TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 64, Issue I, March, 2021

RISK ASSESSMENT USING FUZZY AHP AND FUZZY TOP-SIS HYBRID APPROACH FOR SAFE AND SUSTAINABLE WORK, CASE STUDY

Nadira MAAMRI, Rachid CHAIB, Mohamed BENIDIR, Ion VERZIA

Abstract§ *Every activity involves risks, which can have adverse consequences on the health and safety of workers, property and environment. The uncontrolled risks can go over financial issues to legal and environmental issues. These consequences might affect companies not only for a short term but can have a long term effects. Hence, companies are imposed to be more cautious in protecting its profit and sustainability. Today companies are paying more attention to risk management. So to manage risks properly, first they should be well identified and evaluated. "What couldn't be measured couldn't be managed". That requires safety engineers to choose the relevant analysis method. This paper aims to assess and rank risks inside ACO1 workshop of SIDER EL HADJAR Company, Algeria and propose safety measures to manage existing risks. Risks from insignificant to critical scale are found in the workplace which should be reduced and mitigated through appropriate safety measures.*

Keywords: Fuzzy Multi-Criteria Decision Making; Risk assessment; risk management; fuzzy Analytic Hierarchy Process; fuzzy Top-SIS.

1. INTRODUCTION

Every activity involves risks, which can have adverse consequences on the health and safety of workers, property and environment. The uncontrolled risks can go over financial issues to legal and environmental issues. This automatically can cost companies its image and sustainability. Hence managing safety risks becomes crucial. So to manage risks, first they should be well identified and evaluated. What couldn't be measured couldn't be managed. This requires safety engineers to choose the relevant analysis method. There are several risk assessment tools. That are classified into three main categories; Qualitative approaches such as checklists, HAZOP, What-If Analysis, safety audits, task analysis etc; Hybrid techniques or called semi quantitative technique like ETA (Event Tree Analysis), Risk based Maintenance (RBM) and fault tree analysis (FTA)…etc And Quantitative techniques where risk could be mathematically quantified like, Quantitative Risk-Assessment (QRA),Quantitative Assessment of Domino Scenarios (QADS), Weighted Risk Analysis (WRA), the decision matrix risk-assessment (DMRA)...etc [1]. DEMRA technique is widely used in most occupational health and safety departments. It depends primarily on experts' vision related to risks in their work area. The main goal of risk assessment is to manage priority risks, control workplace safety and minimize the chances of accidents[2][3][4]. Also to assist in making decisions, based on the outcomes of risk analysis, about which risks require action and the priority of its treatment[5][6]. Multi-Criteria Decision-Making technique (MCDM) is a strong and systematic approach to finding the best Choice from among practicable alternatives[7][8]. It represents the process of evaluating the best course of action from the available alternatives[9][10]. Carlsson and Fuller classified MCDM methods into four different types that are : utility theory, multiple objective programming, outranking, and group decision and negotiation theory[11]. While Duckstein and Opricovic considered

MCDM as a complex and dynamic process, including both managerial and engineering level[12].

This approach is largely used in risk assessment studies in many fields. For instance, [13] proposed a risk assessment model for construction joint ventures using AHP-Utility theory. [14] evaluated the construction safety management system and measured prioritization through multicriteria decision. [15] used a Fuzzy MCDM method to assess the level of safety at Construction labors. In aim to provide safe transportation multicriteria decision making techniques are applied [16][17]. [18] utilized MCDM through (T_AHP) and (F_AHP) with (HAZOP) method to assess risks focusing on the deviations with economic, health, and environment approach [19].

Fuzzy AHP and Fuzzy TOPSIS are among the MCDM approaches[7][20][8] [21]. Which are used in this case of study in the aim of assessing and ranking risks that exist in ACO1 workshop at SIDER EL HADJAR Company to manage them better.

2. LITTERATURE REVIEW

2.1. Fuzzy AHP

The fuzzy analytic hierarchy process (FAHP) is a dominant decision making technique to solve the problems of multicriteria analysis (MA) using fuzzy set theory[22][23]. There have been many proposed FAHP methods. [24]determine fuzzy priorities between comparison ratios whose membership functions are trapezoidal. [25] Introduces an approach for handling fuzzy AHP using triangular fuzzy numbers for pair wise comparison scale of fuzzy AHP, and using the extent analysis method for the synthetic extent values of the pair wise comparisons. The AHP method use two ways to find the final weights; the first is called Lambda Max (λmax) and the second is named geometric mean. In this paper the Buckley approach is used. In (AHP) decision makers should give importance to main criteria and to give a preference for each alternative in respect to each criterion for scale rating. The fuzzy AHP is more accurate; it deals with the problem of uncertainty by using fuzzy scale instead of crisp values. The procedural method is presented in the following four steps:

Step 1: The pair wise comparison is used to determine which criteria is most important as shown in formula (1) and (2) .The figure 1 below presents the linguistic scale of importance and the table below presents the triangular fuzzy scale and triangular fuzzy reciprocal scale proposed by [26].

$$\tilde{A} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

$$\tilde{a} = \begin{cases} \tilde{1}, \tilde{3}, \tilde{5}, \tilde{6}, \tilde{7}, \tilde{8}, \tilde{9} & \text{criterion i is of relative importance to criterion j} \\ 1 & i = j \\ \tilde{1}^{-1}, \tilde{2}^{-1}, \tilde{3}^{-1}, \tilde{4}^{-1}, \tilde{5}^{-1}, \tilde{6}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & \text{Criterion j is of relative importance to criterion i} \end{cases} \quad (2)$$

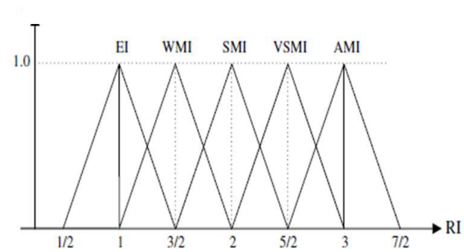

Fig1. Linguistic scale for relative importance

Step2: Using the geometric mean technique the fuzzy geometric mean matrix. It is defined by formula (3) ; The pair wise comparison is used to determine which criteria is most important as shown in formula (1) and (2)

$$\tilde{r}i = (\tilde{a}i1 \otimes \widetilde{ai2} \ldots \otimes \widetilde{ain})^{(1/n)} \quad (3)$$

Table1.Linguistic scales for difficulty and importance

Linguistic scale for difficulty	**Linguistic scale for importance**	**Triangular fuzzy scale**	**Triangular fuzzy reciprocal scale**
Just equal	Just equal	(1,1,1,)	(1,1,1)
Equally difficult(ED)	Equally important(EI)	(1/2,1,3/2)	(2/3,1,2)
Weakly more difficult (WMD)	Weakly more difficult (WMI)	(1,3/2,2)	(1/2,2/3,1)
Strongly more difficult(SMD)	Strongly more important(SMI)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very Strongly more difficult(SMD)	Very Strongly more important(SMI)	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more difficult (AMD)	Absolutely more difficult (AMI)	(5/2,3,7/2)	(2/7,1/3,2/5)

Step3: Fuzzy weights of each criterion is calculated by using the formula (4) below

$$\widetilde{w}i = \tilde{r}i \otimes (\widetilde{r1} \oplus \widetilde{r2} \oplus \ldots\ldots \widetilde{rn})^{(-1)} \qquad (4)$$

Step 4: To transfer the calculated weight from fuzzy number to crisp number center of area (COA) method is used, through equation (5) below:

$$Wi= [(uwi - lwi) + (mwi - lwi)] / 3 + lwi \qquad (5)$$

2.2. Fuzzy Top-sis

The Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) was developed in the aim to choose the best alternative based on the concepts of the compromise solution. It was introduced by Hwang and Yoon (1981)[27]. Fuzzy TOPSIS depends on the fuzzy scale. It is used to solve MCDM problems and choose the best alternative with the shortest distance from a positive ideal solution and farthest distance from the negative ideal solution[20]. Fuzzy top-sis approach were used in several domains such as : location problem, supplier selection and, sustainable and renewable energy etc [28].The procedure is going through the following steps [29] [30]:

Step1: After taking a decision making group, the score of identifying alternative is calculated using the formula below;

$$\tilde{x}_{ij} = \frac{1}{k} (\tilde{x}_{ij}^{1} + \tilde{x}_{ij}^{2} + \ldots + \tilde{x}_{ij}^{k}) \qquad (6)$$

i=1,2,…, m ; j=1,2,…, n

Where $\tilde{x}_{ij}^{k}$ is the rating of alternative Ai with respect to criterion Cj evaluated and

$$\tilde{x}_{ij}^{k} = (a_{ij}^{k}, b_{ij}^{k}, c_{ij}^{k})$$

Step2: Normalize the fuzzy decision matrix

The normalized fuzzy decision matrix denoted by $\widetilde{R}$ is shown as following formula: Where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right) \quad c_j^+ = \max_i c_{ij}$$

Step 3: The weighted fuzzy normalized decision matrix is shown as following:

$$\tilde{v} = [\tilde{v}_{ij}]m \times n, \; i= 1,2,\ldots,m; \; j=1,2,\ldots,n$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j \qquad (8)$$

Step 4: Determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS)

; We can define the FPIS A^+ and FNIS A^- as following formula :

$$A^+=(\widetilde{V}_1^+, \widetilde{V}_2^+, \ldots, \widetilde{V}_n^+) \qquad (9)$$

$$A^-=(\widetilde{V}_1^-, \widetilde{V}_2^-, \ldots, \widetilde{V}_n^-) \qquad (10)$$

Where $\widetilde{V}_j^+ = (1, 1, 1)$ and $\widetilde{V}_j^- = (0,0,0)$ j=1, 2,…, n

Step 5: Calculate the distance of each alternative from FPIS and FNIS.

The distances (d_i^+ and d_i^-) of each alternative A^+ from and A^- can be currently calculated.

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{V}_j^+), \quad i=1,2,\ldots,m \quad j=1,2,\ldots,n \qquad (11)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{V}_j^-) \quad i=1,2,\ldots,m \quad j=1,2,\ldots,n \qquad (12)$$

Step 6: calculate the closeness coefficient (CCi), once the d_i^+ and d_i^- of each alternative have been calculated. Calculate similarities to ideal solution. This step solves the similarities to an ideal solution by formula below:

$$CCi = \frac{d_i^-}{d_i^+ + d_i^-} \quad i=1,2,\ldots,m \qquad (13)$$

According to the CCi, we can determine the ranking order of all alternatives and determine the best one from available alternatives.

3. MATERIAL AND METHOD

The working method is used to assess the risks within the ACO1 workshop based on Fuzzy AHP and FUZZY-TOPSIS. The working methodology goes through the following steps:

1- Identification of risks that exist in ACO1 workshop depending on DEMRA technique (decision matrix risk assessment).

2-Data collection through the participation of health and safety experts;

3-Application of the Fuzzy AHP method for determining the weight of two criteria: severity and probability.

4-Application of the Fuzzy TOP-SIS method for risk ranking.

5-Suggestion of appropriate control measures.

The experts in charge of industrial hygiene and safety position are asked to answer the questionnaire concerning the importance of probability and severity (P, S) and the related alternatives (hazards). The model in Figure 1 shows the steps followed in the risk analysis.

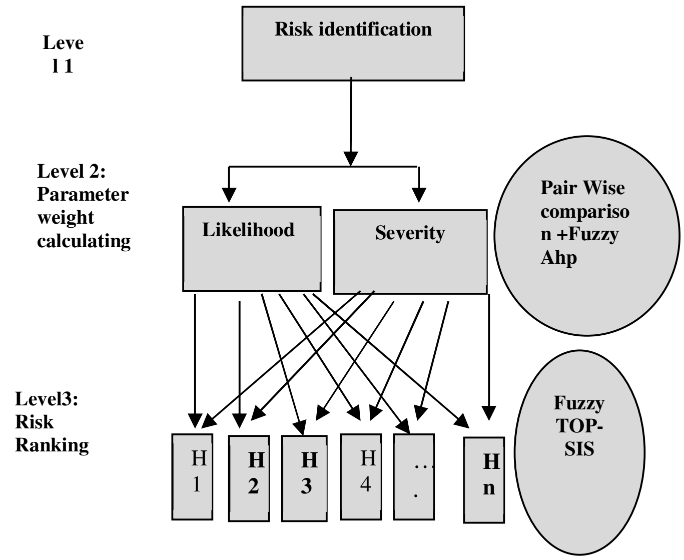

Figure 2.Risk assessment using Fuzzy AHP +fuzzy TOPSIS

4. STUDY AREA

El-Hadjar steel Plant is located at a distance of 15 km from the city of Annaba. The plant is supplied with ore by rail from the mines of Ouenza and Boukhadra (in the South East of the country, 15 km from the complex) and with coal from the port of Annaba to which it is connected by a railroad. Products from the complex are transported by rail to the whole country and to the port for export. El Hadjar steel complex covers an area of 800Ha, of which 300Ha are allocated to the steel production workshops (300Ha) and to the communication routes (200Ha), this steel complex (the company Sider El-Hadjar from Annaba) constitutes one of the most important companies of AFRICA in the sector of the steel industry, at the national level it is one of the flagship companies of the Algerian east.

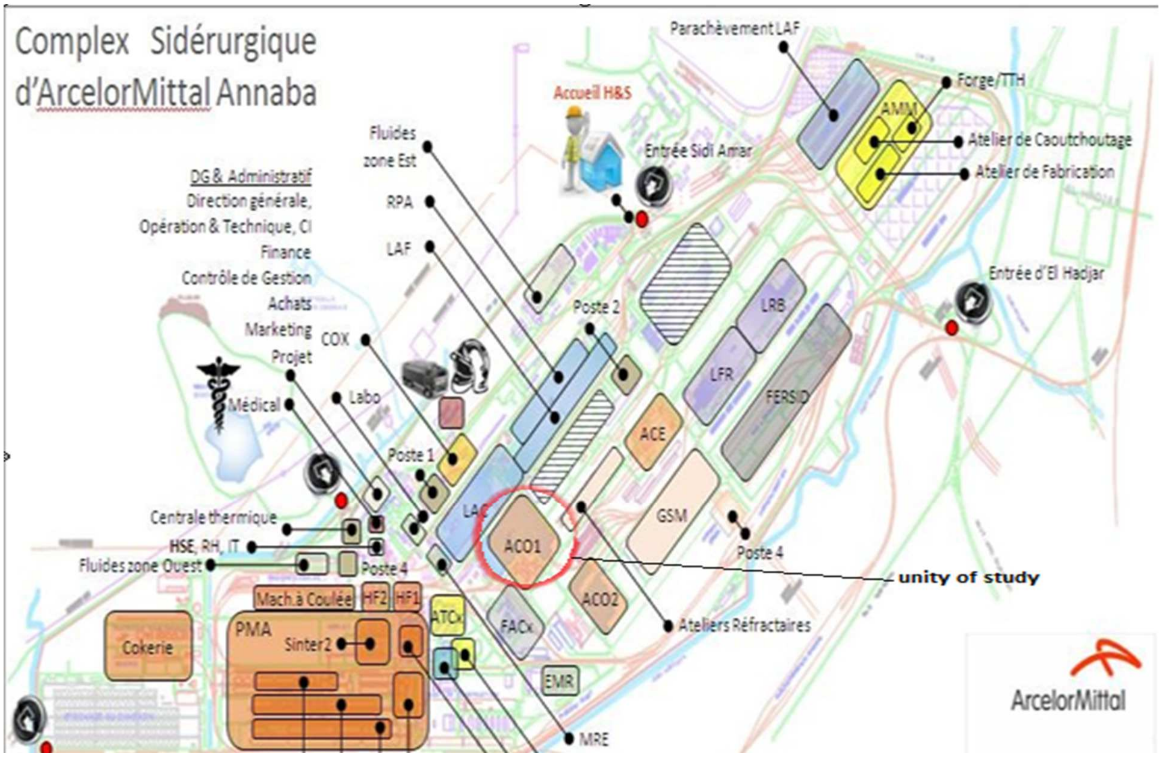

Figure 3. Arcelormittal steel complex (ACO1 workshop)

4.1. Identification of activity sectors:

workshop ACO1 consists of 5 essential areas, namely, Table 3:

Table 3.The different zones of the ACO1 workshop

Zone	Activity
Refining zone	Steel making
Fluid zone	Cooling
Continuous casting machine area	Slab handling and processing
Refractory zone	Preparation and masonry converter, font pocket, steel pocket and repertitaire
Maintenance area	Ensures preventive equipment installation and maintenance

4.2. Severity and Probability evolution in ACO1 workshop

The evolution of severity and probability rate reported at the ACO1 workshop during the period 2015-2019 is as follows, figures 5 and 6.

Figure 4. Evolution of severity rate

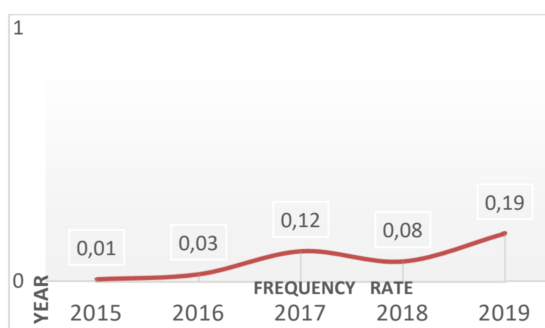

Figure 5. Evolution of probability rate

The matrix (5x5) below is based on the risk classification at ACO1 unit.

Likelihood						
	5 Almost certain	5	10	15	20	25
	4 Likely	4	8	12	16	20
	3 Possible	3	6	9	12	15
	2 Unlikely	2	4	6	8	10
	1 Rare	1	2	3	4	5
		1 Insignificant impact	2 Minor impact	3 Moderate impact	4 Major impact	5 Catastrophic impact
		Severity				

11-25 Unacceptable Risk	7-10 Significant Risk	3-6 Acceptable Risk	1-2 Insignificant Risk

Figure 6.5*5 Matrix of risk classification

5.RESULTS AND DISCUSSION:

Table 4 shown below, presents the evaluation of two risk parameters (likelihood) and (severity) by three O S Experts using linguistic terms table (1) by Pair wise comparison. After following the previous mentioned steps the final crisp value of the weight for both criteria is: Wl: 0.319, Ws : 0.681.

W	severity			Likelihood		
severity	1.000	1.000	1.000	1.500	2.167	3.000
Likelihood	0.333	0.467	0.667	1.000	1.000	1.000
CRI	Ri					
S	1.225	1.472	1.732			
L	0.577	0.683	0.816			
Total	1.802	2.155	2.549			
P (-1)	0.555	0.464	0.392			
CRI	Wi					
S	0.680	0.683	0.679			
L	0.320	0.317	0.320			
CRI	Mi	Ni				
S	0.681	0.681				
L	0.319	0.319				
TOTAL	1.000					

Table6. Evaluations of OS experts in linguistic scale of likelihood and severity

Item	Hazard	Severity (linguistic term)	Likelihood (linguistic term)
H1	Heat release	G, G, MG	MP, P, MP
H2	Falling load	MG, MG, G	G, MG, G
H3	Gas leak	G, MG, G	MP, P, MP
H4	Projected sparks during temperature rise	G, MG, VG	MP, MP, P
H5	Oxygen leak	G, MG, G	MP, MP, P
H6	Mechanical handling	G, G, G	MP, MP, P
H7	Burn	VG, G, G	P, MP, P
H8	Inhalation	MG, MG, G	P, P, MP
H9	slipping	F, F, G	MP, MP.MP
H10	Manual handling	G, VG, VG	MP, P, MP
H11	Electrification	VG, VG, G	P, MP, P
H12	Ground level fall	F, F, MP	MP, MP, P
H13	Fire / explosion	MG, G, MG	Mp, Mp, P

H14	Molten metal projection	G, MG, G	MP, P, MP
H15	Contact with hot elements	G, G, G	MP, MP, P
H16	Noise exposure	F, MG, MG	P, P, MP
H17	Vibration exposure	MG, F, MG	P, P, MP
H18	Human metal exposure	G, G, G	P, P, MP
H19	Loss of control	G, G, FG	P, P, P
H20	Loss from height	VG, G, G	MP, MP, P

Table 7.Combined Decision Matrix

Item	Combined Decision Matrix					
H1	5	8.333333	10	0.4	2.166667	5
H2	5	7.666667	10	5	8.333333	10
H3	5	8.333333	10	0	2.333333	5
H4	5	8.666667	10	0	2.333333	5
H5	5	8.333333	10	0	2.333333	5
H6	7	9	10	0	2.333333	5
H7	7	9.333333	10	0	1.666667	5
H8	5	7.666667	10	0	1.666667	5
H9	3	6.333333	10	1	3	5
H10	7	9.666667	10	1	3	5
H11	7	9.666667	10	0	1.666667	5
H12	1	4.333333	7	0	2.333333	5
H13	5	7.666667	10	0	2.333333	5
H14	5	8.333333	10	0	2.333333	5
H15	7	9	10	0	2.333333	5
H16	3	6.333333	9	0	1.666667	5
H17	3	6.333333	9	0	1.666667	5
H18	7	9	10	0	1.666667	5
H19	3	7.666667	10	0	1	3
H20	7	9.333333	10	0	2.333333	5

Table 8.Normalized and weighted Normalized fuzzy decision matrix

	Normalized fuzzy decision matrix					
W	0.68	0.683	0.679	0.32	0.317	0.32
Item	Severity			Likelihood		
H1	0.500	0.833	1	0.040	0.217	0.5
H2	0.500	0.767	1	0.500	0.833	1
H3	0.500	0.833	1	0.000	0.233	0.5
H4	0.500	0.867	1	0.000	0.233	0.5
H5	0.500	0.833	1	0.000	0.233	0.5
H6	0.700	0.900	1	0.000	0.233	0.5
H7	0.700	0.933	1	0.000	0.167	0.5
H8	0.500	0.767	1	0.000	0.167	0.5
H9	0.300	0.633	1	0.100	0.300	0.5
H10	0.700	0.967	1	0.100	0.300	0.5
H11	0.700	0.967	1	0.000	0.167	0.5
H12	0.100	0.433	0.7	0.000	0.233	0.5
H13	0.500	0.767	1	0.000	0.233	0.5
H14	0.500	0.833	1	0.000	0.233	0.5
H15	0.700	0.900	1	0.000	0.233	0.5

H16	0.300	0.633	0.9	0.000	0.167	0.5
H17	0.300	0.633	0.9	0.000	0.167	0.5
H18	0.700	0.900	1	0.000	0.167	0.5
H19	0.300	0.767	1	0.000	0.100	0.3
H20	0.700	0.933	1	0.000	0.233	0.5

	Weighted Normalized fuzzy decision matrix					
W	0.68	0.683	0.679	0.32	0.317	0.32
Item	Severity			Likelihood		
H1	0.340	0.569	0.679	0.013	0.069	0.16
H2	0.340	0.524	0.679	0.160	0.264	0.32
H3	0.340	0.569	0.679	0.000	0.074	0.16
H4	0.340	0.592	0.679	0.000	0.074	0.16
H5	0.340	0.569	0.679	0.000	0.074	0.16
H6	0.476	0.615	0.679	0.000	0.074	0.16
H7	0.476	0.637	0.679	0.000	0.053	0.16
H8	0.340	0.524	0.679	0.000	0.053	0.16
H9	0.204	0.433	0.679	0.032	0.095	0.16
H10	0.476	0.660	0.679	0.032	0.095	0.16
H11	0.476	0.660	0.679	0.000	0.053	0.16
H12	0.068	0.296	0.4753	0.000	0.074	0.16
H13	0.340	0.524	0.679	0.000	0.074	0.16
H14	0.340	0.569	0.679	0.000	0.074	0.16
H15	0.476	0.615	0.679	0.000	0.074	0.16
H16	0.204	0.433	0.6111	0.000	0.053	0.16
H17	0.204	0.433	0.6111	0.000	0.053	0.16
H18	0.476	0.615	0.679	0.000	0.053	0.16
H19	0.204	0.524	0.679	0.000	0.032	0.096
H20	0.476	0.637	0.679	0.000	0.074	0.16

Table 9: FPISA* and FNIS A- estimation

A*	0.476	0.660	1	0.160	0.264	0.32
A-	0.204	0.296	0.475	0.000	0.032	0.096

Fuzzy TOPSIS final risk Ranking:

Item	di*	di-	CCi	Rank
H1	0.263	0.253	0.490252	13
H2	0.111	0.450	0.80166	1
H3	0.265	0.254	0.489479	14
H4	0.258	0.264	0.505412	12
H5	0.265	0.254	0.489479	14
H6	0.197	0.311	0.612694	8

H7	0.192	0.315	0.621523	7
H8	0.290	0.230	0.442107	15
H9	0.358	0.268	0.428259	16
H10	0.153	0.415	0.729947	4
H11	0.179	0.459	0.71954	5
H12	0.507	0.290	0.363524	19
H13	0.282	0.316	0.528557	10
H14	0.265	0.346	0.56602	9
H15	0.197	0.569	0.742987	2
H16	0.387	0.278	0.417814	17
H17	0.387	0.270	0.41094	18
H18	0.205	0.402	0.662648	6
H19	0.384	0.401	0.510934	11
H20	0.184	0.507	0.734295	3

The most critical risks that are a part of the red zone according to the classification figure (1) are considered unacceptable as well as the risks classified in the orange zone are considered significant and both categories must be reduced to the tolerable zone. Risk management requires a precise identification assessment and ranking of the risks for the implementation of adequate prevention and protection measures for this object. For high and medium risks immediate attention and review of security conditions are required to reduce risks into tolerable zone by following the principle of as low as reasonably practicable (ALARP). which means involves weighing a risk against the trouble, time and money needed to control it [31][32].

6. CONCLUSION

This approach of MCDM has allowed identifying the critical risks in the unit. The assessment of the risks level in the five zones (refining, casting machine, fluid, Refractory, maintenance) of the ACO1 unit at SIDER EL HADJAR company using FAHP and FTOPSIS, will permit to make preventive and corrective measures to reduce severity and likelihood level of risks. This assessment will help to map risks at the company, and also to propose priority of actions based on real events.

The aim of the hierarchy of risks helps classifying risks properly and ensures that risks are treated at its root source and that the measures taken systematically protect workers. Prevention is a prerequisite and a risk assessment in the workplace is essential for better management and sustainable safe work.

Recommendation:

In aim to control risks the following points are recommended:

- Define the measures to be taken to control the risks (Technical, Organizational , Human ...) using the hierarchy of risk control methods ;
- Eliminate or mitigate the risks, and cope with the ones that couldn't be eliminated ;
- Monitor the situation to ensure that risk control measures continue to be effective;
- Integrate workers for participation on risk assessment and prevention by allowing their suggestions from their work area;
- Reducing risks following the principle of as low as reasonably practicable (ALARP),
- Cost Benefit Analysis (CBA) can also be applied for making ALARP decisions related to risk reduction.

7. REFERENCES

[1] C. R. Domínguez, I. V. Martínez, P. M. Piñón Peña, and A. Rodríguez Ochoa, "Analysis and evaluation of risks in underground mining using the decision

matrix risk-assessment (DMRA) technique, in Guanajuato, Mexico," J. Sustain. Min., vol. 18, no. 1, pp. 52–59, 2019, doi: 10.1016/j.jsm.2019.01.001.

[2] "Risk Assessment and Management in the U Context of the Seveso II Directive." 1997.

[3] W. Sghaier, E. Hergon, and A. Desroches, "Gestion globale des risques," Transfus. Clin. Biol., vol. 22, no. 3, pp. 158–167, 2015, doi: 10.1016/j.tracli.2015.05.007.

[4] J. Joy, "Occupational safety risk management in Australian mining," Occup. Med. (Chic. Ill)., vol. 54, no. 5, pp. 311–315, 2004, doi: 10.1093/occmed/kqh074.

[5]C. Lalonde and O. Boiral, "Managing risks through ISO 31000: A critical analysis," Risk Manag., vol. 14, no. 4, pp. 272–300, 2012, doi: 10.1057/rm.2012.9.

[6]M. Merad, "SD-Organizational-09042013 Comment obtenir des Organisations Hautement Durables ? Gouvernance et critères d ' apprentissage de l a durabilité," no. August, 2015.

[7]F. Duran and İ. B. Zafeirakopoulos, "Environmental Risk Assessment of E-waste in Reverse Logistics Systems Using MCDM Methods," pp. 590–603, 2019, doi: 10.1007/978-3-319-92267-6.

[8]Ž. Stevi, "SS symmetry Application of MCDM Methods in Sustainability Engineering : A Literature Review 2008 – 2018," 2018, doi: 10.3390/sym11030350.

[9]R. M. Zulqarnain, M. Saeed, N. Ahmad, F. Dayan, and B. Ahmad, "Application of TOPSIS Method for Decision Making Application of TOPSIS Method for Decision Making," vol. 2, no. 2, 2020.

[10] S. C. Nayak, S. Parida, B. Pati, and C. R. Panigrahi, "Multicriteria decision - making techniques for avoiding similar task scheduling conflict in cloud computing," no. August, 2019, doi: 10.1002/dac.4126.

[11] S. Tesfamariam and R. Sadiq, "Risk-based environmental decision-making using fuzzy analytic hierarchy process (F-AHP)," Stoch. Environ. Res. Risk Assess., vol. 21, no. 1, pp. 35–50, 2006, doi: 10.1007/s00477-006-0042-9.

[12] T. R. Basin, "Multiobjective Optimization in River Basin Development," vol. 16, pp. 14–20, 1980.

[13] S. Hsueh, Y. Perng, M. Yan, and J. Lee, "On-line multi-criterion risk assessment model for construction joint ventures in China," vol. 16, pp. 607–619, 2007, doi: 10.1016/j.autcon.2007.01.001.

[14] C. M. Tam, T. K. L. Tong, G. C. W. Chiu, and I. W. H. Fung, "Non-structural fuzzy decision support system for evaluation of construction safety management system," Int. J. Proj. Manag., vol. 20, no. 4, pp. 303–313, 2002, doi: 10.1016/S0263-7863(00)00055-7.

[15] S. R. Mohandes, H. Sadeghi, A. Mahdiyar, and S. Durdyev, "Assessing Construction Labours ' Safety Level : A Fuzzy MCDM Approach ASSESSING CONSTRUCTION LABOURS ' SAFETY LEVEL : A FUZZY MCDM APPROACH," no. February, 2020, doi: 10.3846/jcem.2020.11926.

[16] D. Nenadić, "RANKING DANGEROUS SECTIONS OF THE ROAD USING," vol. 2, no. 1, pp. 115–131, 2019.

[17] A. Furda and L. Vlacic, "Enabling safe autonomous driving in real-world city traffic using Multiple Criteria decision making," IEEE Intell. Transp. Syst. Mag., vol. 3, no. 1, pp. 4–17, 2011, doi: 10.1109/MITS.2011.940472.

[18] P. K. Marhavilas, M. Filippidis, G. K. Koulinas, and D. E. Koulouriotis, "A

HAZOP with MCDM based risk-assessment approach: Focusing on the deviations with economic/health/environmental impacts in a process industry," Sustain., vol. 12, no. 3, 2020, doi: 10.3390/su12030993.

[19] M. Nazam, J. Xu, Z. Tao, J. Ahmad, and M. Hashim, "A fuzzy AHP-TOPSIS framework for the risk assessment of green supply chain implementation in the textile industry," [GS],International J. Supply Oper. Manag., vol. 2, no. 1, pp. 548–568, 2015.

[20] D. Kacprzak, "Fuzzy topsis method for group decision making," Mult. Criteria Decis. Mak., vol. 13, no. May, pp. 116–132, 2018, doi: 10.22367/mcdm.2018.13.07.

[21] M. Gul and A. F. Guneri, "A fuzzy multi criteria risk assessment based on decision matrix technique: A case study for aluminum industry," J. Loss Prev. Process Ind., vol. 40, pp. 89–100, 2016, doi: 10.1016/j.jlp.2015.11.023.

[22] R. Assessment, "A fuzzy AHP methodology for selection of risk assessment methods in occupational safety," vol. 18, 2015.

[23] S. KaurSehra, Y. Singh Brar, and N. Kaur, "Multi Criteria Decision Making Approach for Selecting Effort Estimation Model," Int. J. Comput. Appl., vol. 39, no. 1, pp. 10–17, 2012, doi: 10.5120/4783-6989.

[24] J. J. Buckley, "Fuzzy hierarchical analysis," Fuzzy Sets Syst., vol. 17, no. 3, pp. 233–247, 1985, doi: 10.1016/0165-0114(85)90090-9.

[25] D. Chang, "Applications of the extent analysis method on fuzzy AHP," vol. 2217, no. 95, 1996.

[26] C. Kahraman and T. Ertay, "A fuzzy optimization model for QFD planning process using analytic network approach," 2004, doi: 10.1016/j.ejor.2004.09.016.

[27] M. Economics, Lectu re Notes in Economics and Mathematical Systems Ching-Lai Hwang Kwangsun Yoon Multiple Attribute Decision Making Springer-Verlag Berlin Heidelberg New York 1981, vol. 1. 1973.

[28] N. Sorin and I. Dzitac, "Fuzzy TOPSIS : A General View Fuzzy TOPSIS : A General View," no. December 2016, 2017, doi: 10.1016/j.procs.2016.07.088.

[29] Multiple Attribute Decision Making. 2011.

[30] A. Jafarnejad, S. Ahangari, M. Moradi-moghadam, and M. Faghei, "A New Integrated Approach of Linear Goal Programming and Fuzzy TOPSIS for Technology Selection," no. February 2016, 2013.

[31] D. S. Bowles, "ALARP Evaluation : Using Cost / Benefit Disproportionality to Justify Risk ALARP EVALUATION : USING COST EFFECTIVENESS AND," no. January, 2016.

[32] J. Hurst, J. Mcintyre, Y. Tamauchi, and H. Kinuhata, "A summary of the ' ALARP ' principle and associated thinking," J. Nucl. Sci. Technol., vol. 00, no. 00, pp. 1–13, 1881, doi: 10.1080/00223131.2018.1551814.

Evaluarea riscurilor utilizând abordarea hibridă Fuzzy AHP și Fuzzy TOP-SIS pentru o muncă sigură și durabilă, studiul de caz

Rezumat : Fiecare activitate implică riscuri, care pot avea consecințe negative asupra sănătății și siguranței lucrătorilor, a proprietății și a mediului. Riscurile necontrolate pot trece peste problemele financiare la problemele legale și de mediu. Aceste consecințe ar putea afecta companiile nu numai pe termen scurt, ci pot avea efecte pe termen lung. Prin urmare, se impune companiilor să fie mai prudente în protejarea profitului și durabilității sale. Astăzi companiile acordă mai multă atenție gestionării riscurilor. Deci, pentru a gestiona corect riscurile, mai întâi acestea ar trebui să fie bine identificate și evaluate. „Ceea ce nu putea fi măsurat nu putea fi gestionat". Acest lucru necesită inginerilor din domeniul siguranței să aleagă metoda de analiză relevantă. Această lucrare își propune să evalueze și să clasifice riscurile în cadrul atelierului ACO1 al companiei SIDER EL HADJAR, Algeria și să propună măsuri de siguranță pentru gestionarea riscurilor existente. La locul de muncă se găsesc riscuri de la scară nesemnificativă la critică, care ar trebui reduse și atenuate prin măsuri de siguranță adecvate.

Nadira MAAMRI, PhD Student**,** Department of transportation Engineering, university of Constantine 1,Algeria.nadira_maamri@yahoo.fr, phone: +213669478786.

Rachid CHAIB, Prof. Dr.Department of Engineering transport and environment laboratory LITE, Mentouri University, Constantine, Algeria. r3chaib@yahoo.fr, phone: +213672883633.

Mohamed BENIDIR, Prof. Dr. Department of transportation Engineering, university of Constantine 1,Algeria.mcbenidir@yahoo.fr, phone:+213667763528.

Ion VERZEA, Prof. Dr. Gheorghe Asachi, technical university of Iasi, Roumania. iverzea@tuiasi.ro, phone: 0232 278683/1214.