TEHRAN UNIVERSITY OF MEDICAL SCIENCES

IJOH INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE
Copyright © 2021 by Iranian Occupational Health Association (IOHA)
eISSN: 2008-5435

IRANIAN OCCUPATIONAL HEALTH ASSOCIATION

ORIGINAL ARTICLE

Analysis of Safety Performance of Construction Projects in India Using Safety Audit Elements, AHP and Taguchi Loss Function: A Case Study

SUNKU VENKATA SIVA RAJAPRASAD*

* *Senior Associate Professor, NICMAR, Jaggamguda, Hyderabad, Telangana, India*

Received May 30, 2021; Revised August 30, 2021; Accepted September 01, 2021

This paper is available on-line at *http://ijoh.tums.ac.ir*

ABSTRACT

Construction safety performance is traditionally assessed based on workplace conditions and analyzing accident statistics, there is no provision to consider the safety management systems which affect site safety. One of the systems use to measure safety performance is occupational safety and health audit which identify failures within a system and the information gathered assist to determine the best course of corrective action. Therefore, this study was designed and conducted to develop a method for evaluating the safety performance of five highway project sites in India using the Analytic Hierarchy Process and Taguchi loss functions. In the first stage of the study, the Analytic Hierarchy Process was applied by obtaining the judgments of the expert team to determine the weights of the safety audit elements. In the second stage, the five project sites were analyzed and ranked by determining the total loss score using the Taguchi loss functions. Based on the Analytic Hierarchy Process analysis, the weights of the safety management (0.1949), hazard identification and risk assessment (0.1460), and safety education and training (0.1268) had the highest impact on the safety performance of the five project sites. The results of the Taguchi loss functions of the five project sites showed that the total loss score was the lowest and highest for project site 3 (77.89) and site 5 (81.54), respectively. In the current study, an integrated method was developed for evaluating the safety performance of five highway project sites. The weights of the nine safety audit elements were vital in determining the total loss score by using the Taguchi loss functions for ranking the five projects sites based on safety performance. Therefore, using this method can be an effective step in identifying the project site with better safety performance as a benchmarking unit for the other sites.

KEYWORDS: *Safety Audit, Weights, Performance, Specification Limit, Total Loss Score, Ranking*

INTRODUCTION

The Indian construction sector is largely characterized by an unorganized workforce and hardly follows standard regulations laid down by government agencies [1]. Unlike in the manufacturing and other industries, implementing safety measures in the onstruction industry is continuous. The progress of the work changes from time to time and the safety systems need to be strengthened. Occupational safety and health (OSH) in the Indian construction industry has been considered an important issue owing to dynamic work activities [2]. To improve safety performance and legislation compliance, all construction organizations irrespective of the size of the workforce should conduct risk assessment practices to mitigate hazards. In India construction safety performance is traditionally assessed based on the workplace conditions and analyzing accident statistics, there is no provision to consider the safety management systems which affect site safety [3].

The construction industry requires an appropriate mechanism to assess safety practices at the project level instead of implementing prevention approaches based on the reactive data. Efforts by the Indian government to enforce OSH rules and regulations have no marked impact on safety performance. Managing safety in an organization is a proactive approach rather than implementing measures on accident data. Studies have shown that outstanding safety performance is closely associated with projects where an effective safety management program is established, implemented, and maintained [4]. Establishing an OSH management system in an organization leads to the decline of occupational hazards and diseases and improves safety performance. Even though numerous studies have been reported in safety management from various parts of the world, there is not much research evidence from India where safety management is yet to get the priority it deserves [5].

Accident prevention is one of the major areas to improve safety performance in construction organizations. As the construction industry is output-oriented, as long as quality, time, and cost criteria are met, little thought is given to ensure protective measures to prevent accidents. In the Indian context, it is estimated that construction accidents amount to about 6 percent of total project cost due to this the industry is encouraged to invest in accident prevention [6]. Occupational health cannot be addressed in isolation but rather has an important relationship with safety.

The best way to prevent occupational health hazards is at the design stage itself by incorporating best practices and configuring work processes. To sustain the blistering economic growth and for enhancing the quality of life as a whole, OSH is extremely important to emerging economies to improve safety performance [7]. Therefore, there is a need for continuous monitoring of safety performance indicators to reduce illnesses, injuries, and fatalities on construction sites. Information about the safety performance indicators is quite useful to implement proactive safety measures. In India, the safety performance is analyzed based on safety indices, frequency, and severity rate [8].

There is an ambiguity in concluding the results of the safety indices as no single index will provide the factual position of the safety performance. Many accidents and property damage that may not cause the man-days lost are not considered in the safety indices. The safety indices are the partial indicators and it is difficult to gauge the overall safety performance. The main aim of measuring safety performance is to create and implement intervention strategies for the potential avoidance of future accidents [9-10]. The concept of leading safety parameters came into existence due to the limitations of reactive data measure safety performance [11].

It is evident from the literature that inadequate safety training, ignoring inspections, and compliance of PPE are the reasons for poor OHS performance in the Jordanian construction industry [12]. Several studies were conducted in the past by considering safety expenditure and type of accidents as inputs and outputs respectively to measure the efficiency of organizations by adopting data envelopment analysis (DEA) but ignored the cost of accident damages [13].

Corresponding author: Svs Rajaprasad
E-mail: rajaprasad@nicmar.ac.in

Published online: September 30, 2021

A model was developed and validated in the USA for monitoring and measuring safety performance on construction sites through the statistical analysis of leading safety indicators data to prevent future accidents [14]. Developing the relationship among safety culture dimensions influences the safety performances of construction companies in Indonesia [15]. The snapshot of safety performance at the project level is known by conducting worker's safety surveys [16]. Previous studies mainly applied optimization or statistical techniques, and questionnaire surveys to measure the safety performance in construction sites.

In the present study, the elements of the safety audit process were considered to analyze the safety performance of the construction projects through a case study. The safety audit is a comprehensive assessment and appraisal of the safety management system to establish compliance with standards [17]. An integrated approach was developed in the current study to analyze the safety performance with the combination of the safety audit elements, Analytic Hierarchy Process (AHP), and Taguchi loss functions. Firstly, the relative weights of audit elements were determined using AHP. Secondly, Taguchi loss functions were utilized to find the loss scores associated with construction projects. Finally, the overall weighted Taguchi loss value of each project was determined and the projects were ranked. The gap in the literature has given enough confidence to develop an integrated approach to measure the safety performance and the methodology was applied to the five highway projects in India.

MATERIALS AND METHODS

The present study integrates AHP and Taguchi loss functions in two stages. In the first stage, the AHP was applied to obtain the weights of the safety audit elements and in the second stage, the Taguchi loss functions method was applied for ranking the construction project sites and determining the best site. The step-by-step procedure of the framework of methodology has been shown in Figure 1.

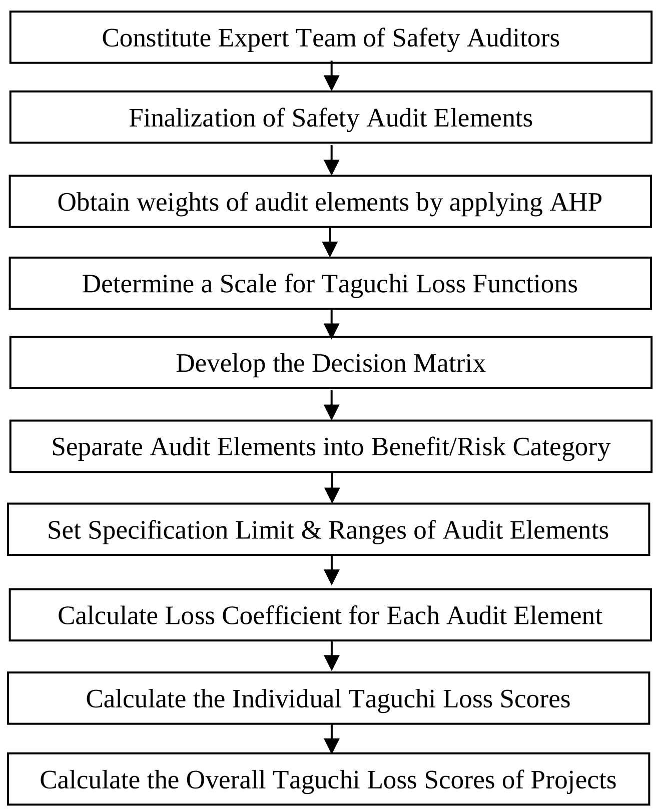

Fig 1. The proposed framework of Methodology

AHP Method:

The AHP technique was the result of the research work carried out by Thomas L. Satty in the 80s. This method aims to derive quantitative scores and weights from qualitative statements on the relative performance of alternatives and the relative importance of criteria obtained from the comparison of all pairs of alternatives and criteria. The procedure can be divided into 3 major parts, decomposition of the problem, comparative judgment, and generation of the priorities [18].

Step by step Procedure:

Step I: To develop a hierarchy of the problem in terms of the goal, criteria, and alternatives.

Step II: Synthesizing judgments by pairwise comparison of criteria and alternatives based on the scale proposed by Saaty (1-equally preferred, 3-moderately preferred, 5-strongly preferred, 7-very strongly preferred, and 9-extremely preferred). Intermediate values between two adjacent judgments are allowed in case of a compromising situation.

Step III: (Consistency checking) AHP provides a method for measuring the degree of consistency among the pairwise judgments provided by the decision-maker by computing a consistency ratio. The ratio is designed in such a way that values of the ratio exceeding 0.10 are indicative of inconsistent judgments. If the degree of consistency is acceptable, the decision process can continue. If the degree of consistency is unacceptable, the decision-maker should reconsider and possibly revise the pairwise comparison judgments before proceeding with the analysis.

Taguchi Loss Functions:

Genichi Taguchi developed a set of methodologies for applying statistics to increase the process and product quality [19]. Till the recent studies, Taguchi philosophy has been accepted widely as an effective approach merely for quality engineering and design of experiments. In the last decades, Taguchi loss functions have been used as a multi-criteria decision-making approach [20]. Three types of loss functions were used in the Taguchi loss function: first, the nominal value (or the best value), where the proper function depends on the magnitude of variation with variations being allowed in both directions from the target value (see Figure 2). The expression for this type of loss function is given by Equation 1[21].

$$L(y) = k(y-m)^2 \quad (1)$$

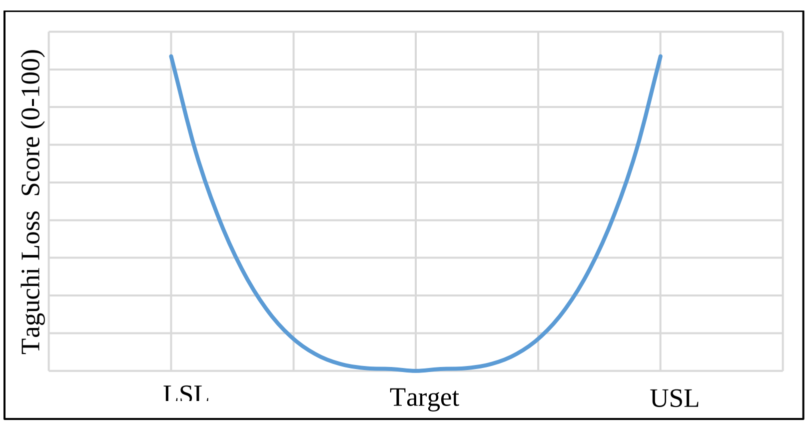

Fig 2. Two-sided equal-specifications. Taguchi loss function

Where L(y) is the loss associated with a particular value of quality character y, m is the nominal value of the specification, and k is the loss coefficient, whose values are constant depending on the cost limits and the range of the specification. The other two functions are the one-sided minimum specification limit, called smaller-is-better (Figure 2), and the one-sided maximum-specification limit function, called higher-is-better (Figure 4). Respective loss functions are given in Equations 2 and 3:

$$L(y)=k(y)^2 \quad (2)$$

$$L(y) = k/y^2 \quad (3)$$

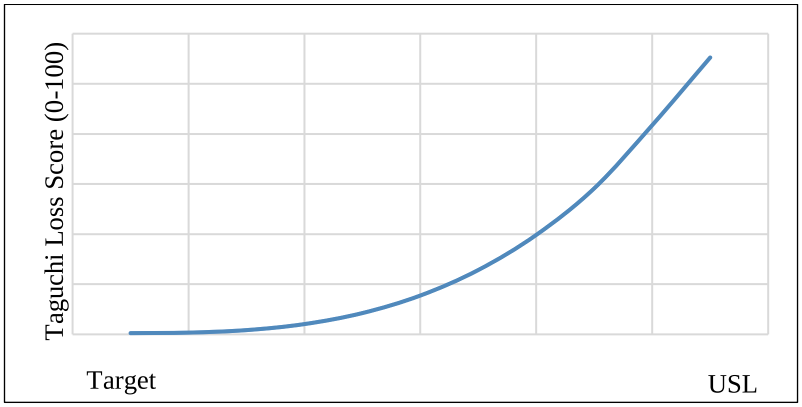

Fig 3. One-sided minimum specification limit function

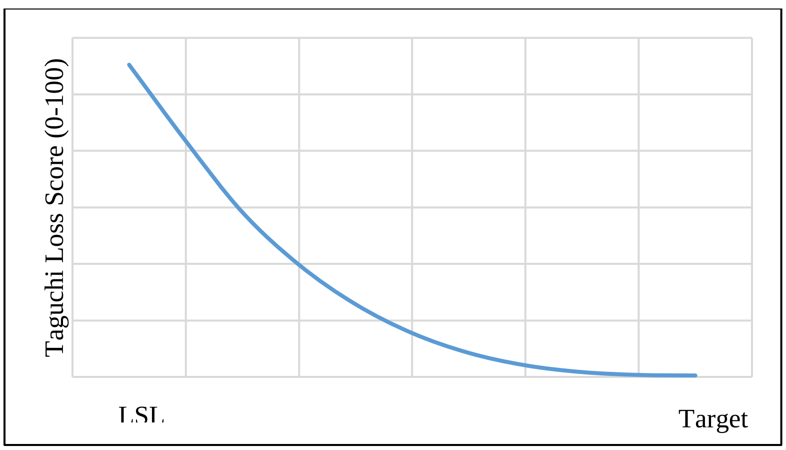

Fig 4. One-sided maximum specification limit function

Case Study:

The study was conducted in a transportation wing of a large construction organization that involved the execution of national highway projects across various states in India. There are sixteen highway projects under the construction organization but five highway projects were considered for analysis of the safety performance in the study. The stretch of the highway projects varies from 150 to 200 km. The execution of the projects is supervised by the National Highway Authority of India (NHAI) for OSH, quality, and progress of the work. The site management of the construction organization is required to follow the NHAI safety guidelines during execution besides conducting the external safety audit to comply with legislation and to provide a safe workplace for employees and the public. The scope of the audit involves auditing the various activities involved in the execution of highway projects which include traffic diversions and signals, zoning concept, the safety of road construction equipment, hot mix plant safety, work environment monitoring, etc. The corporate office has identified an audit agency comprising of three auditors to conduct the safety audit of the five projects. It requires approximately 2 to 3 days to complete the audit as per Indian standard 14489 and NHAI safety guidelines. The reason for considering the five projects was that the same audit team members were involved in conducting the audit so that their judgments will be consistent. The auditors were considered as an expert team and their judgments were utilized as inputs in analyzing the safety performance of five project sites.

Safety Audit (IS 14489):

In India, the need for safety audits is mainly to fulfill safety and statutory requirements. Indian Standard 14489 establishes audit objectives, criteria, and practices, and provides guidelines for establishing, planning, conducting, and documenting audits on OSH systems at the workplace. It provides guidelines for verifying the existence and implementation of elements of the OSH system and for verifying the system's ability to achieve defined safety objectives. It is sufficiently general to permit it to apply or be adaptable to different kinds of organizations [22]. The need to perform an audit is determined by the client, taking into account specified or regulatory requirements and any other pertinent factors. Significant changes in management, organization, policy, techniques, or technologies that could affect the OSH system, or changes to the system itself and the results of recent previous audits, are typical of the circumstances to be considered when deciding audit frequency. Normally an external or third-party safety audit should be conducted once in two years and an internal audit may be organized once every year. The standard also specified the details of safety audit goals, objectives, scope, plan, verification of records, checking the applicability of safety legislations, plant visits, consolidation of observations, report preparation, and submission.

Elements of Safety Audit (IS 14489):

IS 14489 is sufficiently general to permit it to apply or be adaptable to different kinds of organizations. Each organization should develop specific procedures for implementing this standard. There are 31 OSH elements prescribed in IS 14489 and all the elements are not applicable in the construction sector. Based on the recommendations of the expert team, the elements of OSH were consolidated and grouped under nine categories. The elements OSH audit has been presented in Table 1.

RESULTS

In the first stage of the integrated approach, AHP was applied by obtaining the expert's team judgments to determine the weights of the safety audit elements. The pair-wise comparison of the audit elements based on the judgments on the Saaty scale was obtained and has been presented in Table 2.

After finalizing the judgment matrix, the step-by-step procedure of AHP was applied and checked the consistency ratio at each stage. The final weights of safety audit elements with a consistency ratio of 0.066 (less than 0.10). Hence, the judgments were consistent and the weights were used as inputs in the analysis of Taguchi loss functions. The weights have been presented in Table 3.

Table 1. Details of safety audit elements

Element No	Element	Explanation
E1	Safety Management	OSH policy/organizational set up/Employees participation/ Motivational &Promotional measures, Safety Committee, and Safety Budget
E2	Compliance with Statutory Requirements	Safety Manuals, rules, Contractor Safety Systems, Legal requirements, NHAI Safety guidelines
E3	Safety Education and Training	Induction/Mode/Periodic/retraining/Man days used/ Training Plan /Compliance of Training
E4	Hazard Identification& Risk Assessment	Types of hazards, Identification, Prevention measures, Safety audit
E5	Safety Inspections	Types of inspections, frequency, Checklists, Compliance
E6	Accident Reporting & Investigation	Accident data, Types of accidents, Investigation Procedure
E7	Medical Facilities & Working Conditions	First aid, Occupational Health Centre, Prevention of Occupational diseases, Periodical Medical Examination, Ventilation, Illumination, Noise, Work Environment Monitoring
E8	Technical Aspects	Safe operating procedures, Work permit System, Personal protection equipment, Guarding of Machinery, Fire prevention & protection, Electrical Safety, Housekeeping, Storage of materials
E9	Emergency Preparedness Plan	Emergency response team, Mock drills, Assembly points, Communication/Power sources, Mutual aid Scheme

Table 2. Pairwise comparison matrix of audit elements

	E1	E2	E3	E4	E5	E6	E7	E8	E9
E1	1	2	3	2	2	3	2	2	1
E2	0.50	1	1	1	0.50	2	2	0.50	1
E3	0.33	1	1	1	2	2	0.50	3	2
E4	0.50	1	1	1	2	2	2	2	3
E5	0.50	1	0.50	0.50	1	2	2	2	1
E6	0.33	0.50	0.50	0.50	0.50	1	1	1	1
E7	0.50	0.50	2	0.50	0.50	1	1	2	1
E8	0.50	2	0.33	0.50	0.50	1	0.50	1	1
E9	1	1	0.50	0.33	1	1	1	1	1

Table 3. Weights of safety audit elements

Element No	Element	Weight
E1	Safety Management	0.1949
E2	Compliance with Statutory Requirements	0.0992
E3	Safety Education and Training	0.1268
E4	Hazard Identification& Risk Assessment	0.1460
E5	Safety Inspections	0.1132
E6	Accident Reporting & Investigation	0.0641
E7	Medical Facilities & Working Conditions	0.0952
E8	Technical Aspects	0.0760
E9	Emergency Preparedness Plan	0.0861

Safety management was the most important audit element with the weight of 0.1949, followed by hazard Identification and risk assessment, safety education and training with 0.1460, and 0.1268.

In the second stage, the five project sites were analyzed and ranked by adopting Taguchi loss functions. The procedure commences with developing the decision matrix, which shows the assessment of the project sites based on the safety audit elements. Based on the expert team's opinion, the decision matrix was developed by considering a 0-100 scale to rate the project sites to apply more sensitivity to the decision-making process. The five highway project sites were represented by P1, P2, P3, P4, and P5. The decision matrix is shown in Table 4.

Table 4. Decision matrix

Project Sites	E1	E2	E3	E4	E5	E6	E7	E8	E9
	Max	Max	Max	Max	Max	Min	Max	Max	Max
P1	95	86	81	95	89	85	80	89	84
P2	92	91	79	90	90	80	85	86	88
P3	94	93	86	93	91	77	89	90	79
P4	93	85	84	91	88	79	91	87	83
P5	91	87	89	92	86	82	86	85	80

The categories, including benefit and risk, were determined to obtain ranges and specification limits. Regarding the safety management element, as the highest grade showed better safety management, zero loss occurs when 100 points were gained. Since the higher is better, the safety management element was in the benefits category. To calculate the specification limit of the related criterion, the expert team has decided that the project sites, which were above the 95 points limit, were appropriate for the assessment. Thus, any project site that receives 95 points for the safety management element would get a 100% loss. Similar to the safety management element, compliance with statutory requirements, safety education and training, hazard identification and risk assessment, safety inspections, medical facilities and working conditions, technical aspects, and emergency preparedness plan were considered in the benefits category and according to an expert team, the specification limit of these audit elements was determined as 85,80,75,80,70,75, and 70, respectively. The audit element accident reporting and investigation was considered in the risk category to minimize the accident and the expert team earmarked 95 points as the specification limit for the element. Therefore, any project site that receives 95 points for this element would get a 100% loss.

In the next step of Taguchi loss functions, the loss coefficient (k) values were calculated for each safety audit element. The k value for the benefit category elements E1, E2, E3, E4, E5, E7, and E8; and risk element E6 were calculated by using Equations 2 and 3. The values of range, specification limits, and loss coefficients for each safety audit element are presented in Table 5.

Table 5. Range and specification limits of audit elements

No	Element	Weight	Desired value (%)	Range (%)	Specification limit (%)	Loss coefficient (k)
E1	Safety Management	0.1949	100	90-100	90	81.00
E2	Compliance with Statutory Requirements	0.0992	100	80-100	80	64.00
E3	Safety Education & Training	0.1268	100	75-100	75	56.25
E4	Hazard Identification& Risk Assessment	0.1460	100	85-100	85	72.25
E5	Safety Inspections	0.1132	100	80-100	80	64.00
E6	Accident Reporting & Investigation	0.0641	0	0-95	95	110.80
E7	Medical Facilities & Working Conditions	0.0952	100	70-100	70	49.00
E8	Technical Aspects	0.0760	100	75-100	75	56.25
E9	Emergency Preparedness Plan	0.0861	100	70-100	70	49.00

The Taguchi loss score of Project 1 (P1) for safety management element (E1- Benefit) was calculated as shown,

$L(y_{E1, P1}) = 81/(0.95)^2 = 89.75$

Regarding the Risk category (E6), the Taguchi loss score of Project 1 (P1) was calculated as,

$L(y_{E6, P1}) = 110.80 X (0.85)^2 = 80.05$

In the final step, the individual Taguchi loss scores of the project sites were multiplied by the respective weights of the audit elements to arrive at the overall aggregate Taguchi loss scores of the project sites and the values are presented in Table 6.

Table 6. Overall scores of the project sites

Projects	Individual loss score of each project under each audit element									Total Loss Score
	E1	E2	E3	E4	E5	E6	E7	E8	E9	
P1	89.75	86.53	85.73	80.05	80.80	80.05	76.56	71.01	69.44	81.54
P2	95.70	77.29	90.13	89.20	79.00	70.91	67.82	76.05	63.27	81.91
P3	91.67	74.00	76.05	83.54	77.29	65.69	61.86	69.44	78.51	77.89
P4	93.65	88.58	79.72	87.25	82.65	69.15	59.17	74.32	71.13	81.05
P5	97.81	84.56	71.01	85.36	86.53	74.50	56.98	77.86	76.56	81.38

It is observed from Table 6, the total loss score of project 3(P3) was minimum (77.89) and ranked first among the project sites. The variation between the total loss scores of P1, P2, P4, and P5 was marginal.

DISCUSSION

The safety performance of construction sites depends on several parameters and drawing conclusions based on safety metrics, surveys, etc., was not practical. The studies relating to safety performance must focus on a system that includes many dimensions of OSH and the safety audit is one such system that comprehensively evaluates the management system as a whole [23]. The safety audit is the leading indicator while measuring safety performance. The quantitative results of audits are often used by organizations as performance measures [24]. An integrated model was developed to measure the safety performance using safety audit elements. In assessing the safety performance of construction projects, many comprehensive models have been developed by using multi-criteria decision-making methods and the difficulty is in quantifying all the criteria. Though 31 OSH audit elements were prescribed in the code, the elements were combined into nine elements to overcome the difficulty. Practically, it's difficult even for the experts to assign consistent judgments in case the number of criteria is more. In the previous studies conducted on the selection of suppliers by using the AHP and Taguchi loss functions, only four criteria were considered and conducted the analysis [25].

While developing the decision matrix and setting the specification limits in the application of Taguchi loss functions, different scales were adopted in the past. The nine-point Likert scale was used by authors in assessing the risks in marine projects by using the Taguchi loss function [26]. In the present study, the expert team was decided to opt for a 0-100 scale to offer better judgments due to more sensitivity, the desired value for benefit and risk category were 100 and zero [21]. The specification limit for the risk category (Accident Reporting and Investigation) was considered as 95 keeping in view that any project site that gets 95 points will get 100% loss. The reason for keeping the specification limit on the higher side was any major accident may cause loss to the organization in terms of cost of damages.

Finally, the total loss score was used to rank the safety performance and its low for Project site 3. From Table 6, it was observed that there was not much variation in the total scores of other sites and it indicates that the safety audit elements scenario of project sites P1, P2, P4, and P5 was to be compared with the P3 and any deficiencies need to be rectified to minimize the total score.

CONCLUSIONS

This paper proposes an integrated model through combining advantages of two methods namely, AHP and Taguchi loss functions to evaluate the safety performance of five highway project sites by eliminating bias and subjectivity. All the dimensions of the OSH management system were considered in the analysis to rank the highway projects based on safety performance. The safety audit elements cover comprehensively all the systems of the project that influence safety performance and the results depict the snapshot view of the existing safety practices being followed. In general, the results can help site management to achieve the safety objectives at the project level by identifying critical areas which lead to making decisions to prevent, control, and respond to them.

The study was conducted in two stages. In the first stage, the AHP procedure was applied to determine the weights of the safety audit elements. The weights of the safety management (0.1949), hazard identification and risk assessment (0.1460), and safety education and training (0.1268) had the highest impact on the safety performance of the five project sites.

In the second stage, the weights of the safety audit elements were used as inputs to determine the total loss score by adopting the Taguchi loss functions. The total loss score was the lowest and highest for project site 3 (77.89) and site 5 (81.54). The results of the study were useful to the site management of the project sites (P1, P2, P4, and P5) to adopt the safety practices followed in project site P3 to minimize the total loss score. The proposed integrated model acts as a benchmarking tool and also to compare strong or weak areas to improve safety performance. Evaluating the safety performance based on the safety metrics will not represent the complete safety scenario of the organization whereas the integrated model was based on all parameters that will have an impact on the site safety performance.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest in this paper.

REFERENCES

1. Jayakrishnan T, Thomas B, Bhaskara R, George B. Occupational Health Problems of Construction Workers in India. *Intl J Med Pub Health* 2013; 3(4): 225-229.
2. Adsul BB, Laad PP, Howal PV, Chaturvedi RM. Health Problems among Migrant Construction Workers: A Unique Public-Private Partnership Project. *Indian J Environ Med*. 2011; 1(15): 29-32.
3. Devendrakumar P, Jha KN. Safety Performance Assessment of a Construction Site Using Construction Safety Index: Evidence from Indian Construction Industry. *J Saf, Health and Environ Res.* 2015; 11(1): 222-231.
4. Tam CM, Fung IWH. Effectiveness of Safety Management Strategies on Safety Performance in Hong Kong. *Const Manag Econ*. 1998; 16:49-55.
5. Vinodkumar MN, Bhasi M. Safety management practices and safety behavior: Assessing the mediating role of safety knowledge and motivation. *Accident Anal and Prevention.* 2010; 42: 2082-2093.
6. Chockaligam S, Sornakumar T. An Effective Total Construction Safety Management in India. *Asian J Civil Engin.* 2012; 13(3): 405-416.
7. Hital RM. Safety and Occupational Health: Challenges and Opportunities in Emerging Economies. *Indian J Occup Environ Med*. 2008; 12(1): 3-9.
8. IS 3786. *Method for Computation of Frequency and Severity Rates for Industrial Injuries and Classification of Industrial Accidents* 1983; *1-28.* Available from: https://law.resource.org/pub/in/bis/S02/is.3786.1983.pdf.
9. Awolusi IG, Marks ED. Safety Activity Analysis Framework to Evaluate Safety Performance in Construction. *J Const Engin Manag*. 2016; 143(3):1-12.
10. Grabowski M, Ayyalasomayajula P, Merrick J, Harrald JR, Roberts K. Leading indicators of safety in virtual organizations. *Saf Sci.* 2007; 45(10):1013-1043.
11. Fakhradin Ghasemi IM, Ali Reza Soltanian SM, Esmaeil Z. Surprising Incentive: An Instrument for Promoting Safety Performance of Construction Employees. *Saf and Health at Work.* 2015; 6:227-232.
12. El- Mashaleh MS, Bashr M, Al-Smad KH, Shaher MR. Safety Management in the Jordanian Construction Industry. *Jordan J Civil Engin*. 2010; 4(1): 47-54.
13. Beriha GS, Patnaik B, Mahapatra SS. Safety Performance Evaluation of Indian Organizations Using Data Envelopment Analysis. *Benchmarking: An Intl J*. 2011; 18(2): 197-220.
14. Ibukun GA, Eric DM, Alex MH. Framework for Monitoring and Measuring Construction Safety Performance. 55th ASC Annual International Conference Proceedings, 2019, 587-594. Available from: http://www.ascpro.ascweb.org.
15. Yusuf L, Rossy AM, Rosmariani A, Yoko Y. *Understanding the Relationship Between Safety Culture Dimensions and Safety Performance of Construction Projects through Partial Least Square Method.* Engineering International Conference (EIC) 2016 AIP Conference Proceedings, Published by AIP Publishing.
16. Tan Chin K, Nadeera AR. Case Studies on the Safety Management at Construction Site. *J Sus Sci Manag*. 2014; 9(2):90-108.
17. Hinge J, Raymond G. An Evaluation of Safety Performance Measures for Construction Projects. *J Cons Res.* 2003; 4(1): 5-15.
18. Milan J, Reggiani A. An Application of the Multiple-Criteria Decision-Making Analysis to the Selection of a New Hub Airport. *European J Trans Infra Res.* 2002; 2:113-142.
19. Festervand TA, Kethley RB, Waller BD. The marketing of industrial real estate: application of Taguchi loss functions. *J Multi-Criteria Decision Analysis.* 2001, 10(4): 219-228.
20. Liao CN, Kao HP. Supplier selection model using Taguchi loss function, analytical hierarchy process, and multi-choice goal programming. *Comp Indu Engin.* 2010; 58(4): 571-577.
21. Hacer GG, Ahmet AŞ. MACBETH Based Taguchi Loss Functions Approach for Green Supplier Selection: A Case Study in Textile Industry. *Tekstil ve Konfeksiyon.* 2018; 28(2): 0-97.

22. IS 14489. *Code of practice on OSH audit*. Bureau of Indian Standards, New Delhi, 1998; 1-22. Available from: https://law.resource.org/pub/in/bis/S02/is.14489.1998.pdf.
23. Ng K, Laurlund A, Howell G, Lancos G. *Lean safety: Using leading indicators of safety incidents to improve construction safety*. In Proceedings Conference of the International Group for Lean Construction IGLC 20, San Diego. 2012, 1-11.
24. Nielsen KJ, Rasmussen K, Glasscock D, Spangenberg S. Changes in safety climate and accidents at two identical manufacturing plants. *Saf Sci*. 2008; 46: 440-449.
25. Rajnish K, Sidhartha SP, Ashutosh S. Supplier selection of an Indian heavy locomotive manufacturer: An integrated approach using Taguchi loss function, TOPSIS, and AHP. *IIMB Manag Rev*. 2019; 31:78-90.
26. Amir RV, Naser FF, Soleyman I. Risk assessment of marine construction projects using Taguchi Loss Function. *Intl J Coastal and Offshore Engin*. 2019; 3(3): 33-42.