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PAPER

Enhancing Construction Site Safety in Pakistan: A Proposed Health and Safety Framework Based on the Analytical Hierarchy Process

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ABSTRACT

Developing infrastructure is crucial for the economic growth of countries like Pakistan, which are facing financial challenges. However, the construction industry is complex and uncertain, with various associated risks. The purpose of this study is to develop a proactive health and safety strategy by identifying the risk factors that pose a threat to the safety of construction workers in Pakistan. Pairwise comparison matrices were constructed using the Analytical Hierarchy Process (AHP) approach for individual groups and the total sample. This process generated weights, consistency indices, and consistency ratios to validate the data. The fuzzy comprehensive evaluation method (FCEM) was used to evaluate the identified threats. Based on the identified health and safety risk factors, a general matrix, as well as first and second-level ambiguous relations were created. Additionally, a fuzzy comprehensive evaluation matrix was developed. The centesimal values of the goal layer were found to be higher (3.72) than the values of the factors, including unsafe acts (13.08), accidents and hazards (25.14), policies and management (12.15), managing workers at the worksite (6.12), and management of worksite (5.07). The results indicated that all these factors significantly affect health and security in construction projects. Based on these findings, corrective measures could be implemented at the strategic and planning levels to strengthen and regulate these barriers.

KEYWORDS

analytical hierarchical process, construction industry, Delphi method, risk management, fuzzy comprehensive evaluation

1 INTRODUCTION

The construction industry is known to be one of the riskiest sectors globally. Uncertainties arises from various sources, making it dangerous, intricate, competitive, and distinctive field [1]. In the case of non-residential projects, accident-related expenditures can account for 7.9–15% of total project costs. Small building

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construction enterprises without proper safety policies have hazardous workplaces, putting their personnel at risk [2]. Compliance with safety regulations necessitates the implementation of essential health and safety measures by employees to ensure a minimum level of workplace safety [3].

Various techniques or processes, such as the Analytic Network Process (ANP) and the Functional Resonance Accident Model (FRAM), are available for the examination of health and safety policies [4] [5]. ELECTRE, TOPSIS, ENTROPY, SAW and AHP have been utilized to assess the effectiveness of alternative approaches. Among these methods, AHP employs a methodology similar to SAW. AHP is a straightforward and comprehensible approach commonly used as a weighting method in conjunction with other techniques.

The AHP approach aided managers in enhancing performance, minimizing and controlling workplace risks, and facilitating faster, and more accurate and reliable decision-making on high-risk projects [6]. According to a study conducted in China, modelling techniques, with their remarkable adaptability and broad applicability, have the potential to reduce risk by 17% [7]. In Pakistan's construction sector, reactive techniques and regulations are commonly employed, rather than preventative measures [6] [7]. The adoption of a modelling approach, such as AHP, in analysing construction project case studies ensures accurate monitoring of health and safety regulations [7].

The construction industry encompasses activities such as constructing new permanent structures, maintaining and demolishing existing ones, and enhancing the ground condition [8]. The supply chain involved in both new construction projects and renovations and repairs to existing structures is commonly referred to as the "architectural, engineering and construction industry" (AEC industry) [9]. Construction sites are prone to accidents, resulting in worker fatalities, injuries, occupational illnesses and significant additional costs. According to data from the China State Administration of Work Safety, there were 2634 fatal incidents involving construction workers in China in 2011. The US Department of Labor reported that construction workers were among the top 15 industries with the highest fatalities in 2011. According to UK Health and Safety Executive data, construction accounted for 22% of all industrial fatalities in 2011, resulting in 49 deaths with no sign of decline.

Construction safety is a significant concern not only in wealthier nations but also in developing countries like Pakistan, where effective adaptation to technological advancements has been limited. Given that the construction business in the nation employs between six and seven per cent of the labour force, this is very problematic. It is crucial for organizations and employees to prioritize awareness and attention to workplace health and safety [10].

There are many reasons why construction businesses in Pakistan tend to disregard employee health and safety laws, hindering the industry from reaching its full potential. Accidents often occur due to factors such as employee incompetence, working at heights without proper safety measures, operating machinery without protective gear, inadequate site administration and failure to wearing personal protective equipment (PPE) [11] [12]. Despite employing 7.3% of the total workforce in Pakistan, the construction industry experiences a significantly higher accident and injury rate compared to other industries, standing at 17.3%. The majority of accidents in the construction industry involve falls from a height, hoisting incidents and electrocution [13]. The causes of falls from height have been attributed to factors such as inadequate supplies of fall protection equipment, lack of training, tight construction schedules, and absence of suitable anchoring points at construction sites [13] [14]. Risky behaviours and unsafe working environments accounts for 98% of construction accidents. Some construction business sectors operate without proper health and safety regulations or guidelines [15].

Due to lax safety culture, reactive and unsafe activities have become more common in Pakistan's construction industry over time [3]. The lack of a costly regulatory structure means that the construction industry does not place a high focus on worker health and safety [12] [16]. Regrettably, national safety rules do not cover the building industry [17]. According to a research, low construction quality results from less attention to work effectiveness [18]. Workers occasionally experience ergonomic dangers due to physically lifting and carrying heavy loads [19] [20].

Risk management is a relatively new idea in Pakistan's construction industry but has not been thoroughly explored. Project risk management aims to increase the likelihood and positive outcomes of fortunate events by reducing the probability and impact of potential failures. Completely avoiding project risks is not advised, especially when proactive risk detection, risk analysis, quick response, and effective monitoring can transform these risks into opportunities [21] [22]. The current project management methods employed by businesses are challenging to modify to meet the increasing demand for risk management. As a result, many initiatives are not adequately equiped to manage risk. In such circumstances, management must exert leadership, along with patience, direction, allocation of time and resources [23].

Each year, thousands of accidents and fatalities at construction sites are caused by various risks and perils [1] [3]. Approximately 40% of construction workers are injured or killed while at work, with cuts accounting for 25% of these injuries [24]. The entire budgeted cost of the project could increase by as much as 15% due to occupational injuries and accidents. Pakistan's general health and safety laws, including the Worker's Compensation Statute of 1923, the Factories Act of 1934, and the Minimum Wage Law of 1961, govern worker's health-related issues, but these regulations do not cover the construction industry [12]. Regrettably, even though these acts primarily address worker concerns related to occupational health and safety, they do not extend to the construction industry. Despite the industry's recent rapid expansion and significant contribution to the national economy, the government has taken little effort to monitor the health and safety risks faced by the workers [12].

Operational research analysis, known as "multi-criteria decision making" (MCDM), is frequently used to address complex decision-making challenges. One approach is to multi-criteria decision-making is the Analytical Hierarchy Process (AHP), which is considered the most effective and user-friendly method for decision-making. It is frequently employed in the selection and prioritization of projects. In the final phase, alternatives must be assessed using the most pertinent evaluation criteria. The foundation of the AHP approach lies in identifying the main challenge as a hierarchy, with the more minor challenges positioned at, the lower levels. Thus, solutions to the smaller dilemmas combine to resolve the larger challenges.

The hybrid FCE-AHP approach has been frequently used to generate evaluation criteria in various study-related fields [13]. Risk assessment is formed by combining quantitative and qualitative evaluation. With a connection to the health and safety framework for building construction projects, it is not viable to describe the risk variables using a quantitative method. As a result, the FCE approach must be employed to assess the risk.

After conducting a comprehensive review of the literature, it became apparent that most research studies have emphasized the risks and hazards associated with construction projects, but there exists a significant research gap concerning health and safety concerns specific to the construction industry. Given these gaps in the literature, there is a pressing need to develop a framework for managing risks and hazards in building construction projects to safeguard workers from serious mishaps, dangers and threats. Moreover, the majority of the research studies conducted on this topic have been conducted outside of Pakistan. Considering Pakistan's enduring issues with security and health, it is crucial to investigate the specific health and safety risks in building projects within this country. Therefore, the purpose of this study is to utilize AHP to evaluate health and safety risks in building projects and establish numerical hazard principles for early risk prevention.

This paper addresses the gap in the literature on health and safety concerns specific to the construction industry in Pakistan. It aims to develop a framework for managing risks and hazards in building construction projects using the AHP and to develop numerical hazard principles for early risk prevention. The novelty of this study lies in its application of the AHP to enhance health and safety in Pakistan's building sector. It aims to develop a comprehensive framework establishing a preventive safety policy that will not only lower or offset the costs related to injuries and accidents, but also help to provide a secure environment for Pakistan's construction industry. The study's objectives include: identifying and assessing the primary health and challenges in risk safety in Pakistan's construction industry, investigating these significant health and safety risks, developing a framework to evaluate the seriousness of risk factors for safety and health, employing a multi-criteria decision-making method to pinpoint the most pressing problems, and to propose a hierarchical safety management model.

2 METHODOLOGY

In this study, both the survey and the descriptive approaches were used. Figure 1 describes the study technique's schematic presentation.

2.1 Data collection

Primary and secondary data were the two main sources utilized for data gathering in this study project. Questionnaires were used as the primary data-gathering procedures to identify risks to the health and well-being of construction site workers. Secondary data was gathered through scholarly publications, journal papers and conference proceedings. A questionnaire survey using the Delphi method was conducted to collect the data [25]. A list of criteria was prepared through comprehensive interaction with experts and comments from company leaders (Table 1).

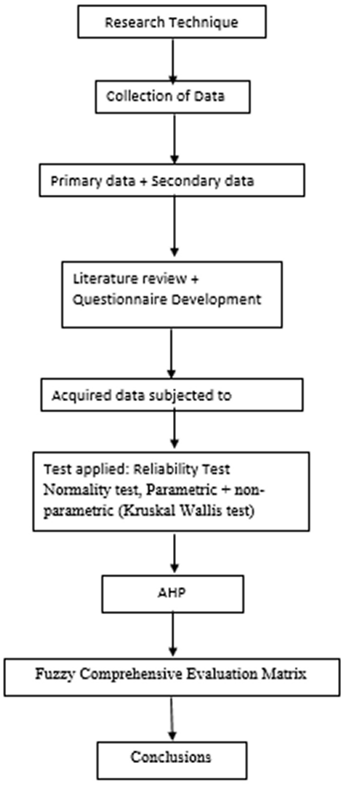

Fig. 1. Schematic diagram of the research methodology

A survey was conducted following the design of a questionnaire. Copies of the questionnaire were distributed to experts, site managers and key individuals from various business and public organizations in Pakistan to gather their feedback. Using 'Statistical Package for Social Sciences (SPSS),' the data acquired from building industry professionals were evaluated [26].

2.2 Data analysis

Reliability analysis is a fundamental technique used to validate the results obtained from the questionnaire. Cronbach's alpha is employed to evaluate the internal consistency and reliability of data collected from the questionnaire [27]. Cronbach's alpha is specifically suitable for reliability analysis A value greater than 0.7 is deemed acceptable, indicating that the data can be reliably analysed for further research [28].

The Shapiro-Wilk's test or S-W test is a well-established technique for assessing normality (1965). In this study, The S-W statistic is used to examine a novel approach to assess high-dimensional normality. This technique describes the use of S-W statistic for evaluating high-dimensional normality with small sample sizes, as there are numerous techniques available for studying large sample sizes in the literature [29].

Table 1. Industrial professionals

Designation	EXP	Profession Category	Sector
Associate Professor	15–20 years	Academia	Private
Director	10–15 years	Consultant Academia	Private
Associate Professor	10–15 years	Academia	Public
Assistant Engineer	10–15 years	Contractor	Public
Chief Engineer	20–25 years	Mentor	Public
Project Manager	15–20 years	Contractor	Private
Director services	Ten years	Contractor	Public

The Kruskal-Wallis test, a non-parametric test, is employed to determine whether the sample data were drawn from a single distribution [30]. The Kruskal-Wallis test is also helpful in determining if the samples originated from the same area. All responders must hold the same viewpoint for the significance level to be greater than 0.05. Here are the alternative and null hypotheses for the Kruskal-Wallis test:

- Null Hypothesis H0: If p > alpha level is maintained, the null hypothesis is that medians are the same (same perception).
- Alternate Hypothesis H1: At least one median is rejected by the p alpha threshold, indicating that not all medians are equal (variation in perception).

According to Kim and Park [31], non-parametric approaches are employed when the data is non-integrated. If the p-value is equal to or below 0.05, the test does not support the normality hypothesis.

2.3 Using AHP in hierarchical framework development

In the AHP approach for addressing complex problems, the highest priority serves as the target, the middle levels serves as criteria and the lowest level represents the options [32].

The methodology used in this study involves categorizing and assessing the significance of data related risks and accidents, risky behaviours and environments, management practices, social groups and natural elements. Each element's value was calculated based on the responses provided by the participants in the dataset. The respondents' preferred intensity level was used to determine the relative significance index for each piece. The ranking scale of 1to 5 was changed to assign the highest score relatively to all elements, enabling the analysis of variable rankings [33]. Equation (1) is used to determine the *RII*:

$$RII = \frac{\Sigma w}{A} \times N \tag{1}$$

ΣW = According to a Likert scale, respondents assigned a weight of 1 to 5 to each factor.

A = Highest value for factors (which is 5 on the Likert scale)

N = Total number of responses

2.4 Pairwise comparison evaluation

The first step involves constructing a pairwise comparison matrix, where each factor is evaluated in pairs against a specific standard. In the resulting real (m x m) matrix (P), that the value of m represents the number of evaluation criteria [1]. The pairwise comparison matrix can be calculated using the following methods:

For comparing factors, a pairwise comparison matrix (P) is built.

1. Each element *ij* of the matrix (Pnorm) is calculated using the following equation (2).

$$aij = aij/\Sigma km = 1akj \tag{2}$$

αij = Entries of the matrix (P)
$\Sigma mk = 1akj$ = Total sum score of each column of the matrix (P)
αij = Entries of the normalized matrix

2. The results measured are normalized to evaluate the relevance of needs using formula (3), or each factor is divided by the total acquired.

$$W = \Sigma mk = 1aik/n \tag{3}$$

$\Sigma mk = 1\alpha ik$ = Each row's average score in the normalized matrix (Pnorm)
n = number of items

3. Eigenvalues (λmax) are computed using formula (4).

$$\Sigma mk = 1akj \times W \tag{4}$$

$\Sigma mk = 1akj$ = Total sum score of each column of the matrix (P)
W = Criteria weight

2.5 Evaluating the consistency patterns

A consistency ratio (CR) of 10% or less is generally considered acceptable by most individuals. However, specific situations may need a higher number [34]. One of the parameter used for AHP validation is the maximum value. To determine whether the pairwise comparison matrix generates a consistent evaluation, the computed factors' CR is utilized as a testimony index, known as max, to examine the statistical data. Together with these procedures, the consistency index and ratio too are determined [35].

1. Use equation (5) to determine the consistency index for each *n*-dimensional matrix.

$$CI = \frac{\lambda \max - n}{n - 1} \tag{5}$$

CI = Consistency Index
λ max = Largest eigenvalue
N = Total number of factors

2. The CR is then computed using formula (6):

$$CR = \frac{CI}{RI} \tag{6}$$

CR = Consistency Ratio
RI = Random Index

According to Saaty, the acceptable range for CR spectrum varies depending on the matrix's dimensions, ranging from 0.05 for (3 × 3) to 0.08 for (4 × 4) to 0.1 for all more significant matrices, $n > 5$ [34]. When the CR value is equal to or less than that sum, the decision-making process within the matrix boundaries is considered acceptable and demonstrates significant coherence compared to the alternatives.

2.6 Fuzzy comprehensive evaluation technique

The level of risk in building projects is determined using AHP and assessment procedures. Several speculative and impossible-to-quantify variables affect the risk level throughout the risk appraisal process. As a result, the assessment technique uses the synthesis theory of fuzzy relations to quantify components with fuzzy edges. It correctly recognizes the objective in light of many factors. Along with the professional grading technique, the fuzzy comprehensive evaluation mechanism (FCEM) pays special attention to the evaluation variables and has the ability to generate accurate findings for the given situation. The following evaluation process embodies the core principles of FCEM [36]:

2.7 Fuzzy comprehensive evaluation matrix (Level 1)

We calculate the membership matrix B_i, commonly known as the first level, thorough evaluation matrix, using equation (7),

$$B_i = Wl \times R \tag{7}$$

Wl = Local weight
R = Fuzzy relation matrix

2.8 Fuzzy comprehensive evaluation matrix (Level 2)

The second-level fuzzy comprehensive evaluation matrix includes all the assessment results from the highest-level complete evaluation matrix, similar to the first-level, extensive evaluation matrix [37]. The overall evaluation matrix B_i displays each comment's rating index R'. To generate a second-level fuzzy exhaustive evaluation matrix, apply the equation (8),

$$B = W \times R' \tag{8}$$

W = Factor's weight
The evaluation index matrix contains r' = Result of the first level FCE assessment.
The table gives the definitions of various dangers.

Table 2. Different catergories of risk types

Types of Risk	Meaning
Very Low	Project risk is less likely to occur, and the possibility of danger would result in less loss.
Low	The likelihood of both project danger and risk-related loss is extremely low.
Moderate	Project danger is moderately likely, and the possibility of threat would result in an ordinary loss.
High	Project danger is likely to occur; if it does, it could result in a significant loss.
Very High	Project risk is more likely to occur, and should it, the potential damage would be more significant.

2.9 Health and safety framework risk evaluation

The effects of health and safety were examined using through questionnaires, considering the unique circumstances of each respondent. A score was assigned to each identified factor. A conference proceeding on cloud computing security, based on AHP and FCE, highlights that the set of remarks V = (v1, v2..., v5) from the assessment entity is often based on the natural world, providing project managers with improved analysis of project risks [38] [39]. The comments collection is constructed using the level argument corresponding to each segment's center [39]. Due to its simplicity and clarity, Zadeh's M(,) model has been widely employed in fuzzy segments. In essence, it performs the role of a ruling element.

- The sign for a low-value choice is "∧"
- The sign for high-value selection is "∨"

The M (x, y) model generated a whole set of assessment comments. By using a formula to calculate the centesimal values of each indicator in the criteria layer, the health and safety framework risk evaluation was created (9).

$$C = R' \times V \tag{9}$$

C = Summary of the entire index object of evaluated risk assessment

R'= first-level fuzzy comprehensive evaluation assessment result is contained in the evaluation index matrix.

V = Cumulative factor

3 RESULTS AND DISCUSSION

Out of the 125 questionnaires distributed, 101 questionnaires were returned, resulting in 85% response rate, which is considered relatively strong for drawing conclusions about the study [40]. The majority of respondents were professionals, as indicated by the demographic information. Based on the demographic statistics, 26% were worksite supervisors, 24% were civil engineers and 23% were workers. The remaining responses came from responses from a range of various other occupations. Several of the survey respondents had previous experience in construction-related duties. Figure 2 displays the respondents' demographic data.

3.1 Data analysis and research reliability

The Cronbach's alpha test was conducted to verify the poll's dependability. A higher score indicates a strong correlation between the survey categories, whereas a lower value suggests a weaker correlation. Reliability is considered acceptable if the alpha falls between 0.70 and 0.99. If the alpha value exceeds 0.70, the data are deemed consistent for further analysis [41].

We obtained a Cronbach's alpha value of 0.846 for our case study, confirming the homogeneity of the data gathered (Table 3). This demonstrates that the reliability analysis's finding that the data is dependable and thereby can be used for further research.

In this study, we focused on five health and safety risks. These risks are further divided into 31 sub-factors, denoted as S = (S1, S2, S3,..... S31) to simplify the risk assessment process.

To evaluate whether the data followed a normal distribution, the S-W test was conducted [42]. If the p-value is less than or equal to 0.05, the results do not support the normality hypothesis. In this study, the magnitude was found to have a significant value of 0.000.

In essence, factor labelling involves using a simplified survey questionnaire with numerical categories. Out of the 125 surveys distributed, 101 were completed and returned. The findings of normality test demonstrate that all significance values are below the alpha level of 0.05, leading to the rejection of the null hypothesis (S-W test). This suggests that data does not follow a normal distribution. Non-parametric tests will be applied for further investigation because the data is non-parametric in nature.

After conducting the normalcy test, it was crucial to confirm the respondents' comprehension level. The concept of normalcy was used to establish the relationship between the non-parametric data and parametric data. As a result, the Kruskal-Wallis test was utilized to measure the respondents' degree of understanding. This test aimed to ascertain if respondents' opinions on each component were comparable or different. If the p-value is less than 0.05, the test result would reject the hypothesis. In this case, the Kruskal-Wallis test result demonstrates that the respondents' null hypothesis is accurate (H0: p > alpha level, equal medians).

3.2 Using AHP in hierarchical framework development

Figure 3 shows the organizational hierarchy for risk assessment. A structure for health and safety is developed to manage complicated concerns at several hierarchy levels, such as the objective layer, criteria layer and index layer. The index layer, which is third section of the sub-criteria, consists of 31 potential risks associated with safety and security in the construction industry. The criteria layer S = (S1, S2, S3,..., S31) and the index layer C = (C1, C2, C3, C4, C5), respectively, refer to dangerous acts, accidents and hazards, policies, coordination, managing workers at the work site and management of the work site to facilitate simplicity in risk assessment. To solve complicated problems, decision-makers can assess quantitative and qualitative evidence using a clear hierarchy and a rigorous multi-criteria approach.

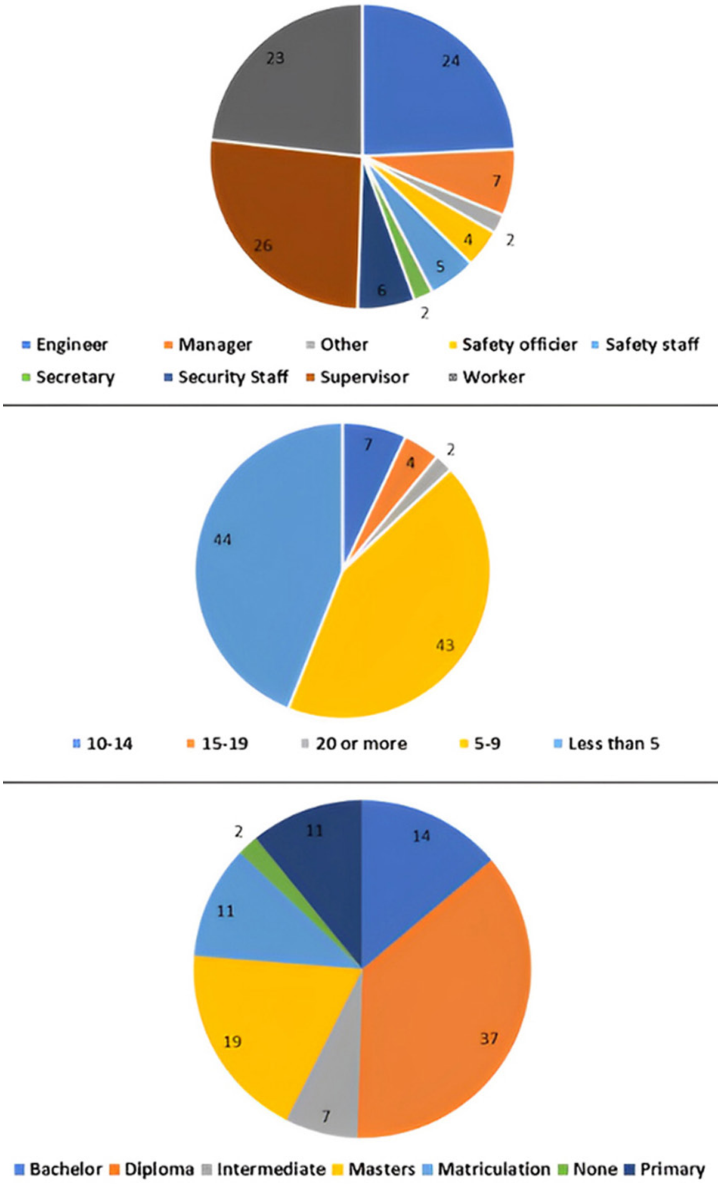

Fig. 2. Respondents' demographic data

The assessment aimed to evaluate the impact of various risky behaviours on building construction operations. Based on the RII rankings, the highest RII value was assigned to the factor 'Absence of Safety Measures' with a value of 0.522. This was followed by 'Inadequate Use of Personal Protective Equipment' (0.515) and 'Using Substandard or Worn-Out Tools' (0.505). 'Lack of Appropriate Safety Equipment and Training' received the lowest RII Value (0.498). A higher RII value for a sub-factor indicates that the component has a significant impact on building sites.

The next objective was to determine factors that contribute to building project accidents and dangers. Among the identified factors, 'Safety events' had the highest RII value (0.568). It was followed by 'Possible tripping hazards' (0.512), while 'Injuries Resulting in Physical Disability' have the lowest value ever (0.508).

Table 3. Cronbach's alpha – reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.846	.856	31

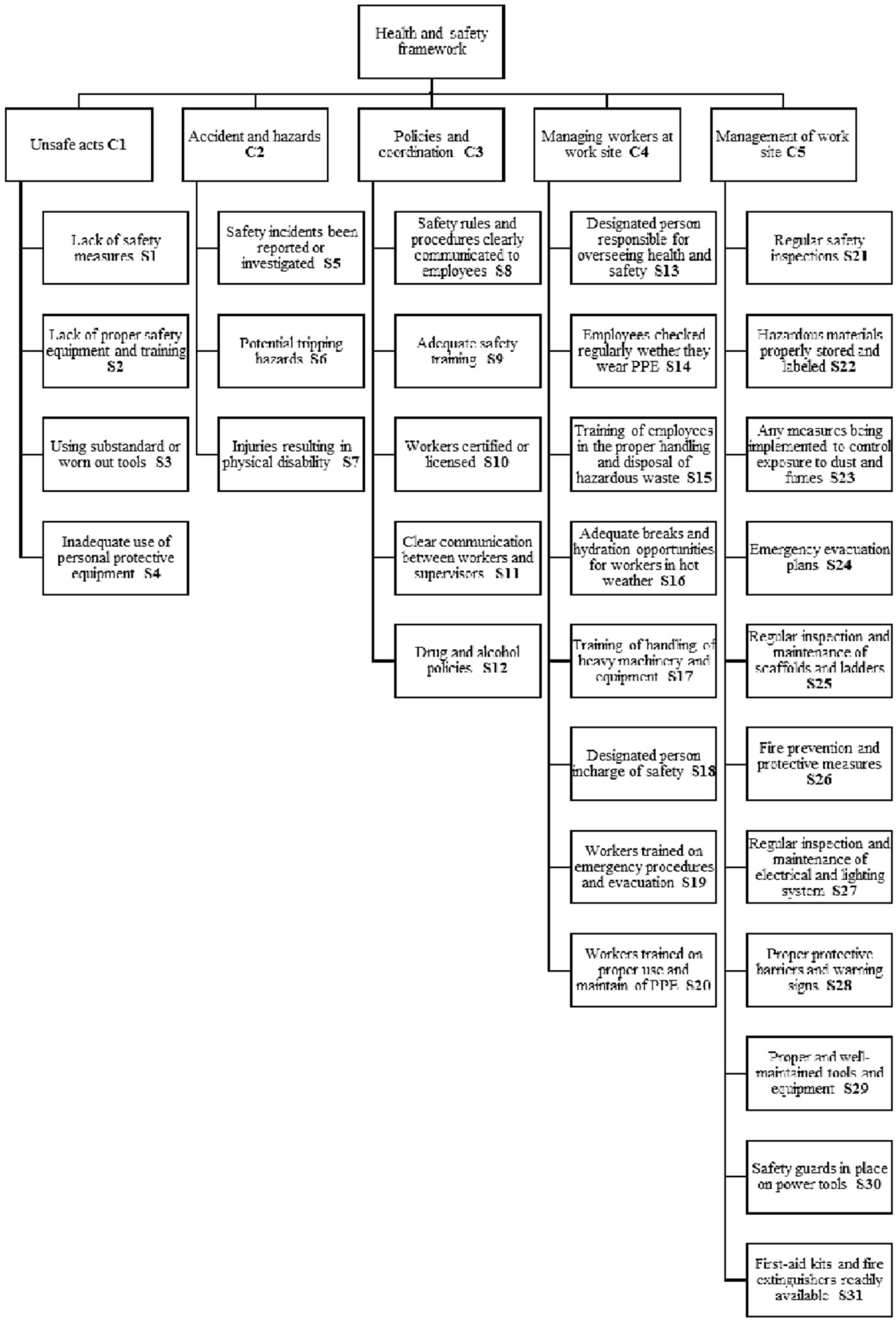

Fig. 3. Risk evaluation hierarchical strategy

According to the results, the factor that holds the highest importance in managing workers on the job site is regular examination of employees to ensure they are wearing personal protective equipment (PPE), as indicated with an RII value of 0.578. With RII values of (0.577) and (0.561), respectively, the proper management and disposal of hazardous waste and adequate breaks and hydration chances for workers in hot weather come in second and third place. High RII-valued variables must be given priority. The designated person in charge of safety had the lowest RII value (0.446).

Evaluating the results of work site management in construction projects served as the final and concluding goal. The five variables with the highest RII scores had a significant impact on construction projects, i.e., regular safety inspections (0.597), controls reducing exposure to dust and fumes (0.591), emergency evacuation plans (0.584), regular maintenance of scaffolds and ladders (0.583) and regular inspection of electrical systems (0.581). Most factors, such as safety guards on power tools, fire prevention and protection measures, have little influence on construction projects. Therefore, effective solutions must be implemented to deal with these issues.

The relative relevance scores of the five collected criteria were computed in Table 4 after gathering data from each sub-criterion for safety and well-being. According to the study, observing employees at work was the third most common cause of unsafe acts, with RII value of 0.520. It was followed by accidents and hazards and variables related to work site management (0.551), which were clearly at the top of the standings with a cumulative RII value of 0.529.

Unsafe Actions are placed second from the bottom of the list, with RII score 0.510, and Policy and Coordination is ranked fifth with a 0.477 RII value. The variables are classified according to their RII values, so the initial goal was to create a pairwise comparison matrix to ascertain the local weights of each variable.

Table 4. RII scores recorded for health and safety factors

Sr. #	Factors	RII	Rank
1.	Management of the work site	0.551	1
2.	Accidents and Hazards	0.529	3
3.	Managing workers at the work site	0.520	5
4.	Unsafe Acts	0.510	7
5.	Policies and Coordination	0.477	9

3.3 Pairwise comparison matrix

Saaty's scale for matrix was used to construct the pairwise comparison matrix. As a result, each component and sub-component obtained a unique weight, indicating that each factor and its precursors have varied degrees of impact on construction sites. A variable with the highest weight has a significant impact than others in a construction project.

3.4 Evaluating the consistency patterns

Typically, a consistency ratio of 10% or less is considered appropriate; however, specific situations can necessitate approving or tolerating a more significant figure.

The computation for the greatest eigenvalues of each condition and index is presented in Table 5.

The first two consistency evaluations were the CR and consistency index (CI), and their respective maximum eigenvalues were equal to the number of criteria relevant to each test (CR). The CI and CR findings for each component are displayed in Table 5.

Table 5. Computed values of maximum eigenvalues (ƛ max), consistency measure and consistency ratio

Criteria	C	C1 (Unsafe Acts)	C2 (Accidents and Hazards)	C3 (Policies and Coordination)	C4 (Managing Workers at the Work Site)	C5 (Management of Worksite)
ƛ max	4.53	6.311	9.312	6.77	8.970	17.106
CI	0.046	0.077	0.032	0.044	0.014	0.061
CR	0.044	0.085	0.054	0.039	0.009	0.035

The CI and CR for each of the variables are shown in table (11). According to Saaty (2012), for matrices larger than (4 × 4), the acceptable limit of CR is 0.01. The matrix investigation is deemed valid if the CR value is equal to or less than that sum. According to the claim, most of the variables in this study have CR scores that are less than 0.1, indicating that the analysed numbers are appropriate and that the next phase can be completed.

3.5 Fuzzy comprehensive evaluation method (Level 1)

The membership grade (Rij = n/N) and frequency-based technique were applied to generate the first-level fuzzy relation matrix R in the initial comprehensive assessment matrix. The fuzzy comprehensive evaluation approach is built on FCEM. FCEM closely monitors the evaluation parameters with the expert grading system and can produce results pertinent to the current circumstance. To create the membership matrix Bi, each factor of the fuzzy relation matrix "R" was multiplied by the local weight of each element as determined by AHP. In the Table 6, the set of fuzzy relations is displayed.

To assess the risk of hazardous activities, the membership grade algorithm produced the first-level fuzzy relation matrix (R – 1) and the first-level fuzzy comprehensive evaluation matrix (FCE-1). The next move can be made since the likelihood, in this case, is 1. This method was also used for calculating the remaining elements R = (R1, R2..., R5).

After establishing the first-level fuzzy relation matrix (R), the following computation were performed. (R – 1) was obtained by multiplying it by the local weight of the index layer of unsafe acts. (R – 2) was obtained by crossing with the local weight of index layer of the accidents and hazards, (R – 3) was gained by multiplying it with the local weight of index layer of policies and coordination. (R – 4) was computed by multiplying it by the local weight of index layer of managing the workers at the work site. (R – 5) was gained by multiplying it with the local weight of index layer of management of workers respectively. These calculations were performed using AHP to determine the first-level fuzzy comprehensive evaluation matrix (Bi).

Using a systematic assessment matrix (Bi-1) and the corresponding Likert scale values for yes (0.133), no (0.105) and maybe (0.031) values, the total values for dangerous acts were obtained. Similarly, the entire evaluation matrices for all five factors (Bi-1) to (Bi-5) were obtained.

A comprehensive evaluation matrix for accidents and risks, policies and coordination, managing personnel at the worksite and management of natural factors at worksite (Bi 2, Bi 3, Bi 4, and Bi 5) was created to calculate total values based on their respective Likert scale. The results are presented in Table 7.

Table 6. Fuzzy relation matrix (R–1)

Unsafe Acts	Yes	No	Maybe	Probability
1	0.55	0.35	0.11	1
2	0.58	0.36	0.07	1
3	0.49	0.52		1
4	0.39	0.62		1

Table 7. First level fuzzy comprehensive evaluation matrix (Bi-1 to Bi-5)

Criteria	Yes	No	Maybe
Unsafe Acts (Bi-1)	0.133	0.105	0.031
Accidents and Hazards (Bi-2)	0.236	0.281	0.040
Policies and Coordination (Bi-3)	0.096	0.099	0.037
Managing workers at the worksite (Bi-4)	0.067	0.055	0.009
Management of the work site (Bi-5)	0.035	0.052	0.010

3.6 Fuzzy comprehensive evaluation matrix (Level 2)

The local weight of the component is multiplied by the evaluation index R' to create a second-level fuzzy comprehensive evaluation matrix. The total assessment Bi represents the evaluation index R'. The assessment method uses the synthesis theory of fuzzy correlations to quantify variables with uncertain boundaries. The setting of multiple variables identifies the purpose. The results of the first-level fuzzy comprehensive evaluation matrix were: dangerous acts (Bi-1), accidents and hazards (Bi-2), policies and coordination (Bi-3), managing workers at the worksite (Bi-4) and management of the worksite (Bi-5). As a result, the second-level fuzzy relation matrix (R'), is created, as shown in Table 8.

The second-level fuzzy comprehensive evaluation matrix B was created by multiplying the local weight of the variables in the criteria layer, as determined by AHP, with the second-level fuzzy relation matrix (R'). The complete assessment matrix can be found in the Table 8.

After obtaining the second-level fuzzy comprehensive evaluation matrix (B), it is possible to calculate the hazard grade level of the attempt. Using the formula maximum membership grade bi0 = max bi (1 I m), it can be determined that the most significant value in the matrix (B) is 0.035. This suggests that the project risk is moderate and its occurrence could result in general damage. To ensure the successful completion of construction projects, it is crucial to implement specific risk management strategies or measures.

Table 8. Second level fuzzy relation matrix (R') and comprehensive evaluation matrix (B)

Criteria Index	Matrix (R')			Matrix (B)		
	Yes	No	Maybe	Yes	No	Maybe
Unsafe Acts	0.133	0.105	0.031	0.047	0.037	0.011
Accidents and Hazards	0.236	0.281	0.040	0.103	0.122	0.017
Policies and Coordination	0.096	0.099	0.037	0.008	0.009	0.003
Managing workers at the worksite	0.067	0.055	0.009	0.006	0.005	0.001
Management of the work site	0.035	0.052	0.010	0.002	0.002	0.001
B				0.033	0.035	0.006

3.7 Risk evaluation of health and safety framework

An assessment system is created to implement the procedure according to the previously stated approach and health and safety performance measurement structure. The assessment results are qualitatively categorized into five groups. The safety and health outcomes assessment set can be classified based on analysis result classifications as V = (v1, v2, v3, v4, v5). The five distinct assessment levels are represented. The centesimal worth of each element in the criteria layer and the health and safety structure in the primary objective layer is computed by multiplying the correlating variables evaluation grades "V" and the second-level fuzzy comprehensive evaluation matrix (R'), Table 8 after the hazard analysis set had been established.

C1= (0.133 x 30) + (0.105 x 60) + (0.031 x 90)
C1= 13.08
C2= (0.236 x 30) + (0.281 x 60) + (0.040 x 90)
C2= 25.14
C3= (0.096 x 30) + (0.099 x 60) + (0.037 x 90)
C3= 12.15
C4= (0.067 x 30) + (0.055 x 60) + (0.009 x 90)
C4= 6.12
C5= (0.035 x 30) + (0.052 x 60) + (0.010 x 90)
C5= 5.07

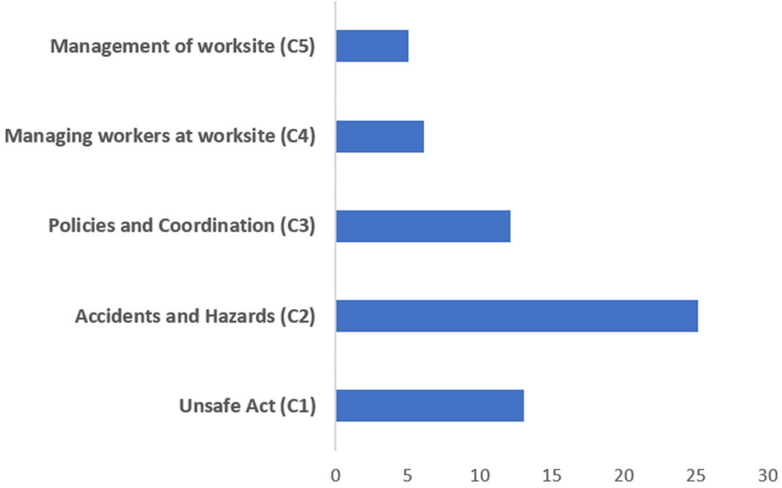

Fig. 4. Centesimal values of each criteria layer variable

Similarly, the building industry's centesimal measure of the health and safety structure (C) assessment was also computed to gauge the severe impact of the criteria layer's element.

Centesimal Value (C) = (0.033 x 30) + (0.035 x 60) + (0.007 x 90)

C = n.

Figure 4 displays the centesimal values of each criteria layer variable and the centesimal value of the objects denoted by (C).

The observed pattern is shown as follows:

Trend: C2 > C1 > C3 > C4 > C5 > C

In terms of centesimal value, C-1 is higher than C-3, C-4 and C-5, while C-2 is higher than most criteria layer variables. Among the criteria, the management of worksite "C-5" has the lowest centesimal value of 5.07, followed by managing workers at worksite "C-4" (6.12). Policies and management "C-3" (12.15), unsafe acts C-1 has a value of (13.08) and accident and hazards has the highest value (25.14). All these values exceed the centesimal value of the target layer (3.72), denoted by the letter C. It means that all of them significantly affect health and security in building construction initiatives. Therefore, it is crucial to give them more consideration in the well-being and security framework for construction projects in Pakistan.

4 CONCLUSION

The results of the study indicate that several adjustments are necessary to ensure the health and safety of workers on construction sites in Pakistan. The findings of the research have provided greater insight into the severe consequences of risk variables for health and safety in construction projects. The study has also identified several critical factors that occur frequently and have a significant impact on construction site safety. A health and safety framework for the construction industry has been developed through this research, which will enable project teams to more effectively assess project risk. Based on these findings, corrective measures can be implemented at the strategic and planning levels to strengthen and regulate these barriers.

5 LIMITATIONS AND FUTURE RECOMMENDATIONS

While significant progress has been made in understanding health and safety issues possible, it is important to acknowledge the limitations of the study. The use of AHP and FCE heavily relies on subjective input from experts. This reliance on human judgment introduces potential for bias in the decision-making process, despite attempts to mitigate it. The outcomes obtained through these methods may vary depending on the expertise and experience of the individuals involved in the process. Another limitation is that the models used in the study are static and do not account for changes in the construction site environment or the workforce over time, therefore, require continuous monitoring. Most incidents involved accidents and risks, along with risky staff behaviour. Multidimensional statistical analysis has not been used to systematically analyze the variables related to dangers and accidents [43]. The research does not assess the costs, benefits, and effectiveness of worker safety and health training efforts.

Following the study, a few recommendations for further research are provided. This structure was developed using the analytic hierarchy method. However, other multi-criteria decision-making techniques may also be employed, such as the game theory approach, the analytical network method and deep learning techniques. A thorough examination of similar systems would enable the construction of a more detailed and successful system. A practical action plan should be developed to implement the corrective activities at the strategic and planning levels of construction projects in Pakistan. The cost-effectiveness of these corrective activities in terms of their impact on the health and safety of workers and the overall success of the construction projects needs to be evaluated. Furthermore, a longitudinal study should be conducted to evaluate the long-term impact of the corrective activities on the safety culture and performance of construction projects in Pakistan.

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