AHP-based methodology for selection of safety parameters in manufacturing industry

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Abstract: This study uses the analytical hierarchy process (AHP) to quantify important occupational safety factors for manufacturing industry and to analyse the weight scores of main and sub factors. A questionnaire was developed and used for collecting the expert opinions by using pair wise comparison. Based on the analysis of expert's choice and consistency test, this study identified the weight scores of nine main and forty sub-factors. The purpose of this study is to prioritise the safety parameters of manufacturing industries regarding worker's safety according to the expert's choice. Six experts are taken from manufacturing industry background. The results of this study shows that personal protective equipment (PPE) has the first priority with highest weights i.e. 30.6% and workplace layout and house-keeping at last with 2.5% weights. The entire main and sub-factors have consistency ratio less than 10% which is acceptable. It is recommended that PPE should be provided to the workers in manufacturing industries for safe work environment.

1 Introduction

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977 and 1994). The AHP has attracted the attention of many researchers mainly due to the fine mathematical properties of the method and a point that the essential input data are rather easy to obtain. It uses a multi-level hierarchical type structure of objectives, criteria, sub criteria, and alternatives. The relevant data are derived by using a set of pair wise comparisons. These comparisons are used to obtain the weights scores of importance of the decision criteria, and the relative performance measures of the alternatives in relations of each individual decision criterion. Some of the industrial engineering applications of the AHP comprise its use in integrated manufacturing [13, 14], in the assessment of technology investment decisions, in flexible type manufacturing systems, layout design [15], and in other engineering problems.

Analytic Hierarchy Process is an Eigen value approach to the pair-wise comparisons. The scale ranges from 1/9 for 'least valued than,' to 1 for 'equal and to 9 for 'absolutely more important. [14]

1.1 Applications of AHP:

1. Prioritizing factors and requirements that impact software development and productivity,
2. Choosing among several strategies for improving safety features.
3. Estimating cost and scheduling options for material requirements planning (MRP),
4. Selecting desired software components from several software vendors,
5. Evaluating the quality of research or investment proposals.

2 Methodology

The analytical hierarchy process (AHP), a hierarchically layered structure, was developed for decision making and the steps as follows:.

Step 1*: Define the problem and determine the goal*

This study created a occupational safety knowledge management platform and, based on a literature analysis, identified the key factors
Step 2: *Select the factors for the model*
Factors in the first hierarchy included main nine factors from literature review, norms and laws of safety and expert's feedback, and those in the second hierarchy included the sub-criteria.
Step 3: *Design the questionnaire*
We designed the questionnaire to facilitate all of the possible pair-wise comparisons among the factors.
Step 4: *Use the questionnaire to collect experts' opinions*
After this, we collect the data from experts.
Step 5: *Test the consistency*
We used the Consistency Index (CI) to express the results' degree of consistency. Saaty (1980) defined the consistency index (CI) as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

Where λ_n is the maximum eigen value of the matrix of the importance ratios and n is the number of factors. Accordingly, Saaty (1980) defined the Constituency Ratio (CR) as follows:

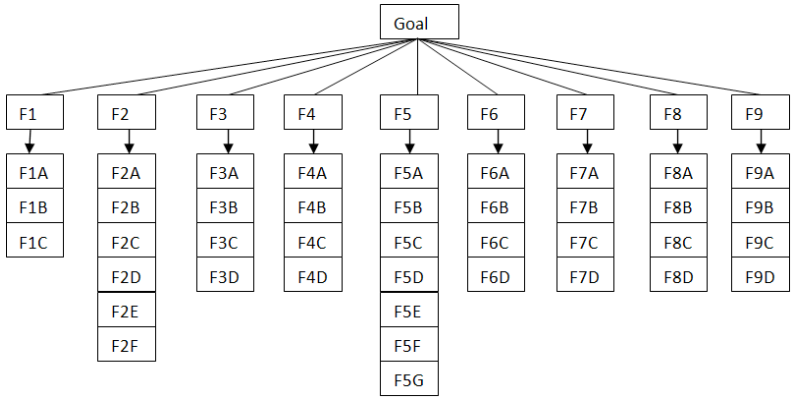
$$CR = \frac{CI}{RI} \quad (2)$$

Where the value of Random Index (RI) is taken from table 1 [23].

Table 1: Random Index

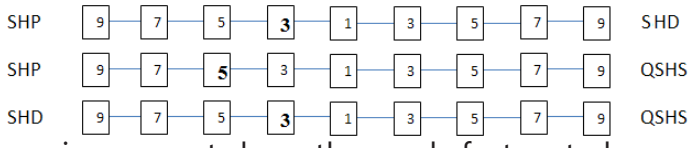
n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3 Hierarchy of AHP model



4 Pair-wise comparison of sub factors under first main factor (F1)

F1A. Safety and health policy (SHP), *F1B*. Safety and health department/division/committee (SHD) *F1C*. Qualified safety and health specialists/officers/engineers (QSHS)



In this pair –wise comparison experts have three sub-factors to be compared and made

subjective judgement on which factor they like best.

1. *If the judgement value is on the left side of 1, we put the actual judgement value.*
2. *If the judgement value is on the right side of 1, we put the reciprocal value.*

$$A = \begin{array}{c} \\ SHP \\ SHD \\ QSHS \\ \\ \end{array} \begin{array}{c} \begin{array}{ccc} SHP & SHD & QSHS \end{array} \\ \begin{bmatrix} 1 & 2 & 5 \\ 1/3 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{bmatrix} \\ \begin{array}{ccc} 23/1 & 13/3 & 9 \end{array} \end{array}$$

The normalized principal Eigen vector is also called priority vector. Since it is normalized, the sum of all elements in priority vector is 1. In our case SHP is 63.7%, SHD is 25.8% and QSHS is 10.5%. Expert's most preferable factor is SHP then SHD and QSHS. Apart from the relative weight, we can check the consistency of expert's answers.

λ_{max} =23/15(0.637) +13/3(0.258) + 9(0.105) = 3.039

Now, after Eigen value we have to find out Consistency Index and Consistency Ratio.

$$\text{Consistency Index } (CI) = \frac{\lambda_{max} - n}{n - 1}$$

We have λ_{max} = 3.039 and three comparisons (n =3), Thus the consistency index is CI = 0.0195. After consistency index we have to find Consistency ratio (CR) i.e.

$$CR = \frac{CI}{RI} \qquad (2)$$

The value of RI taken from table no. 1. Then we have

CR= 0.0195/0.58= 3.3%

Now 3.3% < 10%, thus expert's subjective evaluation about factors preference is consistent. So, in this way we can find out Eigen values and consistency ration for every factor and sub-factor. Consistent ratio in all the comparison is less than 10%. The final results are in table 2 below.

Table.2 Priority ranking of factors and sub factors

Main factors	Sub-factors	Eigen Vector	Priority
Organizational Attributes Eigen vector = 14.0%	Requirement Safety and health policy.	63.7%	1
	Requirement of safety and health department/ division/ committee	25.8%	2
	Qualified safety and health specilists/ officers/ engineers.	10.5%	3
Occupational Safety and Heath Services/ documentation Eigen vector=7.6%	Facility for periodical medical examination	12.8%	3
	Provision of Health/ medical insurance	20.9%	2
	Documentation of safety and health program	48.2%	1
	Records of accident and injury	7.2%	4
	Need of absenteeism and injury	4.1%	6
Workspace Layout and House Keeping Eigen vector = 2.5%	Adequate and smooth material flow	6.6%	4
	Safe and smooth production line layout	25.7%	2
	Neat and clean floors, walls and ceilings	53.0%	1
	Provision of proper disposal of waste	14.6%	3

Equipment & Hand tools safety and machine guarding Eigen vector=10.1%	Need of periodic inspection	15.9%	3
	Availability of proper machine guards	39.9%	1
	Proper space for hand tools storage	8.1%	4
	Provision of training programs for hand tools and techniques use	36.0%	2
Fire Prevention, fire fighting and electrical safety Eigen vector=22.8%	Provision of fire detection system	5.4%	6
	Provision of alarm system	9.6%	5
	Need of fire fighting training and emergency plan	11.3%	4
	Need of extinguishing system	35.3%	1
	Provision of emergency exit and exit signs	3.3%	7
	Covered electrical cables	22.2%	2
	Proper electrical wiring	13.0%	3
Material handling and storage Eigen Vector=4.6%	Provision of safe and proper type of truck	7.5%	4
	Safe cranes and conveyers	50.8%	1
	Need of inspection schedule	26.5%	2
	Provision of safe storage and stacking	15.1%	3
Occupational Exposures Eigen Vector=4.7%	Skin contact with liquid chemicals	50.8%	1
	Exposure to noise and vibration	26.5%	2
	Exposure to high thermal conditions	15.1%	3
	Monitoring of occupational exposures	7.5%	4
Personal Protective Equipment (PPE) Eigen vector=30.6%	Adequate provision of PPE	57.0%	1
	Proper types and use of PPE	16.8%	3
	Proper maintenance of PPE	7.5%	4
	Adequate training on PPE usage	18.7%	2
Hygiene Factors Eigen vector=3.0%	Availability of safe drinking water	26.8%	2
	Availability of clean bathrooms, toilets, urinals	8.0%	4
	Availability of rest area, canteen	8.1%	3
	Provision of proper lighting and ventilation	57.1%	1

5 Conclusion

This study prioritizes the various factors related to safety for iron and steel manufacturing industries using AHP. The results of the study reveal that factors can be prioritized as; personal protective equipment, fire prevention system, organizational attributes and so on. It is recommended that PPE should be provided to the workers in manufacturing industries for safe work environment [12].

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