.

Table 5: Assets Value of the Infrastructure of the Phase of 17 and 18 of Refinery by Implementing the Weight of Indicators

Assets values indicators	Economic value	Functional value	Replacement value	Total scores	Assets priority and importance degree
Key assets	0. 2	0. 525	0.257		
Administrative-service installations	8	6	7	21	Second
	1 .6	3 .15	1.925	6. 675	
Oil and gas installations	10	9	8	27	First
	2	4.725	2.2	8.925	

The results obtained from the table indicated the dependence ratio of the activity of the phases of 17 and 18 of refinery in Asaluyeh region on the assets listed in the table above, in a way that asset dependency had a direct relationship with the obtained scores.

Table 6: Threats Values of the Infrastructure of Phases 17 and 18 of Refinery by Implementing the Weight of Indicators

Threat type	Type	Threat instances	Severity of damage	Enemy's ability	Target attractiveness	Total scores	Prioritizing
		Indicators weight	0. 591	0.146	0.263		
Hard	Tool oriented	Missile and air attacks	9	10	8	27	First
			5.319	1.46	2.104	8.883	

		Chemical, microbial, and nuclear attacks	10	9	8	27	Second
			5.91	1.314	2.104	9.328	
	Method oriented	Marine attacks, regular ground attacks	9	9	3	21	Fifth
			5.319	1.314	0.789	7.422	
Semi hard		Attacks with electromagnetic, graphite, sound bombs and so on	5	9	8	22	Eighth
			2.955	1. 314	2.104	6.373	
Soft threats	Security	Spy and human influence and so on	2	8	5	15	Twelfth
			1.182	1.168	1. 315	3. 665	
		Unsafe demonstration, turbulence and chaos and so on	4	2	1	7	Eleventh
			2. 364	0. 292	0.263	2.919	
	Non-security	Technical sabotage	5	4	3	12	Tenth
			2.955	0. 584	0.789	4.328	
		Economic sanction, psychological operation	6	9	9	24	Seventh
			3. 546	1. 314	2. 367	7 .227	
Special threats	Modern terrorism	Cyber Terrorism	8	8	7	23	Sixth
			4. 728	1.168	1. 841	7.737	
		Biological threats	9	8	8	25	Third
			5.319	1.168	2.104	8. 591	
	Classic	Threat to bombing and implementing it	7	8	8	23	Fourth
			4.137	1.168	2.104	7.409	
		Suicide attacks and remote control explosive shipments	6	6	5	17	Ninth
			3. 546	0. 876	1. 315	5,737	

As can be observed in the table above, threats like air and missile attacks, biological threats and bombing, chemical and microbial threats in the phases 17 and 18 of the refinery had the highest scores.

Table 7: Vulnerability Assessment of the Oil and Gas Installations of the Phases 17 and 18 of Refinery against Probable Threats

Threat type	Threat instances	Confrontation weakness	Defensive and protective weakness	Access possibility	Possibility to discover and identify	Total scores	Prioritizing
	Oil and gas installations threats	0.242	0.092	0.63	0.036		
Hard	Missile and air attacks	9	8	7	8	32	Second
		2. 178	0.736	4.41	0.288	7.612	
Semi hard	Electromagnetic bombs	2	1	1	3	7	Fourth
		0. 484	0.092	0.63	0.108	1. 314	
Soft	Spy and human influence, technical sabotage and economic sanction	3	2	2	4	11	Third
		0.726	0.184	1. 26	0.144	2. 314	
Special	Threat to bombing and implementing it, suicide attacks and explosive shipments	9	10	8	8	35	First
		2. 178	0.92	5.04	0.288	8.426	

As it can be observed in Table (7), the infrastructure of oil and gas installations primarily, had the highest ratio of vulnerability against bombing threat and implementing it, suicide attacks and explosive shipments, and then missile attacks.

Table 8: Vulnerability Assessment of Administrative Service Installations of the Phases of 17 and 18 of Refinery against Probable Threats

Threat type	Threat instances	Confrontation weakness	Defensive and protective weakness	Access possibility	Possibility to discover and identify	Total scores	Prioritizing
	Oil and gas installations threats	0.242	0.092	0.63	0.036		
Hard	Missile and air attacks	8	8	6	7	29	Second
		1.936	0.736	3.78	0.252	6.704	
Semi hard	Electromagnetic and graphite bombs	8	7	3	5	23	Third
		1.936	0. 644	1.89	0 .18	4 .65	
Soft	Spy and human influence, technical sabotage and/or economic sanction	5	4	4	5	18	Fourth
		1. 21	0.368	2. 52	0 .18	4. 278	
Special	Cyber terrorism, biological threats, bombing and implementing it	10	6	8	8	32	First
		2 .42	0. 552	5.04	0.288	8.3	

As can be observed in Table (8), the infrastructure of the administrative service installations primarily had the highest ratio of vulnerability against the cyber terrorism threat, biological threats, bombing and implementing it, then the air and missiles attacks threat. The threat of electromagnetic, graffiti bombs was located in the third place, and spying and human influence, technical sabotage and/or economic sanctions were located in the fourth place.

In the risk matrix of the assets of the phases 17 and 18 of refinery, in one dimension of the matrix, the numbers related to the risk components, and in another dimension, the screened threats were located, so that eventually the risk ratio of each asset against each threat was clearly specified (FEMA A452, 2005, 208). The obtained risk numbers carried useful conceptual outcomes, but it must be specified what the highness or lowness of the numbers of risk mean, that here, the existence of a scale for the interpretation of risk numbers was needed. This scale has been available in Document No. 452 related to Federal Emergency Conditions Management Agency of the United States of America, but the scale provided in that document, regarding the threats from the United States, could not naturally be an accurate and documentable scale for the threats of the domain of this research. Because the present research was carried out for the infrastructures of the phases of 17 and 18 of refinery in the Islamic Republic of Iran, that the nature of threats affecting them was different. So a native scale that is documentable was needed, that in order to obtain logical and tangible results, the observable scale was compiled in the tables below, and was regarded as the analogy basis for the risk analysis of the phases of 17 and 18 of refinery.

Table 9: Final Scale of Risk Degree

Scale	Score	Commentary	Grouping
Too high	600-1000	The asset is severely prone to risk	Group 1
High	250-600	The asset is highly prone to risk	
Medium and upward	200-250	The asset is very prone to risk	Group 2
Medium	150-200	The asset is relatively prone to risk	
Medium downward	100-150	The asset is a little prone to risk	
Low	50-100	The asset is very little prone to risk	Group 3
Very low	1-50	The asset is rarely prone to risk and is not worth to be invaded	

Table 10: Determining the Assets Risk of the Infrastructure of the Phases 17 and 18 of Refinery against Threats

Assets of the phases of 17 and 18 of refinery		Hard threat	Semi- hard threat	Soft threat	Special threat
		Air and missile attack	Electromagnetism and graphite	Sabotage-sanction	Cyber-bombing
Oil and gas installations	Threat number	8.88	6 .37	4 .32	8.59
	Asset number	8. 92	8. 92	8. 92	8. 92
	Vulnerability number	7 .62	1. 314	2 .31	8 .42
	Risk number	603.5772	74.66201	89.01446	645.164
	Degree of risk	1	3	3	1
Administrative-service installations	Threat number	8.88	6 .37	4 .32	8.59
	Asset number	6 67	6.67	6.67	6.67
	Vulnerability number	6.7	4 .65	4. 27	8.3
	Risk number	396.8383	197.5687	123.0375	475.551
	Degree of risk	1	2	2	1

The risk of oil and gas installations infrastructure in the phases of 17 and 18 of refinery for hard and special threat meant that the probability of air and missile and cyber attacks and bombing in such installations has been located in the primary degree of threats.

5. CONCLUSION

Establishing infrastructure installations and projects at the regional and district levels without complying with and compiling their criteria and risk assessment have caused them to be exposed to natural and human threats. This meant that the main purpose of risk assessment management plans was to create and expand removing the barriers and weaknesses of equipment and assets, and to select the optimal location of resources in all regions and sectors of the country. The results of the risk assessment of the South Pars Phases 17 and 18 of Refinery showed that risk assessment for hard and special threats meant that the occurrence probability of air and missile and cyber attacks and bombing in such installations has been located in the primary degree of threats. In other words, if the enemy intends to destroy and destruct the oil and gas infrastructure, the most probable option is to use a hard and special threat. Semi-soft and soft threats, in spite of having third degree of risk, had low and very low probability. Also, the emergence probability of semi-hard threats, such as electromagnetic or graphite bombs, to destroy the oil and gas infrastructure was poor. In the risk of administrative - services infrastructure at the phases of 17 and 18 of refinery, for hard and special threat meant that the occurrence probability of air and missile and cyber attacks and bombing in such installations was located at the primary degree of threats. Also, semi-hard and soft threats, in spite of having a second degree of risk, had low and very low probability compared with the first degree of threats.

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