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AHP Application In Occupational Safety Analysis In An Industrial Gas Manufacturing Company (Ghana)

Evelyn Enchill[1], Edmond Yeboah Nyamah[2]
[1]University of Electronic science and Technology of China, Chengdu, 610054, China.
Email:evechill63@yahoo.com
[2] University of Electronic science and Technology of China, Chengdu, 610054, China.
Email:eddynaa@yahoo.com

ABSTRACT:

This paper used the analytic hierarchy process (AHP) to rank the key safety factors; including human factor, organizational factor, technical factor and environmental factor; that influence safety in an industrial gas manufacturing company in Ghana based on the operations of three production plants including the acetylene plant, carbon dioxide plant and oxynitrogen plant. The ratings of both criteria and alternatives were given based on experts judgements involving three safety managers, one production manager and five production workers using Saaty's AHP pairwise comparison scale. The Business Performance Management Singapore (BPMSG) priority software was then used to calculate the eigenvector and the consistency ratio of both the .criteria and alternatives. The results indicate that safety in the company is significantly affected by human factor. In addition, the oxynitrogen plant was identified as the safest manufacturing plant with the company.

INTRODUCTION

Industrial accidents are unpredictable and have been detrimental to most firms globally. According to [1], accidents can be quite diverse and to a certain extent, they do share a number of common characteristics (such as complexity).

Accidents are normally agreed to be multicausal [13]. The occurrences and consequences of industrial accidents are similar since they occur frequently and mostly result to damage or loss of finished products, inventory, raw materials, fixed assets, human resources and also interrupt business [2]. For instance, three hundred and seventeen million accidents occur on the job annually; many of these accidents or work related issues claim about six thousand and three hundred life daily and bring about huge economic burden [8]. When industrial accidents occur, stakeholder and investors of most firms update their policies about the safety of that particular plant or of the entire firm [3]. Most industrial accidents can adversely affect both domestic and international capital markets through the creation of uncertainty and panic, the promotion of extreme price volatility and the partial destruction of global financial centers [4]. Therefore, a firm's reputation could be damaged as a results of industrial accident thus, the likelihood to hurt a company in the marketplace [9]. The management of occupational accidents enhances firms to maintain and develop intellectual capital that is paramount in organizational development [10]. This can results to lower costs and less interference to the manufacturing process, saves employers the expense of recruiting and training new staff and cut the cost of early retirement and insurance pay-outs. Although managing occupational accidents is among the top priorities of modern business management, the ranking of importance of factors that influence the occupational safety of firms are limited in literature. To bridge this wide gap in safety management literature, this current research adopts an industrial gas manufacturing company in

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Ghana which is well known for the production of industrial and medical gases and apply the AHP method to rank the safety factors that could influence safety management in the company. The company has three plants (acetylene plant, carbon dioxide plant and oxynitrogen plant) and considers organizational factor, human factor, technical factor and environmental factor as occupational safety factors. According to [11], AHP determines the relative importance of a set of activities in a multi-criteria decision problem and also enhances the incorporation of judgments on tangible qualitative criteria and intangible quantitative criteria [12]. This paper contributes by adding to literature of safety indicators and safety performance in Ghana. Also, the results in this paper could educate managers and decision makers on factors that highly influence occupational safety and thereby aid them to strategize sound accident preventive mechanism to increase safety at their work places.

The paper is organized as follows: the subsequent section presents literature review. Section III explains the Materials and methods. A case study on an industrial gas manufacturing company is illustrated in section IV followed by conclusion in section V.

RELATED WORK

Multi Criteria Decision making (MCDM) methods had been applied in many fields concerning safety. Delphi method and fuzzy analytic hierarchy process (fuzzy AHP) had been used to rank key performance indicators of occupational safety community of practice [5]. The research revealed that the quality of the occupational safety community of practice is mainly based on technical and organizational factors. The key safety performance indicators for the road construction industry are identified and ranked according to the results of a survey that involved experts who assessed occupational safety risks in these companies using fuzzy analytic hierarchy process (fuzzy AHP) [6]. Safety evaluation and early warning rating system for hot and humid environments have been established using fuzzy AHP based on trapezoidal fuzzy numbers for the safety evaluation [7].

MATERIALS AND METHODS

Over the years the industrial gas manufacturing company in Ghana measure safety performance using risk management method.[14] outlined how a large company can handle its risks in practice using computer based method for risk analysis, however, one typical difficulty that can be encountered concerning risk management in a large company with different business areas is reaching the workforces. Also, a major weakness of risk management is a missing system for factoring and following up on the results of the risk analysis that has been performed [15]. A further step is to couple knowledge management with risk management systems to capture and preserve lessons learned as described in [16].

This paper employs the Analytic Hierarchy Process (AHP) a hierarchical decision model that is constructed by decomposing safety of the company into decision criteria. The core factors that affect the quality of occupational safety are human, organizational, technical and environmental factors [6]. The importance of the decision criteria are compared in a pairwise comparison manner with regard to the criterion preceding them in the hierarchy [17]. The use of pairwise comparison to collect data from the decision maker offers significant advantages by allowing decision makers to focus on the comparison of just two objects, which makes the observation as free as possible from extraneous influences [12]. Also, subjective preferences, expert knowledge and objective information can all be included in the same decision analysis [17].

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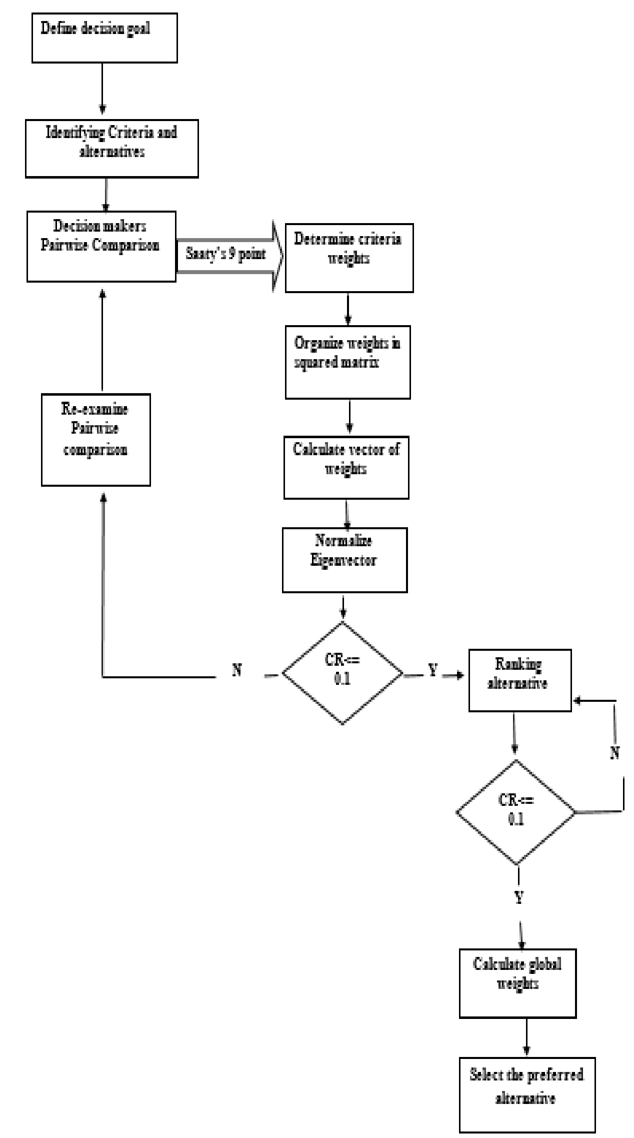

Figure 1. AHP Framework

Figure 1 above shows the main steps of AHP. The details of the Saaty's 9 point scale shown in figure 1 is explained in table 1. The 9-point scale is the standard used to quantify managerial judgments in AHP. The scores of criteria and the alternatives are given based on managerial judgments using the AHP scale.

TABLE I. 9-POINT SCALE FOR PAIRWISE COMPARISON IN AHP

Intensity of Importance	*Definition*	*Explanation*
1	*Equal Importance*	*Two criteria/ sub criteria contribute equally to the level immidiately above.*
3	*Moderate Importance*	*Judgement slightly favors one criterion*
5	*Strong Importance*	*Judgement strongly favors one criterion*
7	*Very Strong Importance*	*One Criterion is favored strongly over the another*
9	*Absolute / Extreme Importance*	*There is evidence affirming that one criterion is favored over another*
2,4.6,8	*Immidiate values between above scale values*	*Absolute Judgement cannot be given and a compromise is required*
Reciprocals of the above	*If element i has one of the none zero numbers assignment whent compared with activity j. j has the reciprocal value when compared to i*	*A reasonable assumption*

Source: Saaty 1980

The pairwise comparisons is used to calculate vector of weights and then multiplied by the matrix of criterion scores to compute a single aggregate value. The priorities of criteria are evaluated by calculating the principal eigenvector "w" of the matrix "A", as

$$Aw = \lambda max w$$

where λmax is the largest eigenvalue of the matrix "A," and the corresponding eigenvector "w" contains only positive entries. The eigenvector "w" is then normalized to produce a vector of weights for each of the individual attribute contributing to the aggregate value.

The Consistency ratio (CR) is computed for each matrix of pairwise comparisons, and only those with CR ≤ 0.10 are included in a combined matrix. In general, CR ≤ 0.10 is considered to be tolerable.

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CR = CI/RI where

CI = (λ max − n)/ (n − 1).

CASE STUDY

The Analytical Hierarchy Process (AHP) method as described above is used for ranking safety factors that influence safety management in the case of an industrial gas manufacturing company in Ghana which is well known for the production of oxygen, acetylene, nitrogen, carbon dioxide, dry ice, and argon for industries such as mining, oil and gas and health. Due to the nature of their manufacturing operations, industrial accidents such as combustion and explosion are likely to happen if safety procedures are not in place or current, delays in equipment maintenance or repair, failure to give proper training to workers, carelessness and recklessness of workers, improper communication among others. The factors mentioned above are incorporated into four main factors which includes human factor, organizational factor, technical factor and environmental factor. The human, organizational, technical and environmental factors are considered as the decision criteria for the purposes of this case. In addition, the alternatives includes three plants (acetylene plant, carbon dioxide plant and oxynitrogen plant) that are basically used for the company's operations. The decision model in relation the occupational safety factors of the company is presented in Fig 2 below.

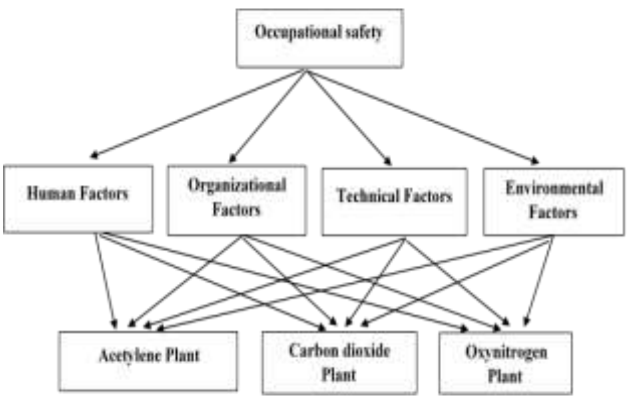

Figure 2. Occupational Safety Decision Model

After the identifying the key indicators of occupational safety, experts including three safety managers, one production manager and five production workers made the pairwise comparisons using the Saaty's 9 point scale of pairwise comparison. The weights of the criteria is presented in Table II.

TABLE II. WEIGHTS FOR THE CRITERIA USING SAATY'S 9-POINTPAIRWISE COMPARISONS SCALE.

Criteria	*HF*	*OF*	*TF*	*EF*
HF	*1*	*2*	*5*	*5*
OF		*1*	*2*	*2*
TF			*1*	*1*
EF				*1*

The criteria weights in Table 2 were used to generate the percentage weights of the decision criteria in Table III. After 3 iterations, the resulting weights for criteria based on saaty's pairwise comparisons of decision makers, includes the human factor (HF) ranking first with the highest percentage of 53.5% followed by organizational factor (OF) (23.9%), technical factor (TF) (11.3%) and environmental factor (EF) (11.3%). The resulting weights are based on the principal eigenvector of the decision matrix with principal eigenvalue of 4.006 and CR = 7.3%. The results indicate that accident prevention in the company is significantly affected by human factor. Therefore, it is identified as the key factor that influence accident prevention. This implies that management should ensure that the knowledge and understanding of employees on safety are continually improved through training. Also, the company should ensure the effective use of all aspects of the organizational factor of the company to improve the safety conditions in the company. That is, safety policies, safety orientation and safety culture in the company should be reinforced.

TABLE III. THE RESULTING WEIGHTS FOR THE CRITERIA BASED ON PAIRWISE COMPARISONS

Criteria	HF	OF	TF	EF	Priority	Rank
HF	1	2.00	5.00	5.00	53.5%	1
OF	0.50	1	2.00	2.00	23.9%	2
TF	0.20	0.50	1	1.00	11.3%	3
EF	0.20	0.50	1.00	1	11.3%	3

The experts also compared each pair of alternatives including acetylene plant, carbon dioxide plant and oxynitrogen plant in relation to each decision criterion including human, technical, organizational and environmental factor. The weights of these alternatives in relation to each criteria are presented in Tables IV, V, VI and VII. Also, the computation of the overall weights of the alternatives in relation to the decision criteria is presented in Table VIII.

TABLE IV. WEIGHTS OF ALTERNATIVES IN CONTEXT OF HUMAN FACTOR

Alternatives	Oxynitrogen	Carbon Dioxide	Acetylene	Priority	Rank
Oxynitrogen	1	4.00	7.00	71.5%	1
Carbon Dioxide	0.25	1	2.00	18.7%	2
Acetylene	0.14	0.50	1	9.8%	3

TABLE V. WEIGHTS OF ALTERNATIVES IN CONTEXT OF ORGANIZATIONAL FACTOR

Alternatives	Oxynitrogen	Carbon Dioxide	Acetylene	Priority	Rank
Oxynitrogen	1	1.00	2.00	38.7%	2
Carbon Dioxide	1.00	1	3.00	44.3%	1
Acetylene	0.33	0.50	1	16.9%	3

TABLE VI. WEIGHTS OF ALTERNATIVES IN CONTEXT OF TECHNICAL FACTOR

Alternatives	Oxynitrogen	Carbon Dioxide	Acetylene	Priority	Rank
Oxynitrogen	1	1.00	2.00	33.3%	2
Carbon Dioxide	1.00	1	3.00	14.0%	3
Acetylene	0.33	0.50	1	52.8%	1

TABLE VII WEIGHTS OF ALTERNATIVES IN CONTEXT OF ENVIRONMENTAL FACTOR

Alternatives	Oxynitrogen	Carbon Dioxide	Acetylene	Priority	Rank
Oxynitrogen	1	4.00	9.00	73.7%	1
Carbon Dioxide	0.25	1	2.00	17.7%	2
Acetylene	0.11	0.50	1	8.5%	3

TABLE VIII OVERALL ALTERNATIVE WEIGHTS IN RELATION TO THE DECISION CRITERIA.

Criteria / Alternatives	Human Factor	Organizational Factor	Technical Factor	Environmental Factor	WEIGHT
Oxynitrogen	0.383	0.092	0.038	0.083	0.596
Carbon dioxide	0.100	0.106	0.016	0.020	0.242
Acetylene	0.052	0.040	0.060	0.010	0.162

The overall weight of oxynitrogen, carbon dioxide and acetylene in relation to human, organizational, technical and environmental factors are 0.596, 0.242 and 0.162 respectively in table VIII. The oxynitrogen plant was identified as the most important alternative priority.

CONCLUSION

The paper has contributed to the industrial gas manufacturing company by identifying the key safety factor that affects occupational safety of the company by applying Analytic Hierarchy Process. It also revealed the degree to which each manufacturing plant in the company is affected by occupational safety factors. Management can therefore take the necessary steps to improving occupational safety within the company by understanding, upgrading and continuously monitor the human factors of the safety management system.

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