JCHR (2025) 15(1), 157-168

Journal of Chemical Health Risks

sanad.iau.ir/journal/jchr/

ORIGINAL ARTICLE

Operation and Maintenance (O&M) Risks Management Based on the Hazard and Effect Management Index (HEMI) in an Oilfield

Ali Askari[1], Hasan Maihanparast[2], Laila Mahdinasab[3], Ali Salehi Sahl Abadi[*4], Masoud Davoodi[5], Mohammad Nemati[6]

[1]*Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*

[2]*Department of Health, Safety, and Environment (HSE), OICO Safety Division Shift Supervisor, Azar Oilfield, Ilam, Iran*

[3]*Department of Work and Knowledge, Work and Education School, Mehran Education Office, Ilam, Iran*

[4]*Workplace Health Promotion Research Center, Department of Occupational Health and Safety at Work, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran*

[5]*Department of Health, Safety, and Environment (HSE), OICO HSE Manager, Azar Oilfield, Ilam, Iran*

[6]*Department of Planning and project control, OICO Planning Division, Azar oilfield, Ilam, Iran*

(Received: 24 April 2023 Accepted: 18 June 2023)

KEYWORDS

Risk Priority Number;
HARPI;
Risk Assessment;
Oil and Gas industry;
HMEI

ABSTRACT: One of the main factors in achieving safety management and safety objectives is designing in addition, applying specific risk evaluation techniques. The present study takes this approach to manage the risks related to non-routine activities and hazardous work in Operation and Maintenance (O&M) project in an oilfield. This semi-quantitative and descriptive study was conducted at the Sarvak Azar oil field in Iran in 2023. A combination of the Hazard and Effect Management Process (HEMP) and the Hazard and Risk Prioritization Index (HARPI) are used to assess the risk of activities. Then, to simplify managers' decisions to implement control measures, final risk scores reported based on the Pareto principle. The results show that based on the conventional use of RPN, T11 (Desalters bypassing; 850), has the highest risk, and T1 (PSV installation on the off spec tank; 30) activity has the lowest calculated risk. However, based on the HEMI, T12 (Electrical substation commissioning; 749.7) has the highest calculated risk, and the lowest estimated risk score is associated with T7 (Loading chemical barrels and collecting pallets and empty barrels; 25.5). Furthermore, a survey of the standard deviation of the data shows that among the factors added to the risk assessment, involved people number (Pi), is more influential than other factors. The study showed we could optimize the conventional use of the risk priority number (RPN) with slight modifications. Changes made while maintaining the simplicity and applicability of the method can improve the accuracy of the priority set by the RPN.

INTRODUCTION

As one of the primary industries supporting socio-political and economic development, the oil and gas industry is in oil-producer countries [1]. In today's world, the necessity for energy ascertains the level of development of countries'

*Corresponding author: asalehi529@sbmu.ac.ir (A. Salehi Sahl Abadi)

DOI: 10.22034/jchr.2023.1984583.1734

industries. Between these, oil-related branches have a critical role in the economic growth of countries [2]. Industries performing in high-hazard conditions must handle intricate technical and other related aspects of processes. Analyses of critical accidents invariably determine how institutions and organizations have failed to manage this intricacy [3]. One of the most significant factors impacting the advancement of safety management is the design and application of specific risk assessment methods to achieve safety and security objectives [4]. Risk management is an approach that aims to minimize the adverse effects of activity through aware actions to foresee and avoid adverse events[5]. Risk management can be assumed as a process to measure or assess risk and then design risk management strategies [5,6]. Risk management is the principal issue of the preventive strategy for safety, and it has become a lawful obligation for employers in many countries[7]. Based on the history of concentration on safety issues, many industrialized countries and global organizations responsible for preserving safety have newly aimed to develop different risk assessment techniques [8]. But selecting a suitable method relies on the conditions that require a risk assessment, and each technique has its advantages and disadvantages [9]. Risk management methods come in many formations, but the top goal is to minimize risk in some areas of the activities relative to the conditions being sought [10]. Consequently, to achieve this goal and based on the other researcher's recommendations an integrated and combined implementation of both quantitative and qualitative methods can be used to increase the efficiency of techniques [8, 9]. So that a correct understanding of the tools available in the field of risk management can facilitate decision-making and help industrial owners in controlling risks, maintaining and improving safety and reducing costs [11]. To assess the risk of non-routine and hazardous works, the contractor uses the instructions prepared by the Health, Safety, and Environment (HSE) unit. This method is known as The Hazards and Effects Management Process (HEMP). According to this guideline, RPN is traditionally used for risk assessment (full details are given in the method section). Chang et al., study shows that most of the current risk assessment methods use the risk priority value (RPN) to assess the risk of failure. However, the RPN method has been scrutinized for having several shortcomings: The assumption that risk elements have an equal weight leads to oversimplification. The RPN scale has non-intuitive statistical properties. Many components of the RPN have repeated values. The only factors the RPN looks at are the severity, occurrence probability, and consequence and it does not consider indirect relationships between components. Chang et al, to solve the above problems, proposed an efficient algorithm based on fuzzy calculations [12]. Our purpose of this study is to investigate and improve the methods used to manage the risks related to non-routine activities and hazardous works which are conducted by the Operation and Maintenance (O&M) contractor which uses the RPN method.

MATERIALS AND METHODS

Introduce of the study location

This study was conducted in the Sarvak Azar oil field in 2023. This field is active in western Iran, with an operational capacity that can produce up to 65,000 barrels/day. The reservoir of this field is shared with the Badra oil field in Iraq. The area of this oil field is about 105 acre (Figure 1). The number of workers are 900 with average age of 32.02 ± 6, which work, in rotational system. This study was conducted according to following steps and based on a conceptual risk process management model (Figure 2).

Figure 1. Sarvak Azar Central Processing Facility.

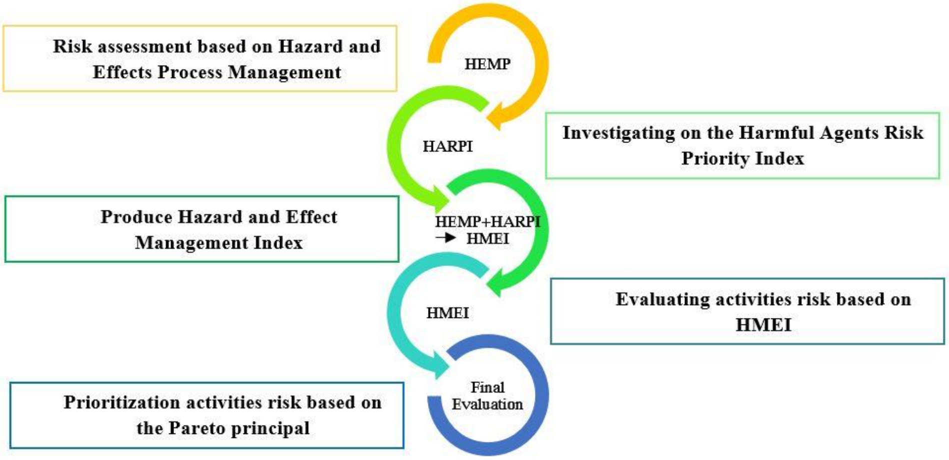

Figure 2. Conceptual risk process management model

Risk management instruction utilized by O & M contractor

The first step of HEMP is to identify the potential health, safety and environmental hazards and effects of activities and operations. Hazards and effects need to identify as early as possible and tracked through the life cycle of each activity. For this purpose, a team of HSE staff, experts and departments' heads formed. To identify hazards, the risk identification team attend in location and by consulting with other personnel, HSE hazards identify. Hazards can identify and assess in a number of ways:

- Through experience and judgement
- Using check-lists
- By referring to codes and standards
- By undertaking more structured review techniques

The next phase in the HEMP is to assess the HSE risks for all activities and then rank these risks. Assessment of risk may be quantitative or qualitative. Risk assessment involves determining the consequences and their probability for the identified hazards and effects, considering the presence (or absence) and effectiveness of any existing control measures. The implications and their likelihood are combined to determine the level of risk. Risk ranking involves comparing estimated levels of risk with risk criteria to determine the level and type of risk significance [14]. Risk evaluation uses the understanding of risk obtained during risk assessment to make decisions about future actions [15]. The final decisions should be under ethical, legal, regulatory, financial, and other requirements. Decisions may include: Whether a risk needs treatment, Priorities for treatment, whether an activity should be undertaken. Equation 1 is used to calculate the risk score, and determine the ranking of risks and risk level in this method is according to Tables 1 and 2 respectively [16].

$$Risk\ Priority\ Number\ (RPN) = Probablity\ (P) \times Sevirity(S) \times Consequenc(C) \quad (1)$$

Table1. Risk assessment matrix.

	Consequence (1, 2, 3, 4, 5)				Probability (1, 2, 3, 4, 5)				
Severity	**People**	**Asset**	**Environment**	**Reputation**	**Never heard of occurrence (1)**	**May occur once in 2 years (2)**	**Could occur once or twice in 1 year (3)**	**Could occur once or twice in a 6 month (4)**	**May occur every month (5)**
1	effect/injury	Slight	Slight effect	Slight impact	1	2	3	4	5
2	Minor health effect/injury	Minor damage	Minor effect	Limited impact	2	4	6	8	10
3	Major health effect/injury	Localized damage	Localized effect	Considerable impact	3	6	9	12	15
4	Permanent Disability (PTD) or 1 fatality	Major damage	Major effect	National	4	8	12	16	20
5	Multiple fatalities	Extensive damage	Massive effect	International impact	5	10	15	20	25

The risk rating scaling of 1 to 25 is expanding in importance. A rating of 1 means negligible risk and a rating of 5 indicates very high risk. This ranking will enable the prioritization of action plans to reduce the risk of exposure [4].

Table 2. Risk ranking.

Risk Category	Risk Score	Action Required
High Risk	15-25	Unacceptable risk. Whatever benefits the activity may bring, risk treatment is essential. Activity must not be undertaken and elimination strategy must be applied
Medium Risk	6-12	Impossible to eliminate or avoid risk entirely. Take reasonable measures to reduce and/or mitigate risk to as low as reasonably practicable (ALARP). Monitor risk controls (effectively & efficiently) to ensure that risks are maintained at their present or lower level
Low Risk	1-5	Acceptable risk. Activities in this category contain minimal risk and unlikely to occur. Activities can be proceeded as planned and no risk treatment measures are needed (Watch list). It is necessary to maintain assurance that risk remain at this level

At this step, due to the fact that the project had officially reached full operation in the last two years and the information related to the implemented risk assessments of this time period was fully available. Therefore, the risk evaluation data was collected in the last two years by checking the permit office database. A list of activities requiring risk assessment was prepared. Then the Risk Priority Number (RPN) value and other additional information, including the frequency of these activities throughout the year, the tasks' duration and the people directly involved in the activities were identified.

Harmful Agents Risk Priority Index (HARPI)

Harmful Agents Risk Priority Index (HARPI) is used to identify, evaluate, and prioritize occupational health risks at workplaces based on equations 2 and 3 [13].

$$HARPI = \frac{\sum_{i=1}^{n} wi\ pi\ ti}{\sum PT} \qquad (2)$$

pi: Number of people exposed to harmful agents
ti: People exposure time (hours)
P: Total number of people
T: Total exposure times

$$WFi = \sqrt{ER \times HR} \qquad (3)$$

WFi: Weight factor for harmful agent
ER: Exposure rate
HR: Hazard rate

Hazard and Effect Management Index (HEMI)

The weight factor calculations in HARPI are according to the exposure rate (ER) and hazard rate (HR) that obtained from related tables [13]. The ER and HR values demonstrated the intensity of agents' pollution and the probability of adverse effects due to exposure to pollutants, respectively [13]. The weight factor calculations in HARPI are according to the exposure rate (ER) and hazard rate (HR) that obtained from related tables. The ER and HR values demonstrated the intensity of agents' pollution and the probability of adverse effects due to exposure to pollutants, respectively.

In this study, by utilizing HEMP, the intensity and probability coefficients of the tasks during the risk assessment process were determined, in addition to the activities' adverse effects and consequences.

Therefore, the average RPN calculated and task frequency is used instead of HR and ER, respectively. In the various studies, since human resources are the most significant organization's assets, maintaining the health and safety of employees has a special place. Therefore, in the current study, in the same way, the duration of exposure and the number of involved people to calculate the risk score associated with the identified tasks were used (Eq.4) [17-19].

$$Hazard\ and\ Effect\ Managment\ Index(HEMI) = 100 \times \frac{(Fr \times RPNavg)^{1/2} \times ti \times pi}{\sum TP} \qquad (4)$$

Where;

RPN avg.; Average calculated RPN for taski
Fr; Number of task repetition in period of investigation (In this case: last two years)
Ti; Task duration time (hour)
Pi; Involved people number
T; Total tasks duration time (hour)
P; Total involved people number

Final evaluation based on the pareto principal

The results obtained through the proposed model were also analyzed through a Pareto principle format to better understand the results. Pareto principle is a simple technique with an overall pattern that explains how roughly 80% of consequences come from roughly 20% of causes [13]. According to the Pareto principle, after obtaining the maximum and minimum HMEI values of investigated activates, the range of obtained results are divided into three segments (Table 3). Activities in the 20 percent highest in HMEI score are the most important and deserve the highest management priority. On the other end of the range, activities in the 20 percent lowest in HMEI score are least important and deserve the lowest levels of priority.

Table 3. Prioritization HMEI scores in Pareto principle

Risk Rank	**High priority**	**Medium priority**	**Low priority**
HMEI score based on Pareto principle	Most leading 20% of the HMEI	Middle range of the HMEI	Lowest leading 20% of the HMEI
Calculations	$HMEI_{Max}$- ($HMEI_{Max}$× 0.2)	$HMEI_{Max}$- ($HMEI_{Max}$× 0.2)<Medium priority≤ ($HMEI_{Max}$× 0.2)	$HMEI_{Max}$× 0.2

RESULTS

According to Table 4, thirty-four activities were identified that require risk assessment. These activities are classified as non-routine activities and hazardous works. Data for the calculated RPN and the total risk assessment are listed for each task. Task frequency, task duration and number of people involved is also included in the assessment. Finally, according to the HEMI (Equation 4), activities are prioritized based on the risk score.

Table 4. Comparison of calculated HEMI and total RPN.

Identified tasks	Activity code	$S_{Average}$	$P_{Average}$	$O_{Average}$	$RPN_{Average}$	*Fr*	Ti	*Pi*	RPN_T	HEMI
PSV installation on the off spec tank	T1	4.27	3.00	1.50	19.22	1	4	15	178	438.3
Blinding	T2	4.66	2.33	1.66	18.02	1	2	4	58	28.3
Welding and cutting	T3	5	3	2	30.00	103	6	5	120	46.4
Leak test (injecting nitrogen)	T4	4.2	2.4	1.4	14.11	1	3	6	76	39.9
Windsock replacement	T5	1.5	3.5	5	26.25	122	0.5	3	50	25.5
HVAC system equipment maintenance	T6	3.66	2.66	1	9.74	12	2	3	30	82.2
Loading chemical barrels and collecting pallets and empty barrels	T7	3.66	2.66	1	9.74	150	4	4	71	72.5
Chemical packages charging	T8	4	3.2	1	12.80	120	5	3	63	32.7
Cameras and other IT equipment maintenance	T9	4.5	3.5	1	15.75	30	1	4	32	32.2
Free-run operation of the gas area compressors	T10	5	4.18	2.18	45.56	5	5	20	640	55.9
Desalters bypassing (Trains 1&2)	T11	4.33	3.22	1.88	26.21	2	48	18	288	54.0
Electrical substation commissioning	T12	5	3.93	2.86	56.20	1	7	24	850	60.5
Carbon active filter equipment installation	T13	4.25	3	1.25	15.94	3	6	13	114	90.1
Corrosion coupon inner cap grinding	T14	4.25	3.12	1.62	21.48	5	4	10	198	111.2
MRT operation of the gas area compressors	T15	4.5	3.75	1.25	21.09	17	6	18	169	164.0
LT and PI maintenance in the upper parts of the sump drum	T16	4.28	3.42	2.14	31.32	2	4	8	272	75.8
Oily water discharge operation	T17	4.25	3.37	1.62	23.20	9	48	6	215	454.3
Insolation kit replacement	T18	4.2	3	2	25.20	158	1	5	162	117.9
Replacing the spool and installing the rupture disc	T19	4.1	3.1	1.6	20.34	1	8	17	264	111.4
Moving the hydrant monitor	T20	4	2.4	1.4	13.44	5	1	7	80	207.3
Excavation to repair and modify underground pipes	T21	4.25	2.75	1.25	14.61	2	6	36	69	424.5
Breathing Apparatus (BA) recharging	T22	4	3.5	2	28.00	350	0.34	2	69	282.5
Dewatering	T23	4	3	2.2	26.40	19	48	3	210	395.8
Washing and cleaning of desalters	T24	4.44	2.88	1.44	18.41	7	12	12	177	375.7
Pigging the export pipeline	T25	4.1	2.8	1.4	16.07	28	6	14	186	301.9
TT check and calibration	T26	4.5	2	1.25	11.25	36	3	4	46	160.6
IRGD connection and troubleshooting	T27	4.25	2	1.25	10.63	29	3	4	44	162.2
Checking and troubleshooting UPS	T28	5	2.87	1.12	16.07	13	2	4	125	230.5
Flushing and draining the Exchanger	T29	5	3	1.83	27.45	3	60	10	165	270.3
Corrosion coupon replacement	T30	4.5	2.5	2.16	24.30	36	1	5	149	451.0
Telecommunication tower PM	T31	4.66	3.33	1.33	20.64	1	1	3	62	364.7
Painting and insulation operations	T32	4.2	2.8	1.4	16.46	159	12	5	92	749.7
Spool alignment operation	T33	4	2.66	1.5	15.96	2	7	6	123	302.5
16 inch export pipeline drilling	T34	5	2.66	1	13.30	1	10	10	120	362.0

Figures 3 and 4 represent the risk prioritization of all activities based on the total calculated RPN score and HEMI scores for each investigated task, respectively. Comparing the graphs well indicates the change in the ranking of priorities.

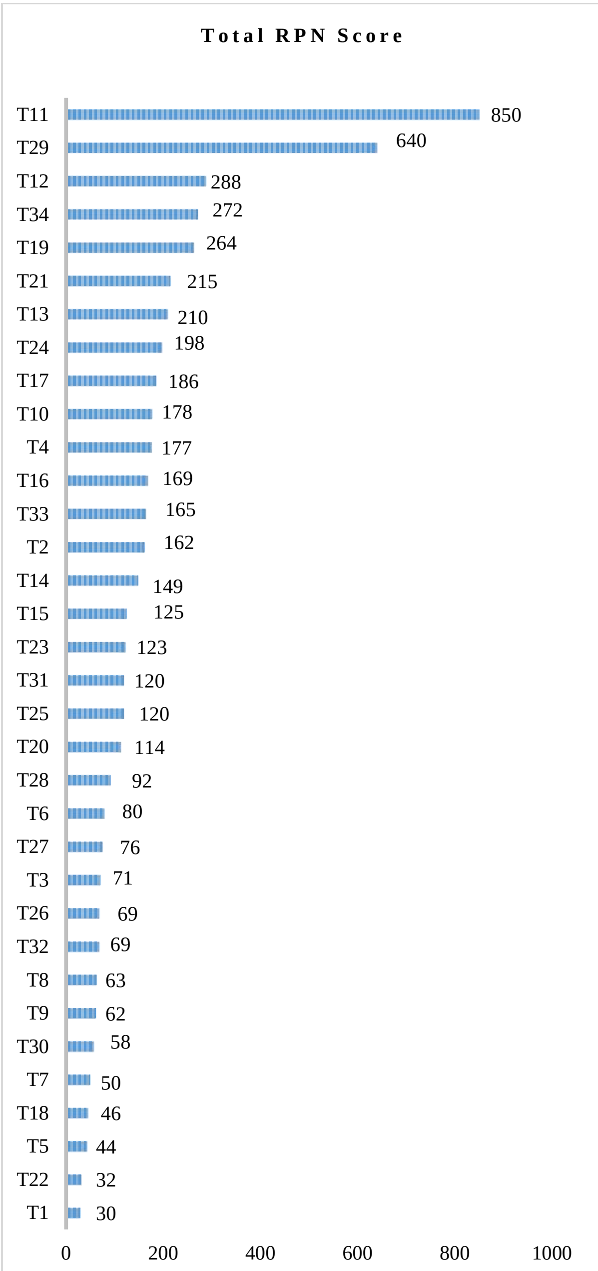

Figure 3. Risk prioritization based on total RPN Score.

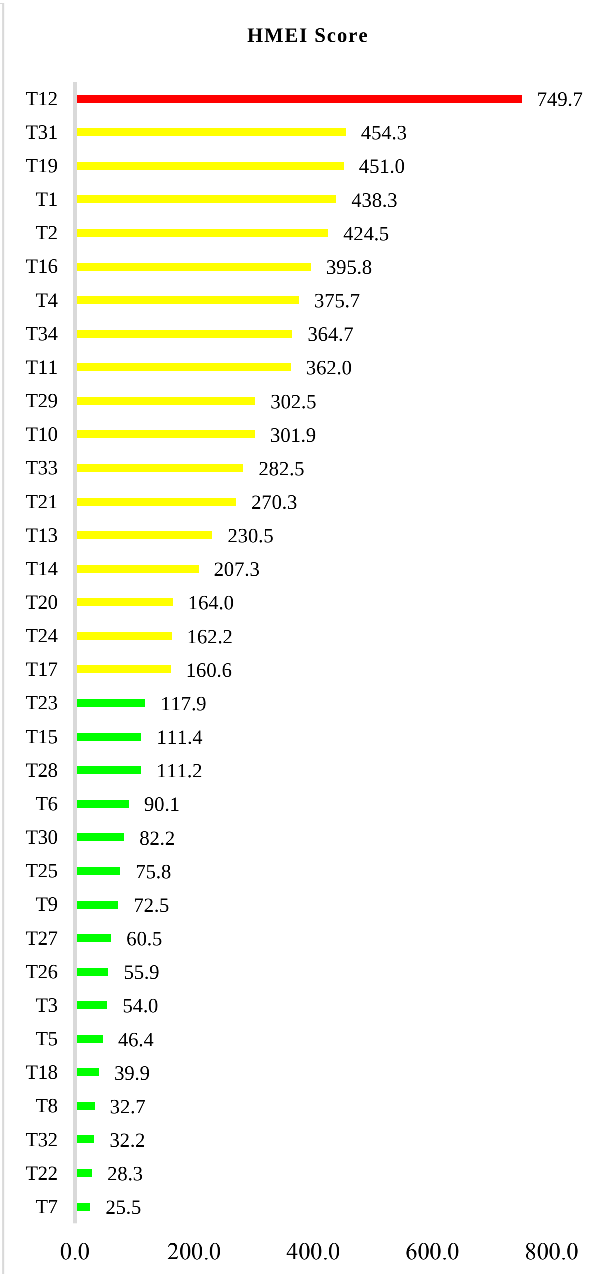

Figure 4. Risk prioritization based on HEMI Score.

A survey of the standard deviation of the collected data among the factors added to the risk assessment method containing the number of task repetitions (Fr), task duration per hour (Ti), and people number (Pi), are displayed in Table 5.

Table 6 represents the risk prioritization of all activities based on the Pareto principle to classify activities' risk in the management aspect.

Table 5. Average of standard deviations (SD) for each additional parameter to HEMI during two recent years.

Activity code	2021			2022			SD Average		
	Fr	**Ti**	***Pi***	***Fr***	**Ti**	***Pi***	***Fr***	**Ti**	*Pi*
T1	0	0	0	1	3	17	0.71	2.12	8.5
T2	0	0	0	1	2	4	0.71	1.41	2
T3	60	5.5	6	43	6.5	4	12	0.71	1
T4	0	0	0	1	3	6	0.71	2.12	3
T5	67	0.5	3	55	0.75	4	8.49	0.18	0.5
T6	0	0	0	12	2	3	8.49	1.41	1.5
T7	70	4	4	80	4	4	7.07	0	0
T8	50	2	6	70	4	3	14.1	1.41	1.5
T9	0	0	0	30	1	4	21.2	0.71	2
T10	0	0	0	5	5	20	3.54	3.54	10
T11	1	56	18	1	40	18	0	11.3	0
T12	0	0	0	1	7	24	0.71	4.95	12
T13	0	0	0	3	6	13	2.12	4.24	6.5
T14	3	3	10	2	1	10	0.71	1.41	0
T15	15	4	18	2	8	14	9.19	2.83	2
T16	2	4	8	0	0	0	1.41	2.83	4
T17	5	48	6	4	48	6	0.71	0	0
T18	94	1	5	64	1	5	21.2	0	0
T19	0	0	0	1	8	17	0.71	5.66	8.5
T20	3	5	1	2	1	9	0.71	2.83	4
T21	0	0	0	2	36	6	1.41	25.5	3
T22	180	0.3	2	170	0.3	180	7.07	0	89
T23	10	48	3	9	48	3	0.71	0	0
T24	4	12	12	3	14	8	0.71	1.41	2
T25	22	6	14	5	6	14	12	0	0
T26	20	3	4	15	3	4	3.54	0	0
T27	17	2	5	12	3	4	3.54	0.71	0.5
T28	8	2	4	5	2	4	2.12	0	0
T29	2	6	10	1	6	10	0.71	0	0
T30	19	1	5	17	1	5	1.41	0	0
T31	0	0	0	1	1	3	0.71	0.71	1.5
T32	104	14	4	92	10	6	8.49	2.83	1
T33	0	0	0	2	7	6	1.41	4.95	3
T34	0	0	0	1	10	10	0.71	7.07	5
SD Average	22.24	6.69	4.35	20.97	8.781	13.2	4.68	2.73	5.06

Table 6. HMEI results classification in Pareto principle.

Risk Rank	High priority	Medium priority	Low priority
HMEI score in Pareto principle	**High ≥ 599.76**	**599.76<Medium≤149.94**	**Low<149.94**
Activities priority	T12(749.7)	T31(454.3),T19(451),T1(438.3),T2(424.5),16(395.5),T4(364.7),T34(364.7),11(362),T29(302.5),T10(301.9),T33(282.5),T21(270.3),T13(230.5),T14(207.3) T17(160.6)	T23(117.9),T15(111.4),T28(111.2), T6(90.1),T30(82.2),T25(75.8),T9(72.5),T27(60.5),T26(55.9),T3(54),T5(46.4),T18(32.7),T8(32.7),T32(32.2),T22(28.3),T7(25.5)

DISCUSSION

By reviewing seventy-five articles in which RPN was used for risk assessment, Liu et al. tried to find answers to their questions in the following areas: 1- Which of the shortcomings of RPN has received the most attention? 2- Where has this approach been most widely used? And 3- Are these approaches sufficient for our needs? They found in their review the other researchers to answer their needs, utilizing the RPN in combined with other methods into five primary forms, which are multi-criteria decision-making (MCDM), mathematical programming (MP), artificial intelligence (AI), hybrid approaches, and others. They observed three points; First, Traditional risk assessment based on RPN is not strong enough in risk priority ranking. Second, alternative approaches are capable of addressing some of the problems associated with the RPN, not all of them. Third, fuzzy rule-based techniques lead to improving the accuracy of the evaluations, but their use is doubtful due to their complexity [20]. Despite what was said, it should be noted that RPN is a concept that appeared with the emergence of the failure mode and effect analysis (FMEA) method. The persistence of this method for more than 40 years is due to the simplicity and ability of RPN to express the effects of the consequences. But this does not mean that there is no need to develop methods [21, 22]. Preferably, it is necessary to be aware that the efficiency of different methods is under the conditions of use [9], and the simplicity and user-friendliness of the approaches, should not be sacrificed for the accuracy of the results by using complicated techniques as long as they meet our needs. Therefore, in the current study, the RPN has been optimized by maintaining the simplicity of the method while using other influential parameters. Thus, this more accurate assessment of the risks in our work environment has been achieved. In Askari et al. [13, 17 and 18] and Mousavi's [19] studies, which were carried out to prioritize control measures related harmful agents in the workplace, in addition to the severity and side effects caused by exposure to harmful factors, the values related to the number of people exposed and the duration of exposure were used as influential parameters. Therefore, in this study, due to the importance of human resources as the primary capital of organizations, the mentioned values were used to prioritize the riskiness of non-routine activities. The results of this study (Table 4, and Figure 3) show that based on the conventional use of RPN, T11 (Score; 850), T29 (Score; 640), and T12 (Score; 30), regarding to desalters bypassing, flushing and draining the exchanger, and electrical substation commissioning, respectively have the highest risk, and T1(Score;30, PSV installation on the off spec tank) activity has the lowest calculated risk. Using the HEMI index, the frequency of each activity, which is happening during the period under consideration, was counted. Additionally, the duration of each task, as well as the number of people necessary to complete the task, was taken into consideration. This process lead to the determination of the level of riskiness and priority of the various activities being calculated in a different way.

Based on Table 4 and Figure 4, activities T12 (Score; 749.7), T31 (Score; 454.3, Telecommunication tower PM), and T19 (Score; 451.0, Replacing the spool and installing the rupture disc) have the highest calculated risk, respectively, and the lowest estimated risk score is associated with T7 (Score; 25.5, Loading chemical barrels and collecting pallets and empty barrels). Also, in the comparison of HEMI and traditional RPN scores, the obtained results are different from each other, and the priorities are due to the influence of the activity frequency values, the duration of the activity, and the number of involved people in the task. According to table four, the average calculated standard deviations for Fr, Ti, and Pi are 4.48, 2.73, and 5.06 respectively. Results show that among the three mentioned factors, the influence of the number of involved people (Table 5) is more than in the other cases. The importance and power of the risk management strategy reside at the point that it consolidates various judgment and discussion techniques, assimilate them into a whole, and provides structure to the decision-making process [23]. Moreover, if the management wishes to adjust the level or risk tolerance of the organization according to the Pareto principle (Table 6, Figure 4), it can be concluded that "electrical substation commissioning (T12)" is exposed to the highest safety risk. Therefore, by using the company risk assessment method (HEMP), the HARPI index was optimized. This is important from two aspects. Firstly, it helps maintain the simplicity, practicality and affordability of the method. Secondly, it increases the accuracy of the RPN by taking into account additional weighting factors in addition to the conventional values of intensity, probability, and consequence.

CONCLUSIONS

The study findings showed that optimization the RPN with slight modifications is possible. The proposed model can provide a more accurate prioritization risk level for non-routine activities and dangerous work in maintenance and operation projects by using the activity frequency values, the number of people involved in the work, and the duration of the activity. Changes made while maintaining the simplicity and applicability of the method can improve the accuracy of the priority set by the RPN. Prioritization of RPN scores of routine and non-routine activities are possible via the HMEI. This model uses the Pareto principle to support and simplify management's decision-making process in such a way as to help allocate resources and reduce risk to acceptable levels in the organizations.

Future works

We have found that the method we have presented is capable of evaluating environmental aspects. Therefore, it is suggested that additional studies are conducted in this field by combining HARPI and HEMI indices.

Study limitation

According to the time frame of the present study, to accurately determine the influence of Fr, Ti, and Pi parameters, it is recommended to examine the study in 5 years.

ACKNOWLEDGEMENTS

The authors of this study would like to special thank the Department of OICO Health, Safety and Environment. The authors further thank Sarvak Azar Oilfield Project Managers.

ETHICAL CONSIDERATION

This work approved by the Health School, and Neuroscience Research Center, Shahid Beheshti University of Medical Sciences (No.IR.SBMU.PHNS.REC.1401.051). Ethical issues (e.g., plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Conflict of interest

The authors declare that they have no conflict of interests.

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