International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Study of Safety Management in Construction Industry

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Abstract: ***Providing safe workplace conditions is one of the main purposes of a safety management system (SMS) in effective construction companies. The current study aims to establish a method for identifying and evaluating the factors that impact workplace safety conditions at construction sites. The fuzzy analytical hierarchy process (AHP) technique was used to determine and measure the qualitative factor weights affecting workplace safety to assist in the evaluation of multiple concurrent criteria. Hence, the fuzzy AHP technique was used to determine criterion weight. Alternatively, a fuzzy technique for Order Performance by Similarity to Ideal Solution (TOPSIS) model was used to evaluate the performance of companies and rank them according to their safety performance. By using these methods determines the leading companies in terms of best practices and provides information for government inspectors to investigate the priorities identified for inspection.***

Keywords: Safety management system, factors' impacts construction worksites, Fuzzy AHP and Fuzzy TOPSIS

1. Introduction

Problems arising in construction projects are complicated and are usually involving massive uncertainties and subjectivities. The Indian society and economy have suffered human and financial losses as a result of the poor safety record in the construction industry. The purpose of the studies in this area is to examine safety management in the construction industry. A safety management system (SMS) aims to decrease the number of accidents, injuries, and health problems among workers at a workplace. safety management is the systematic process of identifying, analyzing and responding to project safety.

The present study used a fuzzy AHP method to determine the most important factors for workplace safety performance. One of the main advantages of the fuzzy AHP method is that it is able to simultaneously evaluate the effects of different factors in realistic situations. The fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method is used to objectively assess construction companies in terms of their safety performance. The combination of the fuzzy AHP and TOPSIS methods is more beneficial than using either method individually. In the hybrid methodologies, qualitative and quantitative data related to SMS criteria must be collected and used to assess the companies' overall performance. The fuzzy TOPSIS method is suitable for solving group decision-making problems in a fuzzy environment. It is an attractive method for selection problems in which the criteria are equally important and the information related to the input criteria is not precisely known. The alternatives are evaluated based on different criteria, and the evaluation process involves mainly quantitative data.

2. Objective of the study

The objective of this thesis are wide such as,

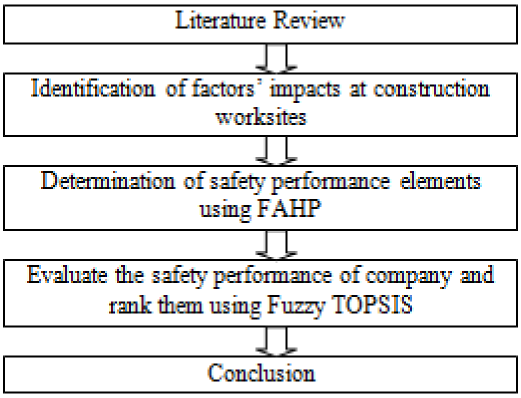
- Provide recommendations for overcoming the current barriers to the successful integration of safety performance
- Improve the level of awareness and performance regarding safety management
- Determination of safety performance elements
- Implement safety management during construction and production of materials
- Implement safety management in all phases of building design planning

3. Scope

Safety management system, enhance and maximize the efficiency of construction management. It helps to improves project performance. Implementation of the safety management system improves clear understanding and awareness of potential safety in project. In meeting these basic requirements, the building should not cause harm to its occupants or the environment. By achieving sustainable future in the building industry covering a number of features such as: Increased level of control over whole project, reduce the expenses, efficient problem solving process, and provides a procedure that can reduce possible and sudden surprises.

4. Methodology

The aim of this study is to identify, evaluate the factors that contribute significantly to SMS performance at construction worksites. Furthermore, the construction companies considered were ranked according to their SMS performance. Methodology selected for this research comprised of a questionnaire design, a questionnaire survey and interviews of the construction industry practitioners, and survey data's are analysed by fuzzy AHP and fuzzy TOPSIS.



5. Factors' impacts at construction worksites

Based on a research studies and expert participants, the main factors that can significantly impact SMS performance are classified in to five factors: safety-management level, safety training, safety behaviour, safety procedures and rules, and worker team level. Then the each main factor is divided to sub-factor.

5.1 Safety-management level

Safety priority, Management commitment, Safety facilities condition, Safety meetings, Safety reports

5.2 Safety training

Safety training programs, Training priority, Participations

5.3 Safety behavior

Performance tendency, Safety rules complying, Rules effectiveness

5.4 Safety procedures & rules

Rules and procedures applying , Safety inspection, Rules effectiveness

5.5 Work team level

Responsibility level, Workers commitments, Safety communications, Safety feedback

6. FAHP – Fuzzy analytical hierarchy process

FAHP approach to identify and evaluate the five most important factors affecting SMS performance, which in turn affects the safety on construction worksites. The importance of the weights and the performance ratings of the criteria are measured using this numerical scale. The current study used eight linguistic terms on a scale ranging from extremely strong (ES; [7, 8, 9]) to equally strong (EQ; [1, 1, 1]).

Hence, let X = {x1, x2, x3,…, xn} be a decision set and G = {g1, g2, g3,, gn} be the goal set for each criterion to simultaneously perform the extension analysis of each criterion. Let M^j_{gi} (j= 1, 2,..., m) be fuzzy triangular numbers to present the pair-wise weights of criteria. Saaty developed the set of fuzzy pair-wise comparison terms presented in Table 3.1 and they were employed for decision making in this study. The inverse of the vector indicating the synthetic extent was calculated, and the Si values were obtained for each criterion

$$S_{ci} = \sum_{j=1}^{m} M_i^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j\right]^{-1} = W = [w_1, w_2, \dots, w_n]$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right)$$

And to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j\right]^{-1}$, perform the fuzzy edition operation of m extent analysis values for a particular matrix such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j\right]^{-1} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

and then compute the inverse of the vector

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

7. Fuzzy TOPSIS - fuzzy technique for order of preference by similarity to ideal solution

The following fuzzy linguistic terms were used to assess the safety and health conditions at workplaces: very low importance (VLI), low importance (LI), moderately important (MI), highly important (HI), and extremely important (EI). The l. linguistic terms are changed to qualitative data. Table 3.3 illustrates the fuzzy linguistic terms employed to determine the importance of attributes and the rating of alternative companies according to the parameters.

The steps for implementing the fuzzy TOPSIS methodology and its results are described below.

Step 1: The importance of all main criteria and sub-criteria was considered to assess the safety conditions at workplaces in a holistic manner. In order to combine the decisions and calculate the average decision for each sub-criterion. Therefore, the fuzzy linguistic terms were used to calculate the outcomes. Equation was used to average the fuzzy numerical values assigned for each main criterion and sub-criteria. Hence, let $N = \{n_1, n_2, \dots, n_6\}$ be the set of construction companies to be assessed. First, fuzzy numerical values were used to evaluate each company with regard to the criteria, and then, a rating order was determined for the companies by multiplying the matrix of outcomes with the vector of criterion weights to determine the safety conditions at workplaces.

$$X_{ij} = \frac{1}{N}\{z_{ij}^{(1)} + z_{ij}^{(2)} + z_{ij}^{(3)}$$

where z_{ij} are *fuzzy numerical values* assigned by the k^{th} decision maker from the assessed company with respect to a criterion and (+) indicates the fuzzy arithmetic summation function. $X = (z_{ij})_{nxm}$ is a fuzzy decision matrix characterized by fuzzy numerical values. A fuzzy term set was used to determine the rate of companies for safety conditions to evaluate the reliability of a workplace.

Step 2: It is possible to avoid complex calculations; a linear normalization is used to convert the various measurement scales into comparable scales. The decision matrices are homogenous and that the range of each component of the normalized triangular fuzzy numbers lies within [0, 1]. The set of R_{ij} was calculated. R_{ij} presents the fuzzy membership degree representing the company's performance with regards to the main criteria. It is the normalized fuzzy decision matrix presents this fuzzy decision matrix for safety condition at workplaces with regard to the criteria. The fuzzified values (r_{ij}) were presented as the matrix.

$$R_{ij} = [r_{ij}]_{mxn},\ i=1,2,\ldots m,\ j=1,2,\ldots.,n$$

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} \\ r_{21} & r_{22} & \cdots & r_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} \end{bmatrix}$$

Where,

$$r_{ij} = \left(r^{1}_{ij}, r^{m}_{ij}, r^{u}_{ij}\right) = \left(\frac{z^{1}_{ij}}{c^{*}_{j}}, \frac{z^{m}_{ij}}{c^{*}_{j}}, \frac{z^{u}_{ij}}{c^{*}_{j}}\right),\ i=1,2,\ldots.,m$$

$$c^{*}_{j} = max\left[z^{u}_{ij}\right],\ j=1,2,\ldots.,n$$

The weighted normalized fuzzy decision matrix (V_{ij}) can be defined as follows. The weighted normalized fuzzy decision matrix is used to transform the crisp outcomes of safety conditions at workplaces to evaluate the reliability of a work-place by the triangular fuzzy numbers within the interval [0,1].

$$V = [v_{ij}]_{mxn},\ i=1,2,\ldots.,m;\ j = 1,2,\ldots.,n$$

Where,

$$v_{ij} = w_j \otimes r_{ij}$$

The fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) are denoted by d_i^* and d_i^-. where $d(d_i^*$ and $d_i^-)$is the distance measurement between two fuzzy numbers. The weighted fuzzy decisions must be normalized. Normalization is a defuzzification process of the decision matrix to determine the distance of these performance values to the ideal performance value. The distances can be on both sides; hence, one side can be defined as the FPIS, and the other side can be defined as the FNIS. The distances can be used to find the similarity co-efficient or closeness co-efficient (CC_i) and ranking order of the construction companies. The closeness coefficient of each alternative company was calculated.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}$$

Where,

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}\ ,i = 1,2,\ldots,m,$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}\ ,i = 1,2,\ldots,m,$$

8. Result and Conclusion

Based on a research studies and expert participants, determine that, the main factors that can significantly impact SMS performance are classified in to five factors: safety-management level, safety training, safety behaviour, safety procedures and rules, and worker team level. Then the each main factor is divided to sub-factor. Hence, the criteria determination, and hybridization of Fuzzy AHP and fuzzy TOPSIS is the base of the fuzzy model developed.

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