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SYSTEM SAFETY IN LPG FIRED FURNACE – A MULTI CRITERIA DECISION MAKING TECHNIQUE

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Abstract:
Risk and safety are the important terms related with any industry and are linked conceptually and pragmatically. This paper illustrates the risk associated with an LPG fired furnace. The major risks involved in an LPG based gas furnaces are: leakages in the main LPG pipelines and improper working of equipment fitted with the LPG furnace. This paper proposes two methodologies for quantification of risk. The first one is based on the traditional risk and the second is based on Analytical Hierarchy Process (AHP). Analytical Hierarchy Process is a multi-criteria decision making technique, which breaks down a decision making problem in to a hierarchical structure, through which decision makers can bring about a comparison among different risk levels. The practical application of both traditional and AHP models are demonstrated with a case study concerning the safety of operations carried out in an LPG based gas furnace. The results obtained by analytical hierarchy process are compared with those obtained by traditional method of risk calculation. Comparing with the traditional method of risk calculation, the AHP technique of risk analysis have two advantages; by using AHP method, the risk assessment procedures become more comprehensive and also the risk calculated provides more precise values than that obtained by using traditional method and AHP is more conservative in the assessment of risks.

Key Words: Risk, AHP, Risk Assessment, Case Study, LPG Fired Furnaces

1. INTRODUCTION

Safety management has increased its importance in recent years, as companies and institutions realized the social and environmental impact of injuries at work. The fundamental objective of safety management is to eradicate human anguish and suffering and to achieve economy of operations in an effective manner. Risk may be defined as combination of the probability of occurrence of a harm and severity of that harm [1]. Risk exists in all human activities and it can be economic or health and safety related. Risk assessment is the "Process of evaluating the risk(s) arising from a hazard(s), taking into account the adequacy of any existing controls, and deciding whether or not the risk(s) is acceptable"[1]. Proper risk assessment is important for all manufacturers and other industries which need to show that they take sufficient efforts to guarantee the safety of their employees and the products they produce. Factors such as governmental regulations, law suits and public pressures also play an instrumental role in demanding need for better risk assessment [2]. In classical approach, risk is calculated by means of two factors, probability of occurrence of a hazardous event and magnitude of injury. In this work an attempt is made to calculate the level of risks associated with each operation carried out in an LPG fired gas furnaces with the help of Analytical Hierarchy Process (AHP). It is a multiple criteria decision-making tool which is used for calculating the risk level in the operations of an LPG fired furnace. AHP is has being used in almost all the applications related with decision-making. Chang et al [3] applied AHP technique for selecting the best silicon wafer slicing machine along with sensitivity analysis.

Zone-Ching Lin and Chu-Been Yang [4] used AHP for machine selection from a range of machines available for the manufacture of particular type of parts with a case study. Omkarprasad and Sushil Kumar [5] had given an overview about the AHP and its applications. Josef Jablonsky [6] used the AHP model for measuring the efficiency of production units. Ho Byun [7] used AHP model for selecting an automobile purchase model. Antonio Armillotta [8] used AHP for the selection of layered manufacturing techniques. Julius soles [9] used AHP for environmental quality indexing of industrial development alternatives. Senthil Kumar et al [10] used AHP along with fuzzy multi criteria decision making for financial product preferences of Tiruchirapalli investors. Terje Aven [11] discussed about different perspective of risk affect, the relationship between the safety/safe and risk. Theodore and Erhan [12] discussed about the application of quantitative risk assessment of rail yard, where tank cars of hazardous materials are received and stored. Hence, risk assessment based on AHP is proposed in this paper. The effectiveness of AHP model is compared with traditional risk assessment method, which is basically depending on probability of occurrence of different events and their severity.

2. RISK ASSESSMENT METHODS

Risk analysis and assessment constitute a critical phase of safety management [13]. As a consequence, to identify the criticality of a hazardous activity, risk 'R', which is the product of the probability 'P' to have an accident on work related to the execution of the considered activity and the magnitude 'M' of the induced injury on a worker, is generally adopted. This gives the classical expression $R = P \times M$ [5] in the traditional risk analysis study which is currently followed in most of the industries. The major steps for risk assessment by traditional methods are [1]:

Step1: Hazard identification: Identification of sources with potential to cause undesired outcomes to the subjects of concern and their likelihood.

***Step2*:** Event scenario assessment: Identification of the initiators and sequences of events that can lead to the occurrence of the hazard.

***Step3*:** Consequence assessment: Identification and assessment of the consequences of the identified hazard.

***Step 4*:** Risk estimation: Risk is estimated by considering two factors namely probability of occurrence of a harmful event and its severity.

***Step 5*:** Decision making: Deciding on actions based on risk evaluation.

3. ANALYTICAL HIERARCHY PROCESS

One of the most popular analytical techniques for complex decision making problem is the Analytic Hierarchy Process (AHP). AHP is a powerful and flexible multi criteria decision making tool used for complex problems where both qualitative and quantitative aspects need to be considered. The hierarchy of AHP can have as many levels as needed to fully characterize a particular decision situation. AHP methodology has the ability to handle decision making situations involving subjective judgments among multiple decision possibilities and the ability to provide measures of consistency in preference. It can efficiently deals with tangible as well as non-tangible attributes, especially where the subjective judgments of different individuals constitute an important part of decision making process. AHP model is based on three principles [6]: Structure of model, Comparative judgment of alternatives and criteria, and Synthesis of the priorities [11]. In the first step, a decision making problem is arranged in a hierarchy model. In this hierarchy model the overall objectives of the problem comes at the top level, criteria and sub criteria are arranged in the middle level and the alternatives are at the bottom. The hierarchy model is presented in Figure 1. Comparative judgment consists of pair wise comparison of each pairs of criteria or alternatives with respect to each criterion. The results of pair wise comparison are arranged in a pair wise comparison matrix form. The pair wise comparisons are based on a standardized comparison scale, Saaty scale of 1-9, which lies between equal importances's

(1) to extreme importance (9) (Table I). If the importance of one factor with respect to the other in a pair is given, then the importance of the second one with respect to the first is the reciprocal of it. Final step of AHP is the priority synthesis, in which priority weights for each criteria or alternatives are determined. The Priority weights are used for ranking the alternatives [14]. Based on pair wise comparison judgments, AHP integrates both criteria importance and alternative preference measures in to a single overall score for ranking decision alternatives [15,16].

Let 'A' be the judgment matrix formed by using the comparison. Let a_1, a_2...... a_n be the set of stimuli. Then the judgment matrix is given as [11]:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}, \quad i, j = 1, 2, 3, \ldots n$$

The elements of judgment matrix should be satisfying the following rules;

$$a_{ij} > 0, a_{ji} = \frac{1}{a_{ij}}, a_{ii} = 1 \; \forall i$$

The Geometric mean of each row in a pair wise comparison matrix is given by,

$$r_j = \sqrt[n]{c_{j1} \times c_{j2} \times c_{j3} \ldots \ldots . . c_{jn}} \qquad (1)$$

The normalization operation is carried out by dividing the value of r_j determined as above by the sum of the values of r_j calculated. The normalized weight 'w_j' of each criterion is given by:

$$w_j = \frac{r_j}{\sum_{j=1}^{n} r_j} \qquad j = 1,2,3 \ldots \ldots . . n \qquad (2)$$

Table I: Saaty Scale [3].

Intensity of importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak\slight	
3	Moderate Importance	Experience and judgments slightly favors one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgments strongly favors one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another, its dominance demonstrated in practice
8	Very strong	
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation

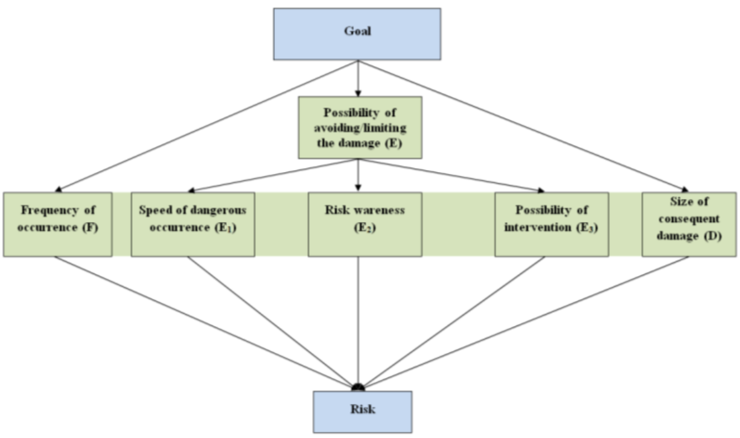

Figure 1: AHP Hierarchy model.

4. CONSISTENCY CHECKING

The consistency of the results is measured by using a consistency ratio (CR). The judgments obtained are acceptable only if CR is less than 0.1. For consistency checking the Eigen value and Eigen vector are to be calculated. For the calculation of maximum Eigen value, the pair wise comparison matrix obtained is multiplied with the weight vector W= (W_1, W_2.... W_n), where W is a column vector. The result of the multiplication would be nW. Hence it can be written as,

$$AW = nW \tag{3}$$

Next Saaty's method computes W as the principal right eigenvector of the matrix A [16];

$$AW = \lambda_{max} W, \tag{4}$$

Where, λmax is the principal Eigen value of the matrix. If matrix A is a positive reciprocal one, then $\lambda max \geq n$[16]

If A is a Consistency matrix, Eigen vector X can be obtained by using, $(A - \lambda_{max} I) = 0$ Consistency Index CI [16] is calculated by using;

$$CI = {(\lambda_{max} - n)}/{(n-1)} \tag{5}$$

Where $\lambda_{max}$the maximum Eigen value and n is the number of factors in the judgment matrix.

Consistency Ratio (CR) as

$$CR = CI/RI \tag{6}$$

Where, RI represents the average consistency index over numerous random entries of same order reciprocal matrices. The value of Random Index for each value of n is given in Table II.

Table II: Random Index (RI).

Matrix Order (n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Random Index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

5. CASE STUDY- LPG FIRED FURNACES

LPG fired furnaces are mainly used in Heat treatment operations as well as stress relieving of various boiler components. It is a double bogie car bottom type 50 tone furnace (Figure 2) and has 48 burners fitted in 4 zones. Eight thermocouples are used for temperature measurement and for zone temperature measurement. The LPG is supplied through the pipelines to the furnace from storage yard and various systems are introduced like digital programmable transmitter, proportionate valve, solenoid valve, ignition transformer, to name a few are connected along the line. The failure modes associated with all parts are identified and the corresponding risks are calculated using both Classical Methodology and AHP. For the hazard of an LPG leakage, the assigned value for the probability of occurrence P is 2 as per Table IV. Since the probability of such occurrence is very rare and the value assigned for magnitude of injury M is 4 as per Table V. For the corresponding magnitude of injury due to this hazard is very high. Hence, the value of risk index R= P×M is 8. Similarly the risk factor associated with all the identified hazards in the operation of an LPG fired furnace is calculated and the results are presented in Table III.

Figure 2: LPG fired furnace.

Table III: Classical Risk Calculation.

Sl no	Hazard	P	M	RI
1	Leakage of LPG	2	4	8
2	Fire\Explosion	2	3	6
3	Main solenoid valve is not working	1	1	1
4	Thermocouple connected with each jobs are not working	1	1	1
5	Solenoid valve connected with each burner was not working	1	1	1
6	Modulating motor and butterfly valves are not working for gas line and zonal header	1	2	2
7	Low pressure LPG supply to the furnace	1	1	1
8	DP transmitter is not working	1	2	2
9	Pressure switch fitted with gas line is not working	1	2	2
10	HT ignition transformer with spark plug is not working	1	2	2
11	UV detector is not working	1	2	2
12	Gas flow meter is not working	1	1	1
13	Air supply valve to the burner is not working	1	2	2
14	FD fan is not working	1	2	2
15	Dilution damper is not working	2	3	6
16	Cooling air supply to the UV sensor is not working	1	2	2
17	Door limit switch is not working	1	2	2
18	ID fan is not working	2	4	8
19	Gas leakages detector is not working	2	3	6
20	Motorized damper is not working	2	3	6
21	Combustion of un burnt gases in flare present just above the furnace	1	2	2
22	Skin burn and injury during loading and unloading of material from furnace	1	2	2
23	Contact by swinging load	1	3	3
24	Dust , smoke coming from furnace	3	2	6
25	Heat radiation	1	2	2
26	Glass wool emission during maintenance , loading & unloading of work	1	3	3
27	Hydrogen embrittlement during maintenance work	1	1	1
28	Visitors and other operators may touch unknowingly the hot material	1	1	1
29	Electrical hazards from panel bard kept near to furnace	2	3	6
30	Fumes coming out from the furnace	2	2	4
31	Falling of load while lifting	2	3	6
32	Hit by tools while working above the furnace	1	1	1
33	Operators positioning the load in the furnace without PPE.	1	2	2
34	Poor housekeeping	1	2	2
35	Electrical hazards due to heating of electrical panel	1	3	3
36	Leakage of LPG from supply yard to process equipment	2	3	6
37	Working around the furnace without work permit	2	2	4
38	Slippery on the floor	2	1	2
39	Falling in to the trenches	2	1	2
40	Modulating motor and butterfly valves are not working for air line and zonal header	2	2	4
41	Filter fitted with FD fan completely choked	1	1	1
42	Pressure gauge of airline and gas line is not working	2	2	4
43	Bogie limit switch is not working	2	2	4
44	Terminal boxes and Switch boxes are not in good condition	2	2	4
45	Improper cable management	2	2	4
46	Power Failure	3	2	6
47	Electrical flash	2	4	8
48	Emergency switch fitted with the furnace is not working	1	4	4

Calculation of Risk factor by AHP method requires the estimation of pair wise comparison of each criterion and sub criterion. For the present work, the main criteria of hazards are frequency of occurrence of damage (F), size of consequent damage (D) and possibility of avoiding / limiting damage (E). The associated sub criteria for the possibility of avoiding/limiting damage (E) are speed of dangerous occurrence (E_1), risk awareness (E_2) and possibility of intervention (E_3). The pair wise comparison of these criteria and sub criteria are given in Table VI and VII respectively. Table VIII shows the ranking of risks with respect to the frequency of occurrence (F) for all the identified hazards. Similarly, ranking of risk with respect to other criteria like D and and sub criterion (E1, E2, E3) are computed and provided in the Table IX, X, XI, XII respectively. From these ranking tables, overall ranking of risks are computed as shown in Table XIII, since the criterion E has three sub criterions E1, E2 and E3, weight of E will be the sum of these sub criteria. The risk index for each hazard is obtained as the sum of the risk values of the hazard with respect to the criteria considered.

Table IV: Consequence Level.

Weight age	Risk Consequence	Description
1	Slightly Harmful	First Aid
2	Harmful	Minor < 48 Hrs Absence
3	Very Harmful	Major, Reportable, Temporary Disability
4	Extremely Harmful	Fatal, Permanent Disability, Major & Involves Large No. Of People

Table V: Risk probability of Occurrence.

Weight age	Probability	Risk Likelihood
1	> Month	Highly Unlikely
2	< Month But > Week	Unlikely
3	< Week But > Day	Likely
4	<Day	Very Likely

Table VI: Pair wise comparison matrix for criteria.

Hazards	Frequency of Occurrence(F)	Size of consequent Damage(D)	possibility of avoiding / limiting Damage(E)	Geometric Mean	Sum of Geometric mean	Weight of each criteria
Frequency of Occurrence(F)	1	3	5	2.4662121	3.9316	0.62728
Size of consequent Damage(D)	0.33	1	4	1.09696131	3.9316	0.27901
possibility of avoiding/limiting Damage(E)	0.2	0.25	1	0.3684031	3.9316	0.0937

Table VII: Pair wise comparison matrix for sub criteria.

Hazards	Speed of dangerous occurrence (E1)	Risk Awareness (E2)	Possibility of Intervention (E3)	Geometric Mean	Sum of geometric mean	Weight of each criteria
Speed of dangerous occurrence (E1)	1	0.33	0.5	0.54848066	3.4992	0.156744
Risk Awareness (E2)	3	1	3	2.08008382	3.4992	0.594442
Possibility of Intervention (E3)	2	0.33	1	0.87065877	3.4992	0.248815

6. RESULTS AND DISCUSSIONS

AHP method enables experts and users to efficiently priorities the risk in a hazardous working environment. For assigning of weights to various risks and ranking of risks for 11 significant hazards are obtained by adapting AHP technique and same are listed in Tables VIII, IX, X, XI and XII, respectively. In Table VIII ranking of hazard with respect to the parameter frequency occurrence (F) is presented. Table IV and X shows the ranking of risk with respect to criteria size of consequent damage (D) and ranking of risk with respect to the sub criteria speed of dangerous occurrence (E_1), respectively. Table XI and XII presents the ranking of risks with respect to the sub criteria Risk awareness (E_2) and possibility of Intervention (E_3), respectively. From the priority weight obtained from the comparison matrix shown in above tables, the resultant risk ranking is obtained by using Eqns. 1 and 2 are listed in Table XIII. The final risk ranking is listed in the Table XIV. Plots between risk index and risk values are drawn for both the classical and AHP approaches for the comparison (Figures 3 & 4). From these plots, it is observed that the hazards like heat radiation, dust & smoke and glass wool emission are having lower priority in classical approach but these hazards have higher priority in the AHP technique. AHP can distinguish the relative risk levels among the hazards which are clubbed together in classical method. Also it is observed that some of the hazards identified possessing higher rank values in Classical methods are actually having lower level risk index value in AHP method and vice versa. From the above plots, it is also seen that the hazards of heat radiation is getting the risk value of 0.1707 by AHP and it lies in top position, even though it has a lower value of 6 by classical method. The hazard heat radiation has adverse effect on human body and will produce long term health effect. The hazards such as dust and glass wool emissions are having the value 0.165645 and 0.1142938, respectively which lies in the top priority by AHP. But in the case of classical methodology, it has only got a risk index as 6 and 3 which lie at the bottom priority positions. In practice during furnace operations, dust and glass wool emissions are the major problems for workers because it has long term health effect and it is perfectly predicted by the AHP method. Hazards like failure of dilution damper, failure of motorized damper, fire/explosion, electrical hazards, failure of gas leakage detector and falling of load from the crane have the value of 6 by classical method. Hence ranking of these hazards for taking appropriate control measures are very difficult. But using AHP, ranking of these hazards are possible and they are ranked as 10^{th}, 5th, 4th, 8th, 6th and 9^{th} respectively. Hence, this is more prominent technique because it considers minimum of six parameters for calculating the risk index. Parameters like Possibility of avoiding or limiting the damage, Risk awareness, speed of dangerous occurrence has significant effects on these hazards. Hazard of failure of induced draft fan, which has got a significant risk value by classical approach, is of 8, and it lies in the top priority position. But in the case of AHP, its rating is at 7^{th} position. The Plant accident statistics shows that results obtained by AHP are proven more effective. This is mainly because consideration of more parameters for the calculation of risk, which has significant effect on risk calculation The Plant accident statistics show that results obtained by AHP are more effective. This is mainly because of the consideration of more parameters for the calculation of risk evaluation by AHP method.

Table VIII: Ranking of risk with respect to Frequency of occurrence (F).

Hazards	A	B	C	D	E	F	G	I	J	K	Geometric mean (G)	Sum of geometric mean (S)	Priority (P) of each hazards(G/S)
Emergency Switch is not working (A)	1	2	0.33	0.33	0.5	0.5	0.2	0.2	0.33	0.5	0.4200729	15.42668	0.027230288
Fire\Explosion(B)	0.5	1	0.33	0.33	0.5	0.33	0.2	0.2	0.5	0.5	0.3703326	15.42668	0.024005984
Dilution Damper is not working (C)	3	3	1	1	3	1	0.2	0.2	3	0.5	0.9026182	15.42668	0.058510205
ID Fan is not working(D)	3	3	1	1	3	2	0.2	0.2	3	0.5	0.9613255	15.42668	0.062315773
Gas Leakage Detector is not working(E)	2	2	0.33	0.33	1	0.33	0.2	0.2	0.5	3	0.5607877	15.42668	0.036351806
Motorized Damper is not working(F)	3	3	1	0.5	3	1	0.5	0.5	3	3	1.2805833	15.42668	0.083010948
Dust , Smoke coming from furnace(G)	5	5	5	5	5	5	1	3	5	5	3.5621851	15.42668	0.230910675
Heat Radiation(H)	5	5	5	5	5	5	1	5	5	5	3.7315095	15.42668	0.241886749
Glass Wool Emission During Maintenance , Loading & Unloading of work(I)	5	5	5	5	5	5	0.3	1	3	3	2.2945181	15.42668	0.148737003
Electrical Hazards From Panel Bard Kept Near To Furnace (J)	3	2	0.33	0.33	2	0.33	0.2	0.3	1	0.5	0.5869076	15.42668	0.038044971
Falling of Load While Lifting (K)	2	2	2	2	0.3	0.33	0.2	0.3	2	1	0.7558437	15.42668	0.048995874

Table IX: Ranking of Risks With respect to size of consequent damage (D).

Hazard	A	B	C	D	E	F	G	I	J	K	Geometric mean	SUM	Priority weight
Emergency Switch is not working(A)	1	0.2	3	0.2	0	0.2	4	5	3	5	1.17254445	15.0565	0.077876
Fire\Explosion(B)	5	1	5	5	5	5	6	5	4	5	4.37536074	15.0565	0.290596
Dilution Damper is not working(C)	0	0.2	1	0.2	0	0.2	5	5	0.2	0.16	0.58290846	15.0565	0.038715
ID fan is not working(D)	5	0.2	5	1	0	4	5	5	0.2	0.2	1.33994032	15.0565	0.088994
Gas leakage detector is not working(E)	5	0.2	0.25	4	1	5	5	5	4	5	2.35747103	15.0565	0.156575
Motorized damper is not working(F)	5	0.2	5	0.25	0	1	5	5	0.2	4	1.33994032	15.0565	0.088994
Dust , smoke coming from furnace(G)	0	0.16	0.2	0.2	0	0.2	1	0.25	0.16	0.2	0.2854183	15.0565	0.018956
Heat radiation(H)	0	0.16	0.2	0.2	0	0.2	0.5	0.25	0.2	0.2	0.25677876	15.0565	0.017054
Glass wool emission during maintenance , loading & unloading of work(I)	0	0.2	0.2	0.2	0	0.2	4	1	0.2	0.2	0.39913851	15.0565	0.026509
Electrical hazards from panel bard kept near to furnace(J)	0	0.25	5	5	0	4	6	5	1	3	1.86115441	15.0565	0.123611
Falling of load while lifting(K)	0	0.2	6	5	0	0.25	5	5	0.33	1	1.08587432	15.0565	0.07212

Table X: Ranking of Risks with respect to speed of dangerous occurrence (E1).

Hazard	A	B	C	D	E	F	G	I	J	K	Geometric mean	SUM	Priority weight
Emergency switch is not working(A)	1	0.2	4	4	4	4	5	5	0.2	0.2	1.65550656	15.5194	0.106673
Fire\Explosion(B)	5	1	5	5	4	5	5	5	0.33	0.33	2.58219419	15.5194	0.166385
Dilution Damper is not working(C)	0	0.2	1	1	2	1	0.5	0.5	0.2	0.2	0.48250439	15.5194	0.03109
ID fan is not working(D)	0	0.2	1	1	3	1	0.5	0.5	0.2	0.2	0.50062158	15.5194	0.032258
Gas leakage detector is not working(E)	0	0.25	0.5	0.33	1	2	0.5	0.5	0.2	0.2	0.41799727	15.5194	0.026934
Motorized damper is not working(F)	0	0.2	1	1	1	1	0.5	0.5	0.2	0.2	0.42537165	15.5194	0.027409
Dust , smoke coming from furnace(G)	0	0.2	2	2	2	2	1	1	0.2	0.2	0.67286537	15.5194	0.043356
Heat radiation(H)	0	0.2	3	3	3	3	2	3	0.2	0.2	0.97739193	15.5194	0.062979
Glass wool emission during maintenance , loading & unloading of work(I)	0	0.2	2	2	2	2	1	1	0.2	0.2	0.64792253	15.5194	0.041749
Electrical hazards from panel bard kept near to furnace(J)	5	3	5	5	5	5	5	5	1	3	3.93632674	15.5194	0.253639
Falling of load while lifting(K)	5	3	5	5	5	5	5	5	0.33	1	3.22066105	15.5194	0.207525

Table XI: Ranking of Risks with respect to Risk Awareness (E2).

Hazard	A	B	C	D	E	F	G	I	J	K	Geometric mean	SUM	Priority weight
Emergency switch is not working(A)	1	0.33	0.25	0.25	1	0.33	0.2	0.2	0.33	0.33	0.33482704	14.6061	0.022924
fire\explosion(B)	3	1	0.33	0.33	2	0.33	0.2	0.2	0.33	0.33	0.45841154	14.6061	0.031385
dilution damper is not working(C)	4	3	1	1	2	1	0.25	0.25	0.33	0.33	0.74770907	14.6061	0.051192
ID fan is not working(D)	4	3	1	1	3	1	0.2	0.2	0.33	0.33	0.72997997	14.6061	0.049978
Gas leakage detector is not working(E)	1	0.5	0.5	0.33	1	0.33	0.2	0.2	0.33	0.33	0.3797985	14.6061	0.026003
Motorized damper is not working(F)	3	3	1	1	3	1	0.2	0.2	0.33	0.33	0.71113635	14.6061	0.048688
Dust , smoke coming from furnace(G)	5	5	4	5	5	5	1	2	4	2	3.03327522	14.6061	0.207672
Heat radiation(H)	5	5	4	5	5	5	1	2	2	2	2.84803587	14.6061	0.194989
Glass wool emission during maintenance , loading & unloading of work(I)	5	5	4	5	5	5	0.5	1	3	3	2.53783252	14.6061	0.173752
Electrical hazards from panel bard kept near to furnace(J)	3	3	3	3	3	3	0.25	0.33	1	0.5	1.27941384	14.6061	0.087594
Falling of load while lifting(K)	3	3	3	3	3	3	0.5	0.33	2	1	1.54564635	14.6061	0.105822

Table XII: Ranking of Risks with respect to possibility of Intervention (E3).

Hazard	A	B	C	D	E	F	G	I	J	K	Geometric mean	Sum	Priority weight(P)
Emergency Switch is not working (A)	1	4	3	3	3	3	2	2	5	5	2.737889458	13.1765	0.20778579
Fire\Explosion(B)	0.25	1	0.25	0.25	0.33	0.33	0.5	0.5	3	3	0.566120824	13.1765	0.042964431
Dilution Damper is not working(C)	0.33	4	1	1	3	1	0.5	0.5	3	3	1.145476425	13.1765	0.086933285
ID Fan is not working(D)	0.33	4	1	1	3	1	0.5	0.5	3	3	1.145476425	13.1765	0.086933285
Gas Leakage Detector is not working(E)	0.33	3	0.33	0.33	1	0.5	0.33	0.33	3	3	0.692036268	13.1765	0.052520492
Motorized Damper is not working(F)	0.33	3	1	1	2	1	0.33	0.33	3	3	0.960294633	13.1765	0.072879341
Dust , Smoke coming from furnace(G)	0.5	2	2	2	3	3	1	1	3	3	1.868985896	13.1765	0.141842363
Heat Radiation(H)	0.5	2	2	2	3	3	0.33	0.33	3	3	1.382574188	13.1765	0.104927271
Glass Wool Emission during Maintenance , Loading & Unloading of work(I)	0.5	2	2	2	3	3	1	1	3	3	1.868985896	13.1765	0.141842363
Electrical Hazards from panel bard kept near to Furnace(J)	0.2	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1	0.5	0.362175634	13.1765	0.027486482
Falling of load while lifting(K)	0.5	0.33	0.33	0.33	0.33	0.33	0.33	0.33	2	1	0.446507049	13.1765	0.03388662

Table XIII: Ranking of Risks.

Hazard	Weight of E1×Priority of E1	Weight of E2×Priority of E2	Weight of E3×Priority of E3	Sum(s)	Weight of E	Weight of E× Priority of E	Weight of F× Priority of F	Weight of D × Priority of D	Sum(Risk Rank)
A	0.016719983	0.0136268	0.05169918	0.082045977	0.0937	0.007687708	0.017081	0.021728	0.0464967
B	0.026079173	0.0186565	0.01068998	0.055425615	0.0937	0.00519338	0.015058	0.081079	0.1013304
C	0.00487311	0.0304303	0.02162987	0.056933292	0.0937	0.005334649	0.036702	0.010802	0.0528386
D	0.005056086	0.0297088	0.02162987	0.056394729	0.0937	0.005284186	0.039089	0.02483	0.0692032
E	0.004221612	0.0154571	0.01306762	0.0327463	0.0937	0.003068328	0.022803	0.043686	0.0695573
F	0.004296091	0.0289419	0.01813311	0.051371072	0.0937	0.004813469	0.052071	0.02483	0.0817145
G	0.006795683	0.1234484	0.0352918	0.165535912	0.0937	0.015510715	0.144846	0.005289	0.1656457
H	0.009871284	0.1159095	0.02610695	0.151887786	0.0937	0.014231886	0.151731	0.004758	0.1707209
I	0.00654377	0.1032849	0.0352918	0.145120439	0.0937	0.013597785	0.0933	0.007396	0.1142938
J	0.039755393	0.0520697	0.00683891	0.098663972	0.0937	0.009244814	0.023865	0.034489	0.0675988
K	0.032527444	0.0629048	0.00843133	0.103863589	0.0937	0.009732018	0.030734	0.020122	0.060588

Table XIV: Risk ranking by AHP.

Rank	Hazards
1	Heat Radiation
2	Dust , Smoke Coming From Furnace
3	Glass Wool Emission During Maintenance, Loading & Unloading Of Work
4	Fire\Explosion
5	Motorized Damper Is Not Working
6	Gas Leakage Detector Is Not Working
7	ID Fan Is Not Working
8	Electrical Hazards From Panel Bard Kept Near To Furnace (J)
9	Falling Of Load While Lifting
10	Dilution Damper Is Not Working
11	Emergency Switch Is Not Working

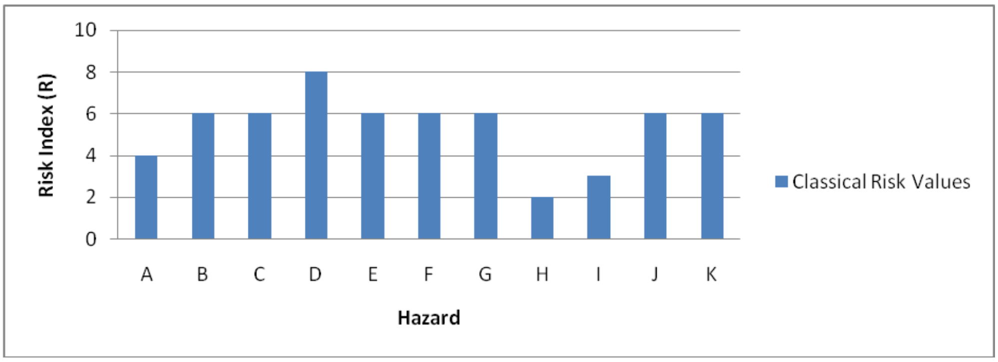

Figure 3: Plot between Risk Index (R) and hazards - Classical approach.

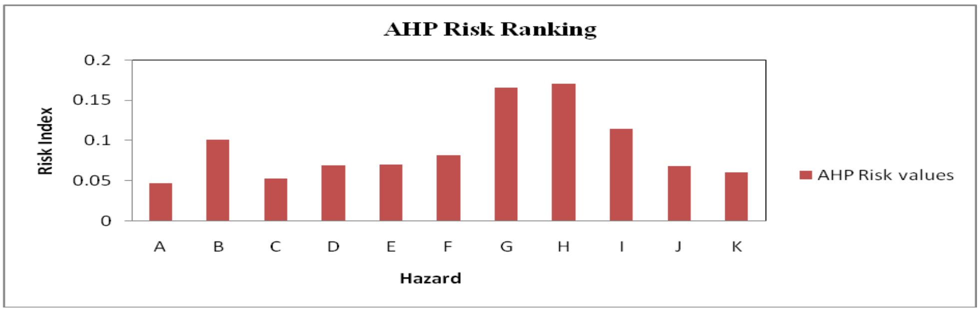

Figure 4: Plot between Risk Index (R) and hazards - An AHP approach.

7. CONCLUSION

In this paper, a new approach for risk calculation is proposed. AHP is a multi-criteria decision making technique, which breaks down a decision making problem in to a hierarchical structure, through which decision makers can bring about a comparison among different risk levels. The main attributes used for carrying risk estimation are Frequency of Occurrence, Size of consequent damage, and Possibility of Limiting/avoiding of damage. The sub criteria go further down on a microscopic scale to estimate the risk comprehensively. The sub criteria of E are speed of dangerous occurrence, risk awareness, possibility of intervention. Here, Risk assessment is carried out in all operations performed in LPG fired furnace by using AHP and the results obtained are compared with that by classical method. From the results obtained it is clear that by considering more parameters for the risk calculation by using AHP, the process of risk assessment becomes very precise and accurate one. Hence, AHP method can be used for the risk calculation in various industries such that where they are using classical method for risk calculations without considering other relevant parameters.

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