Priority analysis of occupational safety factors with AHP for small and medium scale manufacturing industries

Satnam Singh[1], Ankur Bahl[2]

[1,2,] School of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, India

Abstract

The main purpose of this study is to prioritize the occupational safety factors of workers by the use of analytic hierarchy process (AHP) with pair-wise comparisons. The outcome of this analysis enables the small and medium scale manufacturing industries to refer the sequence of factors for effective implementation of safety measures, which will in turn benefit the employees as well as the employer. A questionnaire is developed for conducting the study using AHP technique. Opinion from experienced and proficient experts is recorded on the framed questionnaire for different factors with pair-wise comparison. Based on the AHP analysis it is concluded that factor (personal protective equipments-PPEs) is the prime factor which needs utmost care in both small scale manufacturing industries (SSMIs) and medium scale manufacturing industries (MSMIs). It is suggested to the SMEs that, PPEs should be given highest priority and be supported by regular training programs in order to prevent workplace accidents.

Keywords: AHP,Safety,Medium scale industry,

1. Introduction

AHP approach, developed by Saaty (1990), is a combination of mathematics and interaction of the intended work (Viswanadhan, 2005; WANG and WANG, 2010). AHP is effective in prioritizing the factors to mitigate unforeseen accidents in industries (Akarte et al., 2001; Al-Harbi, 2001; Badri, 2001). Implementation of prioritized factors further saves the unallocated funds. Such tools have the capacity to provide growth in industries (Mudavanhu et al., 2013; Singh et al., 2016). In order to get the best parameter selection for occupational safety, it is important that all the responses are optimized simultaneously. AHP is one of the most successful techniques for solving decision making problems involving the goals, the alternatives for reaching the goals and the criteria for evaluating the alternatives (Harker and Vargas, 1987).

In this technique, by using the simple mathematical theory of Eigen vector and priority, a number of pair-wise comparison matrices are formed as per their relative importance with respect to the parent element. The advantage of this tool is that it combines both qualitative and quantitative parameters (Saaty, 1985). The detailed steps are as follows:

1. At the top most level, this comprises of a goal or a focus. At the intermediate and lower levels, the approach deals with criteria or sub-criteria and the available alternatives, respectively.
2. Construction of a pair-wise comparison matrix for each level with respect to higher levels. In this step, the relative importance of different alternatives with respect to the immediately above sub-criteria is determined.
3. Application of Eigen vector methods to calculate the relative weight for the pair-wise comparison of options on each criterion.
4. Check the consistency related with matrix. This is achieved using consistency ratio (CR) of consistency index (CI) with the proper range of random index (RI).
5. Repeat the above steps.
6. Evaluate the general relative value by linear addition function.

2. Prioritization of Occupational safety Factors using AHP

AHP is successfully implemented in various organizations such as integrated manufacturing, layout design (Al-Harbi, 2001), appraisal of tools (Boucher and MacStravic, 1991), flexible industrialized systems and in many other engineering related fields (Arbel and Orgler, 1990; Saaty, 1990; Cambron and Evans, 1991; Armacost et al., 1994; Shikdar and Al-Araimi, 2001; Das et al., 2012). AHP works on an Eigen value approach which is based on pair-wise comparisons (Saaty, 1990; Boucher and MacStravic, 1991; Bayazit, 2005). Qualitative and quantitative analyses can be performed using AHP and calibration can be done with the help of a suitable numeric scale.

The objective of this analysis is to utilize the effectiveness of AHP to prioritize the factors associated with the safety of workers in the small and medium size manufacturing industries (SSMIs and MSMIs). A questionnaire is developed for conducting the study using AHP technique. Opinion from experienced and proficient experts is recorded on the framed questionnaire for different factors with pair-wise comparison. Based on the results of earlier chapter, a total of nine main factors are considered with 22 and 40 sub-factors for SSMIs and MSMIs, respectively. The methodology of AHP involves five key steps as shown in figure 1. Every step is being scrutinized with ample care.

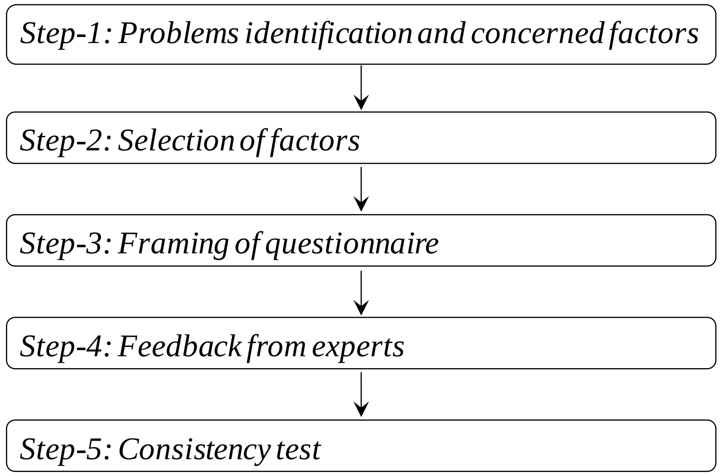

Figure 1. Methodology for analytic hierarchy process

It is ensured after pair-wise comparison, CR is below or nearly 10%, only then the questionnaire is considered good. If CR comes out to be more than 10%, the questionnaire needs to be review if it is not accommodating the possible factors.

3. AHP Hierarchy Model for SSMIs and MSMIs

The hierarchy model for SSMIs is shown in figure 2 in the form of nine main factors and 22 sub-factors. In order to better understand the working procedure of the AHP method, the pair-wise comparison based on experts' opinion is detailed for the sub-factors f_{41}, f_{42}, f_{43} of the main factor f_4 only . These three sub-factors refer to: f_{41}: Need of periodic inspection (PI); f_{42}: Availability of proper machine guards (APMG); f_{43}: Training sessions for tools and equipments use (TPFHT).

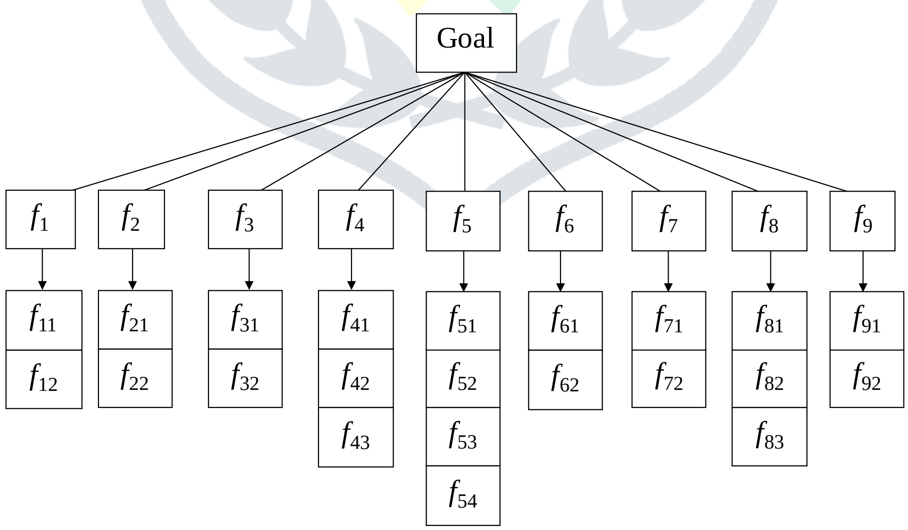

Figure 2. AHP hierarchy model for SSMIs

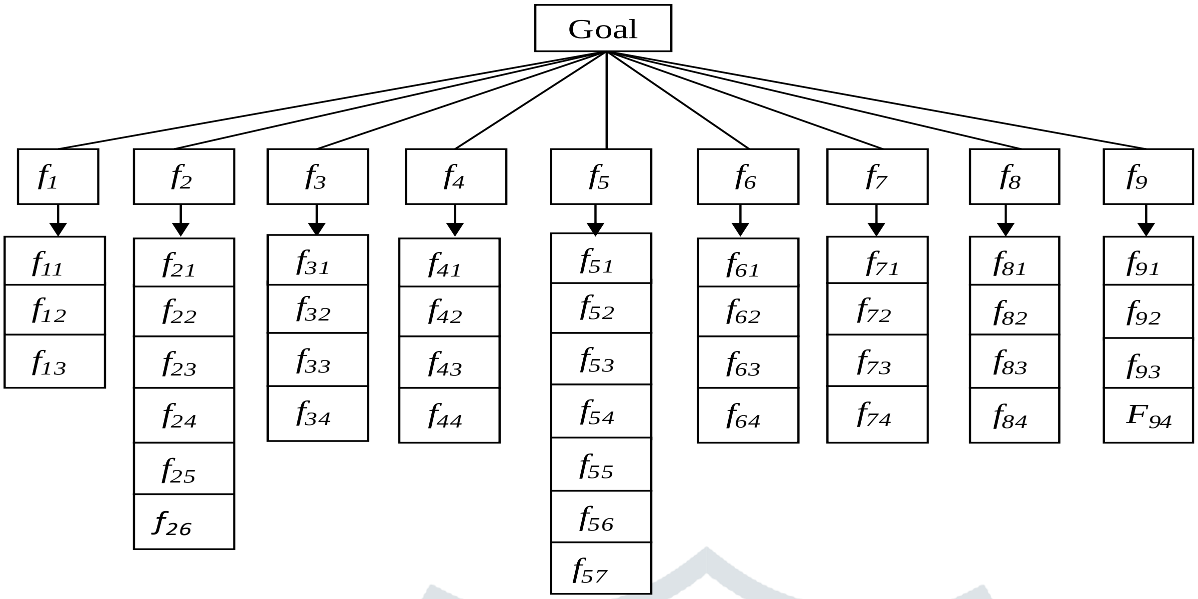

Figure 3. AHP hierarchy model for MSMIs

The hierarchy model for MSMIs is shown in figure 3 in the form of nine main factors and 40 sub-factors. As an example, the pair-wise comparison based on experts' opinion is detailed for the factor f_1 having sub-factors f_{11}, f_{12}, f_{13}. These three sub-factors refer to: f_{11}: Existence of safety policy (ESP); f_{12}: safety department (FSD); f_{13}: Qualified safety and health specialists/officers/engineers (QSHS).

The factors are prioritized using AHP and the priority level is tabulated in Table 1. Based on this analysis, highest priority is found for factor PPEs. Therefore, PPEs is the most critical factor and needs to be taken care at first priority so as to avoid unnecessary loss of life and cost at the workplace of SSMIs. Other factors also need to be implemented as per their priority level given in table 1.

Table 1. Values of Eigen vector and priority for main factors (SSMIs)

Main Factor	*Eigen vector*	*Priority*
Organizational Attributes	16.8%	2
Occupational Safety Services/documentation	8.4%	5
Workplace Layout and Housekeeping	7.0%	6
Equipment and Hand Tools Safety and Machine Guarding	6.4%	8
Fire Prevention, firefighting and electrical safety	10.1%	4
Material Handling and Storage	5.9%	9
Occupational Exposures	6.5%	7
Personal Protective Equipment	27.4%	1
Hygiene Factors	11.4%	3

The major advantage of this analysis is that, the factors as well as their sub-factors are also prioritized. This leads to considerable savings in cost that can be offset for worker welfare. For example, the first main priority factor is PPEs wherein three sub-factors are further prioritized. The adequate provision of PPEs is 3.89 and 9.02 times essential than maintenance and training of PPEs, respectively. So, necessary actions can be taken accordingly and SSMIs can take the benefit from this prioritization.

The main factors associated with worker's safety, in MSMIs are prioritized with AHP expert decision making technique tabulated in table 2. According to expert feedback the personal protective equipments (PPEs) is again given first priority followed by fire prevention system and organizational attributes. It is suggested that PPEs must be provide to the employee, who are working at shop floor. This explains and confirms the relevance of AHP methodology for proper prioritization of occupational safety factors.

Table 2. Values of Eigen vector and priority for main factors of MSMIs

Main Factor	***Eigen vector***	***Priority***
Organizational Attributes	14.0%	3
Occupational Safety Services/documentation	7.6%	5
Workplace Layout and Housekeeping	2.5%	9
Equipment and Hand Tools Safety and Machine Guarding	10.1%	4
Fire Prevention, firefighting and electrical safety	22.8%	2
Material Handling and Storage	4.6%	7
Occupational Exposures	4.7%	6
Personal Protective Equipments	30.6%	1
Hygiene Factors	3.0%	8

4. Conclusion

The technique, AHP is carried out to prioritize the factors of SSMIs and MSMIs. In case of SSMIs, it is observed that first priority is given to f_8 (personal protective equipment) followed by f_1 (organizational attributes), f_9 (hygiene factors), f_5 (fire-fighting, fire Prevention and electrical safety), f_2 (occupational safety documentation /services), f_3 (workplace layout and housekeeping, f_7 (occupational exposures), f_4 (machine guarding and equipment and hand tools safety) and f_6 (storage /material handling). It is recommended that SSMIs can follow this hierarchy while implementing the safety measure.

On the other hand, factors for MSMIs are also prioritized with weightage given by experts. It is found that first priority is given to f_8 (personal protective equipment) followed by f_5 (fire-fighting, fire Prevention and electrical safety), f_1 (organizational attributes), f_4 (machine guarding and equipment and hand tools safety), f_2 (occupational safety documentation /services), f_7 (occupational exposures), f_9 (hygiene factors) and f_3 (workplace layout and housekeeping).

On the basis of AHP analysis it is suggested that factor f_8 (personal protective equipment) is the prime factor which needs utmost care in both SSMIs and MSMIs. It is suggested to the SMEs that, PPE should be given highest priority and be supported by regular training programs in order to prevent workplace accidents. Further, if industry is new and wants to implement some of the safety measure, then also industry can follow above discussed hierarchy for better and safe working environment.

References

1. Akarte, M., Surendra, N., Ravi, B., and Rangaraj, N. (2001). "Web based casting supplier evaluation using analytical hierarchy process". Journal of the Operational Research Society, 52(5), 511-522.
2. Al-Harbi, K. M. A. (2001). "Application of the AHP in project management". International journal of project management, 19(1), 19-27.
3. Andersson, R., and Menckel, E. (1995). "On the prevention of accidents and injuries: a comparative analysis of conceptual frameworks". Accident Analysis & Prevention, 27(6), 757-768.
4. Arbel, A., and Orgler, Y. E. (1990). "An application of the AHP to bank strategic planning: The mergers and acquisitions process". European journal of operational research, 48(1), 27-37.
5. Armacost, R. L., Componation, P. J., Mullens, M. A., and Swart, W. W. (1994). "An AHP framework for prioritizing customer requirements in QFD: an industrialized housing application". IIE transactions, 26(4), 72-79.
6. Atsumbe, B., Amine, J., Umar, I., and Salawu, J. (2012). "Appraisal of Occupational Safety in Manufacturing Industries in Kaduna and Niger States of Nigeria". International Journal of Engineering Research and Development, 6, 55-62.
7. Bayazit, O. (2005). "Use of AHP in decision-making for flexible manufacturing systems". Journal of Manufacturing Technology Management, 16(7), 808-819.
8. Bhagwat, R., and Sharma, M. (2007). "Information system architecture: a framework for a cluster of small-and medium-sized enterprises (SMEs)". Production planning & control, 18(4), 283-296.
9. Boucher, T. O., and MacStravic, E. L. (1991). "Multiattribute evaluation within a present value framework and its relation to the analytic hierarchy process". The Engineering Economist, 37(1), 1-32.
10. Brauer, R. L. (2016). "Safety and health for engineers": John Wiley & Sons.

11. Cambron, K. E., and Evans, G. W. (1991). "Layout design using the analytic hierarchy process". Computers & industrial engineering, 20(2), 211-229.

12. Das, M. C., Sarkar, B., and Ray, S. (2012). "A framework to measure relative performance of Indian technical institutions using integrated fuzzy AHP and COPRAS methodology". Socio-Economic Planning Sciences, 46(3), 230-241.

13. Feyer, A.-M., and Williamson, A. M. (1991). "A classification system for causes of occupational accidents for use in preventive strategies". Scandinavian journal of work, environment & health, 302-311.

14. Harker, P. T., and Vargas, L. G. (1987). "The theory of ratio scale estimation: Saaty's analytic hierarchy process". Management science, 33(11), 1383-1403.

15. Kwon, O.-J., and Kim, Y.-S. (2013). "An analysis of safeness of work environment in Korean manufacturing: The “safety climate” perspective". Safety science, 53, 233-239.

16. Marhavilas, P.-K., Koulouriotis, D., and Gemeni, V. (2011). "Risk analysis and assessment methodologies in the work sites: On a review, classification and comparative study of the scientific literature of the period 2000–2009". Journal of Loss Prevention in the process Industries, 24(5), 477-523.

17. Mudavanhu, N., Zhou, T., and Dzomba, P. (2013). "An assessment of small and medium enterprise owners’ occupational safety and health efforts: the case of Southerton, Harare, Zimbabwe". Journal of Scientific Research & Reports, 4(3), 407-418.

18. Peterson, D. (2005). "Safety improvement: Perception surveys can reveal strengths and weaknesses". Professional Safety, 50(1), 45-48.

19. Saaty, T. L. (1985). "Decision making for leaders". IEEE Transactions on Systems, Man, and Cybernetics(3), 450-452.

20. Saaty, T. L. (1990). "How to make a decision: the analytic hierarchy process". European journal of operational research, 48(1), 9-26.

21. Saiyed, H. N., and Tiwari, R. R. (2004). "Occupational health research in India". Industrial health, 42(2), 141-148.

22. Shikdar, A. A., and Al-Araimi, S. A. (2001). "Ergonomic conditions in small manufacturing industries". Sultan Qaboos University Journal for Science [SQUJS], 6(1), 61-70.

23. Shikdar, A. A., and Sawaqed, N. M. (2003). "Worker productivity, and occupational health and safety issues in selected industries". Computers & industrial engineering, 45(4), 563-572.

24. Singh, S., Singh, L. P., and Kaur, M. (2016). "Analytical Hierarchy Process-Based Methodology for Selection of Safety Parameters in Manufacturing Industry".Advances in Safety Management and Human Factors (pp. 357-366): Springer.

25. Triantaphyllou, E., and Mann, S. H. (1995). "Using the analytic hierarchy process for decision making in engineering applications: some challenges". International Journal of Industrial Engineering: Applications and Practice, 2(1), 35-44.

26. Viswanadhan, K. (2005). "How to get responses for multi-criteria decisions in engineering education–an AHP based approach for selection of measuring instrument". Financial Support, 20.

27. Wang, D.-p., and Wang, X. (2010). "Research on the Green Vendor Selection Index Weight of Iron & Steel Enterprises Based on AHP and Entropy Method [J]". Soft Science,8, 025.

28. Wilson, J. R., and Corlett, N. (2005). "Evaluation of human work": CRC press.

29. Zwetsloot, G., and Leka, S. (2010). "Corporate culture, health, and well-being". Occupational health psychology,21(2) 250-268.