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Safety analysis in construction worksite using fuzzy AHP and fuzzy TOPSIS

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ABSTRACT

Safety on construction sites is a complex issue. A safety management system (SMS) aims to decrease the number of accidents, injuries, and health problems among workers at a workplace. Ensuring safe workplace conditions at construction sites depends on different factors, including safety rules, management commitment, safety training, and safe behaviour. The current research 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. Based on the results and findings of the presented approaches, four companies were ranked for their overall safety performance. The findings are encouraging and can be used in the construction industry to benchmark the performance of construction companies for their application of safety rules and regulations. The approach also determines the leading companies in terms of best practices and provides information for government inspectors to investigate the priorities identified for inspection.

Keywords: *Safety in construction work-site, Safety management system, Factor's impact safety, and safety analysis using FAHP and fuzzy TOPSIS.*

1. INTRODUCTION

The significance of construction industry to the economic and social life of the country is noteworthy. The Indian society and economy have suffered human and financial losses as a result of the poor safety record in the construction industry. Problems arising in construction projects are complicated and are usually involving massive uncertainties and subjectivities. Compared with many other industries, the construction industry is subject to need more safety due to the unique features of construction activities, such as being long period projects including complicated processes, abominable environment, financial intensity and dynamic organization structures. The purpose of the studies in this area is to examine safety management in the construction industry. This also enables us to reveal several factors of pure safety management.. Occurrence of project safety may have positive or negative effects on one of the following project objective, such as time, cost, safety, quality or sustainability. On the other hand, safety issues are threats to project success, failure to adequately dealing with safety issues has been shown to cause higher costs and time overruns in construction projects, eliminating all risks in construction projects is impossible. Thus, there is a need for a formal safety assessment and control process to manage all types of safety issues in the projects. Without the safety measures the construction project fully leads to the failure. So that the safety in construction worksite very important thing.

Safety on construction sites is a complex issue in which the management team, who has the authority to allocate resources and enforce the organization's policies, plays a key role in its success. Managers must be willing to accept responsibility for the safety of their employees and must consider safety an integral part of doing business. 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. Providing safe workplace conditions in effective construction companies. The effectiveness of the system depends on different factors, such as management commitment, effective use of resources, and worker participation, and communications. The most important functions of an safety management system is to provide safe workplace conditions that significantly impact the health and productivity of workers and support the construction company's financial status.

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 fuzzy AHP method helps decision makers determine the factors that are most likely to be the cause of unsafe work conditions. This method assigns weights to determine the factors' importance. Determination the weight of various factors is one management function that a company should consider to improve the safety conditions at worksites. 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.

2. OBJECTIVE AND SCOPE

Safety management system, enhance and maximize the efficiency of construction management. 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. 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.

3. 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.

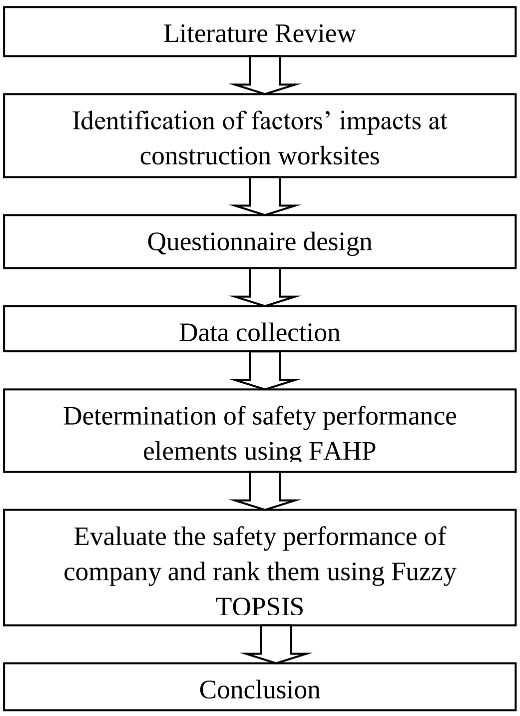

Fig - 1: Research methodology

3.1 Questionnare design

The questionnaire was design based on factors identified for assessment of construction worksites' safety management system (SMS). The questionnaire mainly based on fuzzy linguistic variables and their term sets for the construction industry. The fuzzy linguistic terms are different for each factor.

3.2 Data collection

Data collection is the most critical part of the study since the accuracy of the data will determine the success or failure of the research. Data obtained through these questionnaires will be analysed accordingly using appropriate analysis techniques. Responses from questionnaires will then be compiled and analysed. Data collected from different questions will be gathered to answer different objectives. The questionnaire survey was conducted from about ten companies (10 Respondent's). Questionnaire contributes to following parties of the project. Most of the data was collected from construction buildings site and interview was done with safety engineers and safety advisors.

4. IDENTIFIED FACTORS AFFECT SAFETY MANAGEMENT SYSTEM 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. The five main factors in the current model that contribute to the assessment of construction worksites' safety management system were carefully identified and structured.

According to this current study the factors are consistent with safety training programmes, safety behaviour, safety communication and feedback, safety rules, management commitment, and individual safety performance. The safety-management level includes safety priority, management commitment, safety facilities' conditions, safety meetings, and safety reports. To take safety priority in consideration, a huge amount of safety commitment is required. A high level of management commitment in safety issues means that the company strives for good safety conditions, appropriate safety welfare, and highly prioritizes safety. These factors are crucial because priority in anything make that particular area more reliable and adequate to all. These factors have a positive, significant impact on how employees and the lower management feel about safety at the worksites.

Safety training involves safety training programmes, training priority, and participation. Training programmes contribute significantly to reducing accidents and the number of injuries at worksites. Suitable training programmes help workers identify common types of hazards and how they can deal with them. In addition, increasing workers' participation in effective training programmes leads to increased levels of knowledge and skill amongst workers regarding types of hazards at worksites, which decreases the number of injuries and accidents and impacts the overall safety management system performance.

Safety behaviour is impacted significantly by management commitment, which comprises three sub-factors: performance tendency, safety-rules compliance, and safety awareness. Safety behaviour is an important factor that can impact SMS performance negatively. Most likely, if the safety supervisor and workers do not have a high level of safety awareness regarding construction worksites' hazards and fail to comply with safety rules, injuries and accidents will occur, even if safety management applies high-standard safety rules and procedures. There are companies who are packed with safety measures but are seldom delivered to workers on time of emergency, this where the question of responsibility and commitment arrive in regards to the carelessness of the scenario. Good safety behaviour amongst workers plays a significant role in increasing their perception and attention towards safety-hazard records and the importance of using safety tools and equipment.

Clear and simple safety procedures and rules amongst all management levels in a company are important factors that lead to increased effectiveness of the overall safety management system performance. According to the current study's expert safety participant, some activities at construction worksites require clear and effective procedures and steps, such as using cranes and scaffolds. These types of safety rules and procedures contribute significantly to preventing accidents. Safety inspection is one of the most important procedures that prevents different types of accidents and increases workers' safety knowledge and awareness.

Finally, the worker team level factor includes responsibility level, worker commitment, safety communication, and safety feedback. This factor focuses on workers and safety at construction worksites. Responsibility level refers to the level of worker concern towards safety (i.e. a worker performs his job under highly safe work conditions). In other words, the worker considers his safety and his co-workers' safety, and implements safety rules and procedures while performing his task. The level of workers' compliance with the safety rules and procedures is an important sub-factor that can impact SMS performance negatively.

5. DETERMINATION OF SAFETY PERFORMANCE ELEMENTS USING FAHP

The improved fuzzy extent analysis of Chang's method was employed to determine the weights of criteria using fuzzy triangular numbers. 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]), as illustrated in Table 1.The linguistic scale in the fuzzy AHP method was used to categorize the criteria (C) based on their current status. FAHP approach to identify and evaluate the five most important factors affecting SMS performance, which in turn affects the safety on construction worksites. The FAHP provides a means of decomposing the problem into a hierarchy of sub-problems which can more easily be comprehended and subjectively evaluated. The subjective evaluations are converted into numerical values and processed to rank each alternative on a numerical scale. Table 2 presents the fuzzy numerical scale for the pair-wise comparison of criteria and m extent analyses were conducted for each criterion. The importance of the weights and the performance ratings of the criteria are measured using this numerical scale. To build the pair-wise comparison matrix, each criterion in the set was mutually evaluated and an extension analysis was performed. The m extent analyses of criteria (The fuzzy triangular obtained for the criteria of the SMS of a construction company); the results are presented in Table 3. The outcomes of the fuzzy synthetic extent with respect to the criteria were calculated. The pair-wise comparison was performed for each criterion in the set, the results were evaluated, and the extension analysis was performed. These are weights to determine the mutual comparative importance of the safety criteria. The results of the fuzzy synthetic extents (Sc1) for each criterion are presented in Table 4.

Table-1 : Fuzzy linguistic terms determined for the criterion weights comparison

Extremely Strong (ES)	(7,8,9)
Very Strong (VS)	(5,6,7)
Strong (ST)	(3,4,5)
Moderately Strong (MS)	(1,2,3)
Equally Strong (EQ)	(1,1,1)

Table-2: Fuzzy pair-wise comparison of construction project criteria

Fuzzy pair-wise comparison matrix	C1	C2	C3	C4	C5
C1: Safety- Management Level	(1,1,1)	(1,2,3)	(5,6,7)	(1/3,1/2,1)	(3,4,5)
C2 : Safety Training	(1/3,1/2,1)	(1,1,1)	(3,4,5)	(1/5,1/4.1/3)	(1,2,3)
C3 : Safe Behaviour	(1/7,1/6,1/5)	(1/5,1/4.1/3)	(1,1,1)	(1/9,1/8,1/7)	(1/3,1/2,1)
C4 : Safety Procedures & Rules	(1,2,3)	(3,4,5)	(7,8,9)	(1,1,1)	(5,6,7)
C5 : Work Team Level	(1/5,1/4.1/3)	(1/3,1/2,1)	(1,2,3)	(1/7,1/6,1/5)	(1,1,1)

Table-3 : Fuzzy triangular numbers used to define the weight of decision criteria

Fuzzy pair-wise decision matrix	Weights
C1: Safety- Management Level	(10.33,13.50,17)
C2 : Safety Training	(5.53,7.75,10.33)
C3 : Safe Behaviour	(1.79,2.04,2.68)
C4 : Safety Procedures & Rules	(17,21,25)
C5 : Work Team Level	(2.68,3.92,5.53)

For example. The calculation are presented in below for the criteria 1.

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j\right]^{-1} = [60.54, 48.21, 37.33]^{-1} = \left(\frac{1}{60.54}, \frac{1}{48.21}, \frac{1}{37.33}\right)$$

$$S_{C1} = \sum_{j=1}^{m} M_i^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i^j\right]^{-1} = (10.33, 13.50, 17) \otimes \left(\frac{1}{60.54}, \frac{1}{48.21}, \frac{1}{37.33}\right)$$

$$S_{C1} = (0.17, 0.28, 0.46)$$

Table - 4: Fuzzy weight of the decision criteria

Fuzzy pair-wise decision matrix	Weights
C1: Safety- Management Level	(0.17,0.28,0.46)
C2 : Safety Training	(0.09,0.16,0.28)
C3 : Safe Behaviour	(0.03,0.04,0.07)
C4 : Safety Procedures & Rules	(0.28,0.44,0.67)
C5 : Work Team Level	(0.04,0.08,0.15)

6. ASSESSING SAFETY CONDITION IN THE CONSTRUCTION INDUSTRY BY USING FUZZY TOPSIS

TOPSIS begins by benefiting from the weights computed by fuzzy AHP and the orders priorities are by computing the relative distance between the alternatives and the ideal solutions. After the fuzzy criterion weights were determined by the fuzzy AHP method, the safety conditions of each construction company were assessed based on the selected criteria. The DMs generally use the linguistic terms to evaluate the alternative companies with respect to the criteria. Table 5. Shows the fuzzy linguistic variables and their term sets for the construction companies' health and safety-management parameters. Table 6 illustrates the fuzzy linguistic terms employed to determine the importance of attributes and the rating of alternative companies according to the parameters.

	Table - 5: Fuzzy linguistic variables and their term sets for the construction industry					
1.	Safety Management Level	Fuzzy Linguistic Terms				
	Safety Priority	Very low	Low	moderate	high	Very high
	Management's Commitments	Very low	Low	moderate	high	Very high
	Safety Facility Condition	Poor	Fair	good	Very good	excellent
	Safety Meetings	Very rare	Rare	sometimes	often	always
	Safety Reports	Low important	Slightly important	Moderately important	Highly important	Extremely important
2.	Safety Training	Fuzzy Linguistic Terms				
	Safety Training Programmes	Poor	Fair	good	Very good	excellent
	Training Priority	Very low	Low	moderate	High	Very high
	Participation	Low	Slightly low	moderate	Slightly high	high
3.	Safe Behaviour	Fuzzy Linguistic Terms				
	Performance Tendency	risky	Slightly risk	normal	Slightly safe	safe
	Safety Rules Compliance	Extremely unacceptable	unacceptable	normal	Slightly acceptable	acceptable
	Safety Awareness	unaware	Slightly aware	Somewhat average	Moderately aware	Extremely aware
4.	Safety procedure & rules	Fuzzy Linguistic Terms				
	Application of rules& procedures	never	Rarely	Sometimes	often	always
	Safety inspection frequency	never	Rarely	sometimes	often	always
	Effectiveness of procedures & rules	Low	Slightly low	moderate	Slightly high	high
5.	Work team level	Fuzzy Linguistic Terms				
	Responsibility level	Very low	Low	moderate	high	Very high
	Workers commitment	Very low	Low	moderate	high	Very high
	Safety communication	Poor	Fair	good	Very good	excellent
	Safety feedback	Poor	Fair	good	Very good	excellent

Table - 6: Linguistic terms and their numerical intervals for fuzzy TOPSIS

Fuzzy Linguistic Terms for Decision Making	Numerical Values
Very Low Important (VLI)	(1,2,3)
Low Important (LI)	(2,3,4)
Moderately Important (MI)	(3,4,5)
Highly Important (HI)	(4,5,6)
Extremely Important (EI)	(5,7,9)

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 determined were used to calculate the outcomes. Average the fuzzy numerical values assigned for each main criterion and sub-criteria. Hence, let $N = \{n_1, n_2, \ldots, n_6\}$ 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.

Table - 7: Decision matrix for safety- management level by fuzzy linguistic terms

C1: Safety-Management Level	C11: Safety Priority	C12: Management Commitment	C13: Safety Facility Condition	C14: Safety Meetings	C15: Safety Reports
DM1	EI(5,7,9)	EI(5,7,9)	HI(4,5,6)	EI(5,7,9)	EI(5,7,9)
DM2	EI(5,7,9)	HI(4,5,6)	HI(4,5,6)	MI(3,4,5)	HI(4,5,6)
DM3	HI(4,5,6)	LI(3,4,5)	MI(3,4,5)	LI(2,3,4)	LI(2,3,4)
DM4	HI(4,5,6)	MI(3,4,5)	MI(3,4,5)	MI(3,4,5)	MI(3,4,5)
DM5	EI(5,7,9)	HI(4,5,6)	MI(3,4,5)	LI(3,4,5)	LI(2,3,4)
DM6	EI(5,7,9)	HI(4,5,6)	HI(4,5,6)	HI(4,5,6)	HI(4,5,6)
DM7	MI(3,4,5)	MI(3,4,5)	LI(2,3,4)	MI(3,4,5)	LI(2,3,4)
DM8	HI(4,5,6)	MI(3,4,5)	MI(3,4,5)	LI(2,3,4)	LI(2,3,4)
DM9	HI(4,5,6)	EI(5,7,9)	HI(4,5,6)	LI(2,3,4)	MI(3,4,5)
DM10	EI(5,7,9)	HI(4,5,6)	HI(4,5,6)	LI(2,3,4)	LI(2,3,4)

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].. 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} .The maximum and minimum values of the fuzzy numerical values (z_{ij}).

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

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

Where,

$$r_{ij} = (r_{ij}^1, r_{ij}^m, r_{ij}^u) = \left(\frac{z_{ij}^1}{c_j^*}, \frac{z_{ij}^m}{c_j^*}, \frac{z_{ij}^u}{c_j^*}\right), \; i=1,2,\ldots,m$$

$$c_j^* = max[z_{ij}^u], \; j=1,2,\ldots,n$$

Table 8: Decision matrix for construction companies with regard to the criteria

R_{ij}	C1	C2	C3	C4	C5	cj^*
Company 1	(4.8,6.6,8.4)	(4.0,5.0,6.0)	(4.7,6.3,8.0)	(5.0,7.0,9.0)	(4.5,6.0,7.5)	9
Company 2	(4.0,5.2,6.4)	(3.7,4.7,5.7)	(3.3,4.3,5.3)	(5.0,7.0,9.0)	(4.2,5.5,6.7)	9
Company 3	(2.8,3.8,4.8)	(2.0,3.0,4.0)	(3.0,4.0,5.0)	(3.7,4.75.7)	(3.7,4.7,5.7)	5.7
Company 4	(3.2,4.2,5.2)	(9.0,4.0,15)	(2.7,3.7,4.7)	(4.3,5.7,7.0)	(3.2,4.2,5.2)	7
Company 5	(3.4,4.6,5.8)	(3.3,4.3,5.3)	(3.7,4.7,5.7)	(3.0,4.0,5.0)	(2.8,3.8,4.8)	5.8
Company 6	(4.2,5.4,6.6)	(5.0,6.0,7.0)	(4.3,5.7,7.0)	(4.7.6.3,8.0)	(4.0,5.2,6.5)	8
Company 7	(2.6,3.6,4.6)	(2.7,3.7,4.7)	(2.3,3.3,4.3)	(3.0,4.0,5.0)	(2.5,3.5,4.5)	5
Company 8	(2.8,3.8,4.8)	(2.7,3.7,4.7)	(2.7,3.7,4.7)	(3.3,4.3,5.3)	(2.5,3.5,4.5)	5.3
Company 9	(3.6,4.8,6.0)	(2.3,3.3,4.3)	(3.0,4.0,5.0)	(4.3,5.7,7.0)	(3.2,4.2,5.2)	7
Company 10	(3.4,4.6,5.8)	(3.0,4.0,5.0)	(4.0,5.3,6.7)	(5.0,7.0,9.0)	(4.2,5.8,7.2)	9
weight	(0.17,0.28, 0.46)	(0.09,0.16, 0.28)	(0.03,0.04, 0.07)	(0.28,0.44, 0.67)	(0.04,0.08, 0.15)	

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,

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

Table 9: Final aggregation of company grades with respect to all criteria using fuzzy triangular numbers

Companies V_{ij}	C1	C2	C3	C4	C5
Construction company 1	(0.09,0.21,0.42)	(0.04,0.09,0.19)	(0.01,0.03,0.06)	(0.15,0.34,0.67)	(0.02,0.05,0.13)
Construction company 2	(0.08,0.16,0.33	(0.03,0.08,0.18)	(0.01,0.02,0.04)	(0.15,0.34.0.67)	(0.01,0.05,0.11)
Construction company 3	(0.08,0.18,0.38)	(0.03,0.08,0.12)	(0.02,0.03,0.06)	(0.18,0.36,0.67)	(0.03,0.07,0.15)
Construction company 4	(0.08,0.17,0.34)	(0.04,0.09,0.20)	(0.01,0.02,0.05)	(0.17,0.36,0.67)	(0.02,0.05,0.11)
Construction company 5	(0.10,0.22,0.46)	(0.05,0.12,0.26)	(0.02,0.03,0.07)	(0.14,0.30,0.58)	(0.02,0.05,0.12)
Construction company 6	(0.09,0.19,0.38)	(0.06,0.12,0.25)	(0.01,0.02,0.06)	(0.16,0.35,0.67)	(0.02,0.05,0.12)
Construction company 7	(0.09,0.20,0.42)	(0.04,0.12,0.26)	(0.01,0.03,0.06)	(0.17,0.35,0.67)	(0.02,0.05,0.13)
Construction company 8	(0.08,0.20,0.41)	(0.05,0.11,0.25)	(0.01,0.02,0.06)	(0.17,0.36,0.67)	(0.01,0.05,0.13)
Construction company 9	(0.09,0.19,0.39)	(0.02,0.07,0.17)	(0.01,0.02,0.05)	(0.17,0.35,0.67)	(0.01,0.04,0.11)
Construction company 10	(0.06,0.14,0.30)	(0.03,0.04,0.15)	(0.01,0.02,0.05)	(0.16,0.34,0,67)	(0.02,0.05,0.12)

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

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

Table 10: Efficiency rates and closeness coefficients of the companies

Construction companies	FPIS (d_i^+)	FNIS (d_i^-)	Similarity co-efficient (CC_i)	Ranking of the construction companies
company 1	1.904	0.557	0.226	1
Company 2	1.937	0.560	0.224	2
Company 3	1.912	0.518	0.213	8
Company 4	1.920	0.547	0.222	4
Company 5	1.897	0.520	0.215	7
Company 6	1.896	0.546	0.223	3
Company 7	1.912	0.508	0.209	9
Company 8	1.894	0.499	0.208	10
Company 9	1.925	0.539	0.219	5
Company 10	1.951	0.538	0.216	6

7. CONCLUSION

According to the result of current study using fuzzy AHP, criteria four had the highest weight. So the safety procedure & rules had best performance out of the five criteria considered. And other four factors are also important factors. By using this result, determine which construction company exhibited the best safety management performance.

The similarity coefficient of Construction Company 1 is 0.226. i.e. the company has applications closer to ideal values. So the company 1 provide best safety management performance. The similarity coefficient of company 8 is 0.208. So the company 8 far from the ideal value and the company lower safety management performance. According to the result in Table 4.11. the ranking of construction companies with regard to SMS performance is as follows company 1> company 2 > company 6 > company 4 > company 9 > company 10 > company 5 >company 3 > company 7 > company 8. From the final results of the current study, Company 1 had the best performance and rendition out of the ten companies taken.

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