Prioritizing Occupational Health and Safety Protocols in Pakistan's Construction Industry: A DEMATEL-Based Causal Analysis

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Construction continues to be one of the most dangerous industries for employment, especially in developing countries, where the lack of enforcement of occupational health and safety (OHS) regulations has helped to create frequent workplace accidents and occupational illnesses. Although the construction industry has a considerable role in the economic development of Pakistan, limited research on prioritizing the OHS protocols within the local context has been done. The purpose of this study is to find out critical issues of OHS that affect construction projects in Pakistan and to examine their relationship using decision making trial and evaluation laboratory (DEMATEL) approach. A thorough literature review was conducted to determine possible safety factors and then further confirmed by discussions with knowledgeable construction professionals. A structured questionnaire was used for collecting data from the engineers and project managers working with the contractors registered with Pakistan Engineering Council (PEC), out of which 160 valid questionnaires were obtained. The internal consistency (Cronbach's alpha) is 0.836 and the agreement among experts (Kendall's W= 0.188 and χ^2 = 79.211, df = 9, and p< 0.001) was used to verify the reliability and consistency of the data collected and then to establish the causal relationship between the factors identified by applying the DEMATEL technique. The results suggest that the main driving (cause) factors for the occupational health and safety performance are eight-hour work shift, permanent and temporary workforce management and overall safety management practices. The highest prominence (7.163) and strongest net causal influence (1.6234) is for "Eight-hour work shift", followed by permanent/temporary workforce management. Social welfare, PPE, child labor, compliance with the minimum wage, employee insurance, inclusion of persons with disabilities, first aid facilities are all in the effect group and are largely dependent upon improvements in the driving factors. The results confirm that enhancing management and organizational safety approaches can lead to multiple safety outcomes in the downstream system. The study adds value to the existing construction safety literature by developing a prioritized decision support system for OHS management in Pakistan. The results provide lessons for contractors, project managers, and policy makers who can use them to make better decisions about how limited resources can be used more efficiently to ensure safer, more sustainable construction and support the national development agenda.

Keywords: Occupational health and safety; Construction industry; DEMATEL; Pakistan; Sustainable construction; Safety management.

Introduction:

The construction sector is a major contributor to the global growth, infrastructure, and jobs. It is a significant component of the national gross domestic product (GDP) and helps to develop transportation systems, residential and commercial structures, and public infrastructure. Despite its economic importance, construction is one of the most dangerous industries due to the changing nature of the site, the use of heavy machinery, the temporary nature of worksites, and the use of both skilled and unskilled labour**.** As such, construction workers are often subjected to occupational risks which lead to injuries, illnesses, disabilities, and deaths [1][2][3].

In recent years, the emphasis on occupational health and safety (OHS) has grown. Not only because governments and regulatory agencies are aware that protecting employees is essential, but also because construction companies are putting increasing focus on improving workplace safety to ensure greater productivity, better project performance and greater organizational sustainability. Properly managed safety lowers costs associated with accidents, decreases project delays, boosts employee morale and can be a factor in sustainable economic growth. Thus, safe working environments directly contribute to the United Nations Sustainable Development Goals (SDGs) such as SDG 3 (Good Health and Well-being), SDG 8 (Decent Work and Economic Growth) and SDG 11 (Sustainable Cities and Communities).

Though much has been done to improve the safety of the construction industry in many developed countries by enacting strict regulations, conducting regular training on construction safety and implementing enforcement measures, in developing countries, construction accidents happen at an excessive rate. However, poor compliance with the standards of occupational safety, lack of adequate safety culture, insufficient worker training, and limited regulatory enforcement are significant problems in these countries [4][5][6]. With construction activities growing, it is imperative to enhance the occupational health and safety standards to ensure sustainable infrastructure development in developing economies.

The construction industry is one of the most important sectors in Pakistan's economy, providing jobs and contributing to the country's infrastructure development. In recent years the sector has grown significantly as a result of increased investment by the public and private sectors in housing, transport and industrial development. This quick development has not, however, led to corresponding improvements in OHS practices. Many construction sites face safety problems that are due to poor compliance of safety regulations, lack of personal protective equipment, lack of safety training, lack of adequate welfare facilities, or poor institutional practices controlling safety. Consequently, construction workers continue to be at high risk of accidents and occupational injuries at the workplace [3][5].

Table 1. Injuries statistics (Percentage) in Major Industries.

S. No	Major Industry	2018-19	2019-20
1	Agriculture	38.6%	29.3%
2	Manufacturing	16.2%	19.1%
3	Construction	21.5%	19.7%

Looking at the statistics presented in Table 1, it can be seen that the construction industry in Pakistan has a higher proportion of occupational injury reporting compared to the agricultural sector, although the sector employs a smaller percentage of the national workforce. All the above findings highlight the importance of systematic identification and prioritization of the health and safety factors which most significantly affect construction site performance. Prioritizing is critical for helping policy makers, contractors, and project managers make the best use of available resources and take proactive safety measures instead of taking a reactive approach after an accident.

Research into construction safety has gained more focus in the last 20 years, focusing on the causes of construction accidents and the effectiveness of measures to make the

workplace safer. In the context of construction safety performance, several factors have been identified in the previous works such as management commitment, safety culture, worker competency, risk assessment, training, personal protective equipment (PPE), welfare facilities and regulatory compliance [7][8]. Some recent research also indicates that a proactive approach to safety management systems and organizational commitment are more effective in accident prevention than reactive systems after an accident has occurred [9][10].

The integrated and proactive approach to construction safety has become the focal point of the latest construction-safety research instead of single compliance approaches. According to the latest reviews [11][12][13], hazard recognition, safety climate, management commitment, worker participation, training effectiveness, and organizational learning are interrelated factors that contribute to the success of construction site safety. The new paradigm of safety – called Safety-II – supplements the traditional accident prevention paradigm by considering how the organization functions successfully in changing site conditions [13]. In addition, recent studies suggest that the success of occupational health and safety training goes beyond mere training delivery to the workplace support and supervision given to the trainees, and their ability to apply the knowledge and skills they have gained in their work [14]. The developments show the importance of considering OHS protocols as an interconnected management system and not safety protocols on their own.

There are several decision-support methods that have been used to assess the safety of construction. A variety of multi-criteria decision-making (MCDM) approaches, including the Analytic Hierarchy Process (AHP), the Interpretive Structural Modelling (ISM), the Best-Worst Method (BWM), and DEMATEL are used to prioritize the safety related factors and to assist managerial decision making [1][2]. Of these, the DEMATEL technique is very useful not only for ranking the most important critical factors but also for determining the causal relationships and the mutual influences between the factors, allowing decision makers to distinguish between driving factors and dependent factors. This information is crucial for designing programs to improve safety and to allocate resources effectively.

Recent applications have further demonstrated the suitability of DEMATEL for analyzing interconnected construction-safety problems. [15] integrated Fuzzy Delphi, Fuzzy DEMATEL, and RANCOM to assess the root causes of construction accidents. Their analysis identified safety policies, safety culture, supervision, regulatory enforcement, equipment expertise, and PPE use as critical interconnected factors. This application demonstrates how DEMATEL can move beyond simple factor ranking by revealing the direction and strength of causal relationships within a complex construction-safety system.

While construction safety in developed countries has garnered significant research interest, the studies addressing construction safety in developing economies are still limited, particularly in Pakistan. Previous studies in Pakistan focused on the factors causing accidents, awareness of safety, safety climate and occupational health and safety performance [16][3][6]. Although these studies have contributed to understanding the safety issues in the industry, most have focused on one safety concern at a time and have limited knowledge on how multiple occupational health and safety protocols relate to each other. However, in situations with limited financial and managerial resources, construction companies may be challenged as to which safety measures to prioritize.

In addition to accident prevention, occupational health and safety in construction also covers other areas. The proper setting of working hours, the social welfare of the workers, the safeguarding of employees' insurance, the prevention of child labor, the observance of the minimum wage, the inclusion of people with disabilities, and the provision of proper medical first aid facilities all have an impact on the overall welfare of workers and the project's performance. But these have not been studied together in one analytical framework using the context of Pakistan's construction industry.

This study aims to overcome these limitations by using the DEMATEL approach for developing a list of critical occupational health and safety protocols, prioritizing them, and looking at the causal relationships between them. The study clearly identifies the driving and dependent factors and offers a well-structured decision-supportive framework for the implementation of more effective safety management strategies and improvement of the performance of occupational health and safety in the construction sector of Pakistan by contractors, project managers, and policy makers.

Although numerous studies have been conducted on construction safety, there are still some key areas of unmet research needs. Most current research has concentrated on one aspect of worker safety, including: causes of accidents, safety climate, adherence to PPE, and worker behavior, without looking at how the various worker safety protocols relate to one another. However, when resources are limited, construction managers typically do not have a systematic process to select which safety measures should be emphasized.

Second, while a range of multi-criteria decision-making approaches has been used to evaluate construction safety, few studies have explored the causal relationships between OHS protocols in the context of the construction industry in Pakistan. It is important to understand these interactions as the improvement in one safety practice can impact several other aspects of occupational health and safety, directly or indirectly. Thus, understanding what factors fuel greater improvements can help decision makers to design more successful and cost-effective safety plans.

In order to overcome these gaps, this study utilizes the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to understand the causal relationships among the various important occupational health and safety protocols that can be used in Pakistan's construction sector. DEMATEL is different from the traditional ranking methods because it not only determines the relative importance of the factors, but also their influence on each other, which allows the factors to be classified into cause/effect groups. This will offer a more holistic view of safety management priorities and assist in evidence-based decision making.

Research Objectives:

For this reason, the objectives of this study are:

To conduct a detailed literature review and expert consultation to identify important Occupational Health and Safety protocols which impact construction projects in Pakistan.

Using the DEMATEL approach, analyze the causal relations between these protocols.

Rank order was used to identify protocols by influence in the occupational health and safety system (3).

Give realistic suggestions to contractors, project managers and policymakers to improve the occupational health and safety standards in the construction industry in Pakistan.

This study has three major contributions. It offers a thorough assessment of occupational health and safety measures applicable to the construction industry in Pakistan, instead of just tackling one particular aspect of safety. Second, it shows that the DEMATEL method is applicable for establishing causal relationships between the occupational health and safety factors, which can help to prioritize safety interventions more effectively. Lastly, the results offer a practical framework for decision support, which will help construction organizations and regulatory bodies enhance their safety performance, boost the well-being of workers, and promote sustainable construction practices.

Literature Review:

Construction Safety Management:

The ever-changing work environment, temporary worksites, heavy machinery and the inherent nature of the industry and its working practices make construction one of the most dangerous industries in the world. Accordingly, a successful delivery of construction projects has come to rely on effective occupational health and safety (OHS) management. There have

been previous studies which showed that five factors, namely management commitment, safety culture, worker competence, risk assessment, and continuous safety training are important factors to reduce workplace accidents and enhance overall project performance [4][7][2].

Organizations that implement a proactive approach to safety management have been found to perform better than organizations that primarily take measures to correct safety failures once they have happened. Continuous monitoring, regular safety inspections, employee participation and a commitment of leadership are keys to building a positive safety culture and achieving long-term OSH improvements [6][8]. However, their adoption is still problematic in many developing countries, mainly because of financial constraints, lack of enforcement of the regulations, and poor level of safety awareness.

Table 2. Major causes of construction accidents reported in previous studies.

Authors	Country	Analysis	Sample size	Critical factors identified
[17]	China	GRA	571	Delayed elimination of hazard, lack of adequate safety inspection, lack of professional safety engineers, non-compliance of worker, lack of safety awareness, safety engineers' fault, inadequate safety training, and serve work onsite condition.
[18]	South Korea	Correlation, Chi-square	675	Lack of manger's safety consciousness, lack of education about safety, insufficient construction period
[19]	Ghana	Descriptive and Inferential Statistics Analysis,	634	Distal factors (work structure, trade specialization, working hours, job/task location, and monthly off days), proximal factors (age, sex of worker, and income)
[20]	Malaysia	Descriptive analysis	129	Unsafe methods, the unique nature of industry and job site conditions, work at high elevation, incorrect or no work procedure and failure of structure.
[21]	Ethiopia	Descriptive Statistics Analysis, bivariate and multivariate logistic regressions analysis	355	Without Personal Protective Equipment, lack of training, and working overtime
[22]	Oman	Descriptive analysis	40	Poor instruction by the supervisor, lack of training, lack of workers' awareness, lack of maintenance of equipment and underestimating dangers by workers

[23]	Bangladesh	Descriptive analysis	90	site unprotected against falling, high noise level, no personal safety, fatigue, no personal safety,
[24]	Iran	Regression Analysis	500	Individual and organizational factors, Health and safety training factors and risk management system factors
[25]	Hong Kong	Fisher's exact test and latent class analysis (LCA)		Ill planning, violation, hidden hazards created by others, and incapable staffing.
[26]	India	Descriptive analysis	220	Poor management of workforce, improper working conditions, tools, and working methods.
[27]	Australia	Chi-Square Analysis	24,764	Age, experience, gender and language background and work environment variables such as organization size, project size and location, mechanism of accident, and body location of the injury
[28]	USA	Chi-Square Analysis	300	Lack of proper training
[29]	Spain	Descriptive analysis	1,630,452	Age, type of contract, time of accident, length of service in the company, company size, day of the week,
[30]	Taiwan	Support–Confidence framework	309	Weather conditions and seasonal variation
[31]	UK	Factor analysis	126	Organizational policy, supervision and equipment management, industry norms, risk taking, management behavior

Major causes of construction accidents identified in various countries are summarized in Table 2. The factors that cause occupational accidents are reported to differ by geographical region, but insufficient safety management, insufficient training, poor supervision, and failure to comply with safety regulations are always reported as the most influential factors. The results reveal the necessity of an overall safety management system which considers both organizational and human aspects rather than safety issues.

Occupational Health and Safety Protocols in Construction:

The safety and health issues in a construction organization do not just relate to the prevention of accidents but also the practices that are related to the organization, society and welfare that have a direct effect on the health, productivity and performance of the project. Effective safety management has been demonstrated to involve a combination of administrative controls, regulatory compliance, worker protection measures, and supportive workplace policies, not just one intervention [8][3][9].

Effective safety management is one of the basic elements of occupational health and safety; it establishes the organizational infrastructure for the identification and assessment of hazards, supervision, safety training and compliance with regulations. The positive safety culture that is promoted through a strong safety management system leads to **a** reduction in

accidents at work and improves project performance, while also boosting communication between the project stakeholders and encouraging the adoption of proactive risk control [2][6]. Likewise, the nature or structure of the workforce and working hours affect the physical and mental health of workers. Longer working hours and fatigue have been linked to lower concentration and productivity, higher risk of accidents, whereas good management of permanent and temporary workers leads to better safety compliance and operational efficiency [32][33].

Labour standards and the provision of sufficient welfare facilities are also significant in the protection of workers. However, one of the best ways to minimize occupational injuries is by using personal protective equipment (PPE), as long as suitable personal protective equipment is available, workers are adequately trained on its use and compliance is constantly monitored [34]. Furthermore, social welfare, employee insurance, and minimum wage compliance boost worker motivation and job satisfaction, and enhance organizational commitment and financial and social safety against occupational hazards [35][36].

There are also social and ethical responsibilities that affect the construction safety. Addressing child labor and encouraging the inclusion of persons with disabilities are key to meeting national labor law and international best practice requirements and creating a fair and inclusive workplace [37][38]. In addition, having sufficient first aid facilities and trained staff members **allow** a quick response in case of an emergency, minimizing the seriousness of work injuries and ensuring preparedness of the workplace [39].

All of these occupational health and safety measures form a combined safety management system where enhancements to one aspect of the system can affect another. Consequently, a multi-level assessment of the protocols, rather than an independent one, gives a more complete picture of the occupational health and safety performance, and aids in better prioritizing the interventions needed for a building project.

Multi-Criteria Decision-Making Methods in Construction Safety:

Due to the complexity of construction safety, researchers have used multi-criteria decision making (MCDM) techniques to assess safety-related factors and assist the management's decision-making. In contrast to traditional statistical techniques, MCDM methods allow for the consideration of several qualitative and quantitative criteria, and they are especially well suited to studies related to occupational health and safety because many of these factors are interrelated, and affect the overall level of safety performance [1].

In the field of building safety studies, several MCDM techniques have been used. A large number of studies have been conducted on the use of Analytic Hierarchy Process (AHP) to prioritize safety risks and assess safety performance by expert judgment. In the same way, the Best-Worst Method (BWM) and Analytic Network Process (ANP) are used to identify the relative importance of safety criteria and interpretive structural modelling (ISM) is used to determine the hierarchical relationship among safety factors, respectively [2]. These techniques offer useful decision support but mainly rank or hierarchize and have little indication of the interactions between the safety factors.

A great advantage of the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method is that it can establish both the intensity and the direction of the relationships between the factors at the same time. It differentiates cause and effect factors and enables the decision makers to determine which of these factors are the most significant drivers of the entire occupational health and safety system. Therefore, DEMATEL can offer a better perception of complex safety problems and develop intervention strategies instead of single corrective measures [2].

Occupational health and safety protocols in construction are inherently interrelated, so analyzing them separately cannot be a reliable indicator of the impact of the various protocols on the safety of the workplace. For this reason, the DEMATEL approach was

chosen for this study, as it allows the identification of causal relationships between the OH&S protocols, and assists in the prioritization of interventions that may lead to the greatest overall improvement in the performance of construction safety. The ability of DEMATEL makes it an ideal tool for supporting the evidence-based decision-making process in Pakistan's construction industry where financial, technical, and regulatory resources are scarce.

Research Novelty:

Past construction-safety research primarily has focused on a single topic, such as the causes of accidents, safety climate, personal protective equipment, worker behavior or regulatory compliance. Likewise, those applications of MCDM in construction have largely involved the ranking of individual safety risks or technical aspects of the project. While the use of DEMATEL has branched out to various construction problems, such as accident causation, building defects and project risks, but little attention has been given to the causal interrelationships among a comprehensive set of protocols related to occupational health, safety, labour and worker-welfare in the construction industry of Pakistan.

The novelty of this study is that it combines 10 OHS protocols such as working hours, permanent and temporary workforce management, employee insurance, minimum-wage compliance, prevention of child labour, personal protective equipment, first-aid facilities, social welfare, inclusion of persons with disabilities, and overall safety management in a single cause-and-effect context. The DEMATEL analysis not only lists these protocols by priority but also those protocols that are underlying drivers and those protocols which are foremost dependent factors. This systems approach allows decision makers to look for interventions that can bring about improvements in multiple interdependent aspects of worker safety and welfare.

Moreover, the study offers context-specific empirical data based on construction professionals dealing with the contractor organizations enlisted in the Pakistan Engineering Council. Hence, it applies DEMATEL not only to existing technical and project-risk situations, but also to integrated OHS management in the context of building in developing countries. The prioritization framework that is generated is useful for contractors, project managers, and regulatory agencies to distribute limited safety resources to the protocols most likely to have the maximum systemic effect.

Material and Methods:

The study used a quantitative research approach to identify and prioritize the occupational health and safety (OHS) protocols in construction industry in Pakistan. The research process involved five stages: (i) extensive literature review for identifying OHS protocols, (ii) expert consultation to validate the identified protocols, (iii) design and collection of questionnaires, (iv) reliability test of the collected data, and (v) causal analysis and prioritization of the protocols through the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. The overall research method used in this study is shown in Figure 1.

Identification of Occupational Health and Safety Protocols:

A thorough literature review on construction safety, occupational health, labour welfare, accident prevention and safety management was conducted to develop an initial pool of occupational health and safety procedures. Research on construction practice in Pakistan and similar developing country environments received special focus to make sure that the construction protocols reflected the local construction industry operational and regulatory environment.

This initial pool was pre-screened in two rounds. First, protocols with similar meanings were merged, redundant items were eliminated and statements which were vague, overlapping or not relevant to construction OHS management were not included. Secondly, the selected protocols were considered by eight experts, who included project managers, site engineers, safety officers, and academics with knowledge and experience in construction safety.

For each protocol, four retention criteria were included during the expert review: relevance to occupational health and safety in construction, applicability to construction projects in Pakistan, clarity and avoidance of ambiguity, and suitability to assessing causal influence as per the DEMATEL method. The protocols were kept when the experts felt that they were relevant, well-defined, and applicable in practice, as well as different from the other protocols. The items that were left out, combined with other conceptually similar items, or modified after the expert discussion were those for which multiple interpretations occurred.

Ten protocols were retained in this screening and consensus process: compliance with minimum wages, management of permanent and temporary workers, employee insurance, prevention of child labour, 8-hour work shifts, first-aid facilities, personal protective equipment, safety management practices, social welfare and inclusion of persons with disabilities. These protocols were then used to develop the questionnaire and to build the DEMATEL pairwise-influence matrix.

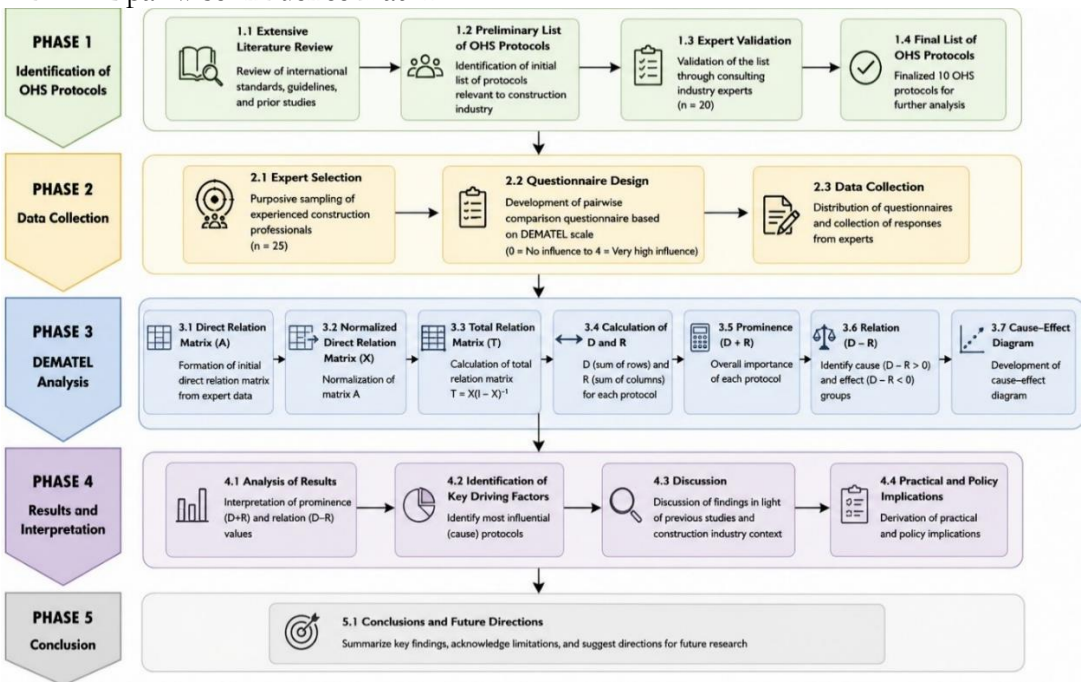


Figure 1. Research methodology adopted in this study.

Questionnaire Design and Data Collection: The ten OHS protocols were identified and subjected to expert screening to develop a structured questionnaire for collecting pairwise influence judgements for the DEMATEL analysis. The questionnaire consisted of two parts. The first section gathered general demographic and professional data of the respondents such as job designation, educational qualification, professional experience, and type of organization. In section 2, the ten protocols were shown in a pairwise matrix, and they were evaluated according to the DEMATEL linguistic scale, ranging from 0 = no influence to 4 = very high influence, on the degree to which each protocol influenced every other protocol.

The draft questionnaire was expertly validated and piloted before being fully distributed. The instrument was reviewed by eight experts, comprising project managers, site engineers, safety officers, and academics with experience in construction and occupational safety. Content validity was qualitatively assessed by determining whether the questionnaire adequately covered the OHS dimensions of literature. The experts also judged the relevance of the items for the construction industry in Pakistan, clarity of the items, elimination of redundancies and applicability in pairwise comparison using DEMATEL.

To determine the face validity, experts were asked regarding the understandability of the instructions, protocol definitions, influence scale, and pairwise-comparison format and

whether they elicited the desired judgements. According to their responses, the wordings of the overlapping terminology were consolidated, ambiguous statements were reworded, and the definitions of the protocols and response scale were clarified. The revised questionnaire was then reviewed again to ensure that the items were relevant, different, and comprehensible before full-scale administration.

The target population of this study included engineers, project managers, construction managers, safety officers and other technical professionals of the Contractor Organisations registered with Pakistan Engineering Council. To make sure that the respondents had relevant knowledge and practical experience in construction-safety management, purposive sampling was used. Of the 200 questionnaires, 160 were completed and returned and were usable and valid, and the effective response rate was 80%.

Face and content validity were mainly confirmed in the pilot stage. Finally, the statistical reliability was evaluated using the full valid set of data since there was no pilot set of data large enough for **a** reliable estimate of internal consistency. Internal consistency was tested with Cronbach's alpha and agreement among respondents was tested by Kendall's coefficient of concordance. These tests were carried out prior to the building of the DEMATEL matrices and interpretation.

Reliability and Data Validation:

The responses were first analyzed for their reliability and consistency before conducting the DEMATEL analysis in order to ensure that the set of responses is of good quality. The internal consistency of the questionnaire was determined by Cronbach's alpha, as shown in Table 3 below, which is one of the most popular internal consistency measures of Likert-scale instruments. Cronbach's alpha values exceeding 0.70 were generally regarded as being acceptable for reliability and values exceeding 0.80 were regarded as a good level of internal consistency [40][41].

Kendall's coefficient of concordance (W) was also used to measure the level of agreement between the experts involved. The suitability of Kendall's W has been noted: When the judgments of experts are being studied, then Kendall's W is particularly suitable since it is used to measure the consistency of judgements across several respondents. A statistically significant coefficient implies that the respondents agree satisfactorily and this leads to the conclusion of the reliability of the opinions that were collected from the experts as shown in table 4

The calculated reliability statistics showed that the questionnaire had acceptable internal consistency and had an acceptable degree of agreement among the respondents. Thus, the data gathered were deemed appropriate for further causal analysis on the DEMATEL method.

Table 3. Reliability analysis of the questionnaire.

Cronbach's Alpha	Number of OHS Protocols (factors)	Number of respondents
.836	10	160

Table 4. Kendall's coefficient of concordance.

N	100
Kendall's Wa	0.188
Chi-Square	79.211
Df	9
P-value.	0.0001

DEMATEL Method:

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was employed to analyze the complex interrelationships among the identified occupational health

and safety protocols. Originally developed by the Battelle Memorial Institute, DEMATEL has been widely applied in engineering and management research to investigate causal relationships within complex systems [42]. Unlike conventional ranking techniques, DEMATEL identifies both the magnitude and direction of influence among factors, enabling their classification into cause-and-effect groups.

There are different Multi-Criteria Decision-Making (MCDM) methods such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Interpretive Structure Modelling (ISM) and Best Worst Method. However, DEMATEL was selected because the study aim was to determine the direct causal influence between the different protocols, which is not possible through AHP, ANP, and BWM. Moreover, ISM relies on binary judgements, which were not applicable.

The implementation of the DEMATEL method in this study consisted of the following steps:

Step 1: Construction of the initial direct-relation matrix based on expert evaluations.

Step 2: Normalization of the direct-relation matrix.

Step 3: Development of the total-relation matrix by incorporating both direct and indirect relationships.

Step 4: Calculation of the prominence ((D+R)) and relation ((D-R)) values for each occupational health and safety protocol.

Step 5: Classification of the protocols into cause-and-effect groups based on the calculated relation values.

The mathematical formulations used to perform these calculations are presented in Equations (1) – (7).

$$f_{ij} = \frac{1}{R}\sum_{k=1}^{R} x_{ik} \quad (1)$$

$$D_{ij} = \begin{bmatrix} 0 & \cdots & \frac{f_1}{f_n} \\ \vdots & \ddots & \vdots \\ \frac{f_n}{f_1} & \cdots & 0 \end{bmatrix} = \begin{bmatrix} 0 & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & 0 \end{bmatrix} \quad (2)$$

$$\eta = \frac{1}{max_i(\sum_{j=1}^{n} D_{ij})} \quad (3)$$

$$N = \eta D \quad (4)$$

$$T = N\,(I - N)^{-1} \quad (5)$$

$$R_i = \sum_{j=1}^{n} t_{ij} \quad (6)$$

$$C_j = \sum_{i=1}^{n} t_{ij} \quad (7)$$

Where n denotes the number of OHS protocols (n=10), R is the number of respondents, which in this case is 160, x_{ik} is respondents raw score, f_{ij} shows each respondent pairwise influence score into single value per protocol pair, and η is normalized factor. T is the total relation matrix, R_i is the row sum of T for protocol i, and C_j is column sum of T for protocol j.

The value of (D + R) gives an overall measurement of the prominence of each protocol in the occupational health and safety system, reflecting the total amount of interaction with other factors. On the other hand, the value of (D − R) provides information about the net effect of each protocol. If the values are positive, they represent cause factors which impact other protocols; if negative, they represent effect factors which are strongly impacted by other factors.

These occupational health and safety prominence and relation values give a systematic basis for prioritizing the occupational health and safety protocols and the critical driving factors which should be given priority by construction managers and construction policymakers.

Results and Discussion:

Reliability and Agreement Analysis:

Before the DEMATEL analysis, the reliability and consistency of the responses gathered were checked. Internal consistency of the questionnaire was checked by Cronbach's alpha and the extent of agreement between the experts was evaluated by Kendall's coefficient of concordance.

The results of the reliability analysis are shown in Table 5, which showed a good internal consistency for the questionnaire. Likewise, Kendall's coefficient showed a high level of agreement among the respondents that was statistically significant, thus indicating the necessary consistency between the experts' evaluations for subsequent causal analysis.

Table 5. Reliability and agreement analysis.

N	100
Kendall's Wa	0.188
Chi-Square	79.211
Df	9
P-value.	0.0001

These findings confirm that the collected data are reliable and appropriate for analyzing the causal relationships among occupational health and safety protocols using the DEMATEL method.

DEMATEL Analysis of Occupational Health and Safety Protocols:

The consistency of expert judgments and reliability of the questionnaire were checked, after which the DEMATEL procedure was used to explore the causal relationships between the ten occupational health and safety protocols. The analysis was carried out using the standard DEMATEL procedure, starting from the construction of the initial **direct-relation** matrix, the normalization of the matrix, the calculation of the total relation matrix and the calculation of the prominence and relation values.

Table 6. Initial Direct-Relation Matrix

	MW	PTW	EI	CL	EHS	FAB	PPE	SA	SW	SP
MW	0.000	0.823	1.011	0.979	0.754	1.057	0.949	0.939	0.946	1.037
PTW	1.215	0.000	1.228	1.189	0.916	1.284	1.153	1.141	1.149	1.260
EI	0.989	0.814	0.000	0.968	0.746	1.045	0.939	0.929	0.936	1.026
CL	1.022	0.841	1.033	0.000	0.770	1.080	0.969	0.960	0.966	1.059
EHS	1.326	1.091	1.341	1.298	0.000	1.402	1.259	1.246	1.254	1.375
FAB	0.946	0.779	0.957	0.926	0.714	0.000	0.898	0.889	0.895	0.981
PPE	1.054	0.867	1.065	1.032	0.795	1.114	0.000	0.990	0.997	1.093
SA	1.065	0.876	1.076	1.042	0.803	1.125	1.010	0.000	1.007	1.104
SW	1.057	0.870	1.069	1.035	0.797	1.117	1.003	0.993	0.000	1.097
SP	0.964	0.794	0.975	0.944	0.727	1.019	0.915	0.906	0.912	0.000

The responses obtained from the experts were aggregated to construct the initial direct-relation matrix, which represents the direct influence of each protocol on the others as shown in Table 6

The initial matrix was normalized to remove scale differences and ensure numerical stability during subsequent calculations presented in Table 7

Table 7. Normalized Direct-Relation Matrix

	MW	**PTW**	**EI**	**CL**	**EHS**	**FAB**	**PPE**	**SA**	**SW**	**SP**
MW	0.000	0.071	0.087	0.084	0.065	0.091	0.082	0.081	0.082	0.089
PTW	0.105	0.000	0.106	0.103	0.079	0.111	0.099	0.098	0.099	0.109
EI	0.085	0.070	0.000	0.084	0.064	0.090	0.081	0.080	0.081	0.089
CL	0.088	0.073	0.089	0.000	0.066	0.093	0.084	0.083	0.083	0.091

EHS	0.114	0.094	0.116	0.112	0.000	0.121	0.109	0.107	0.108	0.119
FAB	0.082	0.067	0.083	0.080	0.062	0.000	0.077	0.077	0.077	0.085
PPE	0.091	0.075	0.092	0.089	0.069	0.096	0.000	0.085	0.086	0.094
SA	0.092	0.076	0.093	0.090	0.069	0.097	0.087	0.000	0.087	0.095
SW	0.091	0.075	0.092	0.089	0.069	0.096	0.087	0.086	0.000	0.095
SP	0.083	0.068	0.084	0.081	0.063	0.088	0.079	0.078	0.079	0.000

Based on the normalized matrix, the total relation matrix was computed to capture both the direct and indirect influences among the occupational health and safety protocols.

Table 8. Total Relation Matrix

	MW	**PTW**	**EI**	**CL**	**EHS**	**FAB**	**PPE**	**SA**	**SW**	**SP**
MW	0.276	0.292	0.359	0.348	0.268	0.375	0.337	0.334	0.336	0.368
PTW	0.432	0.276	0.436	0.422	0.325	0.456	0.410	0.405	0.408	0.448
EI	0.351	0.289	0.276	0.344	0.265	0.371	0.333	0.330	0.332	0.364
CL	0.363	0.299	0.367	0.276	0.274	0.383	0.344	0.341	0.343	0.376
EHS	0.471	0.388	0.476	0.461	0.276	0.498	0.447	0.442	0.445	0.489
FAB	0.336	0.277	0.340	0.329	0.253	0.276	0.319	0.316	0.318	0.349
PPE	0.374	0.308	0.378	0.366	0.282	0.396	0.276	0.352	0.354	0.388
SA	0.378	0.311	0.382	0.370	0.285	0.400	0.359	0.276	0.358	0.392
SW	0.376	0.309	0.380	0.368	0.283	0.397	0.356	0.353	0.276	0.389
SP	0.342	0.282	0.346	0.335	0.258	0.362	0.325	0.322	0.324	0.276

To evaluate the robustness of the DEMATEL results, a threshold sensitivity analysis was conducted using the total-relation matrix presented in Table 8. The mean value of all elements in the matrix was 0.3508, with a standard deviation of 0.0568. Five threshold scenarios were examined: $\mu - 0.50\sigma$, $\mu - 0.25\sigma$, μ, $\mu + 0.25\sigma$, and $\mu + 0.50\sigma$. Only relationships with influence values equal to or greater than the specified threshold were retained in each scenario.

Table 9. Threshold Sensitivity Analysis of the DEMATEL Relationships

Sensitivity scenario	**Threshold value**	**Retained relationships**	**Prominence ranking**	**Cause–effect classification**
$\mu - 0.50\sigma$	0.3224	70	Unchanged	Unchanged
$\mu - 0.25\sigma$	0.3366	59	Unchanged	Unchanged
μ	0.3508	49	Unchanged	Unchanged
$\mu + 0.25\sigma$	0.3650	38	Unchanged	Unchanged
$\mu + 0.50\sigma$	0.3792	26	Unchanged	Unchanged

The number of the relationships that remained across the threshold progression dropped from 70 at the least restrictive threshold to 26 at the most restrictive threshold (see Table 9). This reduction reflects the fact that weaker inter-protocol relationships were progressively dropped and the strongest causal relationships were still discernible. The number of relationships (shown) that were affected by the threshold had no impact on the ranking order of the relationships in the cause–effect network, or on the cause–effect classification of the relationships (which was determined using the total-relation matrix without thresholds), since these values were computed first.

In all five threshold scenarios the eight-hour work shift, permanent and temporary workforce management and safety management practices stayed in the cause group, and the other seven protocols stayed in the effect group. The stability of these classifications by the more restrictive thresholds confirms the robustness of the main causal interpretation of the DEMATEL results.

Using the total relation matrix, the prominence (D+R) and relation (D−R) values were calculated for each protocol. These values were subsequently used to classify the protocols into cause-and-effect groups and determine their relative importance.

Table 10. Prominence (D+R), Relation (D−R), Ranking, and Cause–Effect Classification of Occupational Health and Safety Protocols

Factors	Ri	Di	Ri + Di	Rank	Ri – Di	Rank
Minimum wage	3.292935	3.698889	6.991824	6	-0.40595	7
Permanent and Temporary Workers	4.018171	3.030163	7.048334	2	0.988009	2
Employee Insurance	3.256673	3.739958	6.99663	5	-0.48328	8
Child Labor	3.365458	3.619346	6.984804	7	-0.25389	6
Eight-Hour Shift	4.392877	2.76963	7.162507	1	1.623247	1
First Aid Box	3.111625	3.913566	7.025191	3	-0.80194	10
Personnel Protective Equipment (PPE)	3.474244	3.506118	6.980362	9	-0.03187	5
Safety Aspects	3.510506	3.469901	6.980407	8	0.040605	3
Social Welfare	3.486331	3.493964	6.980295	10	-0.00763	4
Special People (Handicapped)	3.172062	3.839347	7.011408	4	-0.66728	9

The DEMATEL analysis was performed to determine the prominence and causal relationships among the identified occupational health and safety (OHS) protocols. The calculated values of prominence (D + R) indicate the overall importance of each protocol within the OHS system, whereas the relation (D − R) values distinguish the protocols into cause-and-effect groups. The complete DEMATEL results are presented in Table 10.

The analysis identified a cause group consisting of eight-hour work shifts, workforce composition (permanent and temporary workers) and safety management, which have a high influence on other occupational health and safety practices. Social welfare, personal protective equipment (PPE), child labour, minimum wage compliance, employee insurance, inclusion of persons with disabilities, and first aid facilities were regarded as effect factors because they are likely to be affected by the strengthening of the driving factors mentioned above.

In all identified protocols, eight-hour work shifts had the greatest causal influence in the system. It is a well-recognized fact that overworking can cause fatigue, reduce concentration, and decrease compliance with safety procedures in workers. This can have a positive effect on several other safety related practices and as such improving the scheduling of work and adherence to standard working hours should have a positive impact. These results are consistent with previous studies that found that working long hours leads to fatigue and leads to a higher risk of work accidents and lowers general safety performance.

Additionally, from the results it was found that safety management was one of the main driving factors. The organizational basis of hazard identification, risk assessment, worker training, supervision and compliance with regulations is provided by effective safety management. Thus, enhancing safety management capability can help enhance various downstream safety outcomes such as PPE compliance, emergency preparedness, and worker welfare. The phenomenon observed here aligns with the existing literature that highlights the importance of management commitment as a key factor in determining construction safety performance.

The same applies to the management of permanent and temporary workers, which proved to be an influential protocol within the causal group. Temporary workers are a common part of the construction industry in Pakistan, and they are often not as well-trained or supervised in safety measures as permanent workers. So, the application of uniform safety

policies, frequent safety training and equal access to safety resources for all construction site workers can improve overall occupational health and safety outcomes.

The protocols such as PPE, first aid facilities, employee insurance, payment of minimum wages, social welfare, child labor prevention were all classified as effect factors. The protocols are still important for protecting the workers, but the study shows that the effectiveness of their implementation is highly reliant on organizational commitment, appropriate supervision and an effective safety management system. Thus, the root causes are more likely to result in broad and more permanent change than are individual corrective steps.

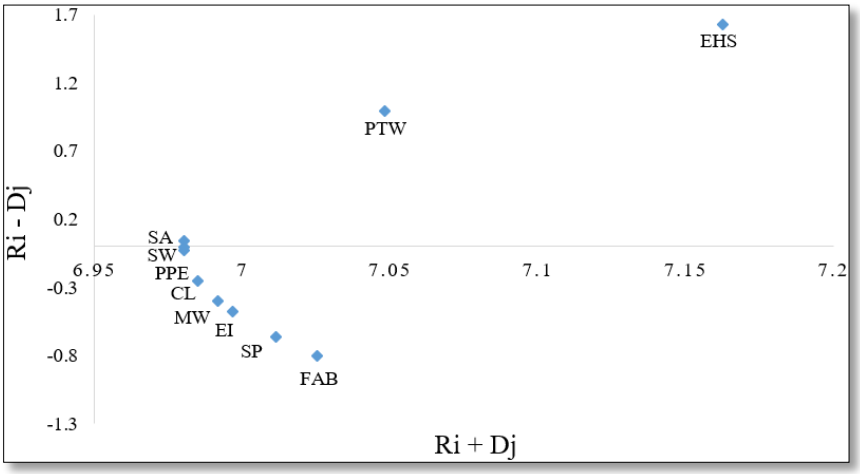


Figure 2. Cause–effect relationship among occupational health and safety protocols obtained through DEMATEL.

The interrelationships between the different occupational health and safety measures are illustrated in the cause–effect diagram shown in Figure 2. The protocols that are in the positive part of the relation axis are primarily influencing the overall safety system, while those in the negative part are mainly influenced by improvement in the driving factors. The diagram clearly shows that improvements in organizational and managerial practices can have a cascading effect on improvements in a range of occupational health and safety outcomes, which can aid in the more effective use of scarce safety resources.

Discussion:

The findings of this study show that organization and management have more influence than individual safety measures to enhance the performance of occupational health and safety (OHS) in the construction industry of Pakistan. The DEMATEL analysis identified workforce composition, safety management, and eight-hour work shifts as the most prominent driving factors because an improvement in them would likely have a positive impact on several OHS protocols. This finding is consistent with the systems perspective of construction safety, in which the conditions for the behaviours and regulatory compliance of workers and for safety performance are established through organizational decisions.

To help to situate the findings in the international construction-safety literature, Table 11 compares the driving and dependent OHS factors identified in this study with the most significant results found in some earlier studies.

Table 11. Comparison of the Present Findings with Previous International Studies

Study and context	Method and focus	Principal findings	Agreement with the present study	Difference from the present study
[7]	Questionnaire and factor analysis of	Management support was the most influential factor; worker	Supports the classification of safety	Working hours, workforce employment

	construction safety programmes	involvement, safety control, safety arrangements, and management commitment were critical dimensions.	management as a driving factor.	status, and broader welfare protocols were not examined.
[43]	Structural-equation modelling of temporary construction workers' safety behaviour	Organizational conditions, safety climate, and individual factors influenced temporary workers' safety behaviour.	Supports the importance of managing permanent and temporary workers as a driving factor.	Focused on workers' safety behaviour rather than causal relationships among OHS, labour, and welfare protocols.
[2]	Fuzzy Delphi and DEMATEL analysis of construction safety-programme factors	Safety commitment, personnel selection, safety professionals, safety planning, and employee involvement were identified as influential factors.	Strongly agrees that safety management and workforce-related decisions drive wider safety outcomes.	Did not identify working hours as the strongest driver and did not include minimum wage, insurance, child labour, or disability inclusion.
[32]	Review of heat exposure and occupational injuries	Fatigue, heat exposure, and physically demanding work conditions reduce attention and increase injury risk.	Provides support for controlling working duration and fatigue through an eight-hour work shift.	Examined occupational injury mechanisms rather than the systemic cause–effect structure of construction OHS protocols.
[14]	Empirical analysis of OHS training-transfer intentions among construction workers	Organizational support and the work environment influence whether workers apply acquired OHS knowledge and skills.	Supports the driving role of organizational safety management in improving downstream worker practices.	Concentrated on training-transfer intention rather than labour welfare, regulatory compliance, and cause–effect classification.
[13]	Review of Safety-I and Safety-II research in construction	Contemporary construction safety increasingly emphasizes organizational learning, system resilience, and proactive safety management.	Supports the present study's systems-based interpretation of OHS management.	Provides a conceptual synthesis and does not rank or classify individual OHS protocols into cause-and-effect groups.

Present study, Pakistan	DEMATEL analysis of ten integrated OHS protocols	Eight-hour work shift, permanent and temporary workforce management, and safety management practices were identified as driving factors; the remaining seven protocols were classified as dependent factors.	Confirms the international emphasis on management, workforce organization, fatigue control, and systemic safety improvement.	Extends previous work by integrating worker protection, labour compliance, and social-welfare protocols within one causal framework for Pakistan.

The comparison reveals that there is significant overall consensus on the importance of organizational and managerial factors to construction-safety performance. The consistency of the results from the studies conducted in Thailand, South Korea, Malaysia and Australia **is** that management commitment, the organization of the workforce, the supervision, the safety climate and organizational support affect workers' safety practices and safety outcomes in general. This evidence is expanded in the present findings, in which eight-hour work shifts, permanent and temporary workforce management, and safety management practices are identified as the key factors within the Pakistani construction context.

The major difference from the work done previously is that most studies have concentrated on the traditional safety-programme components, the behavior of the workers, training or accident prevention. They did not often combine the elements of compliance to labour and worker welfare – minimum wage, employee insurance, child-labour prevention, social welfare, first-aid facilities and the inclusion of persons with disabilities – into one analysis. Their classification as dependent factors do not mean that these are not important, but rather that the level of strength and consistency in which they are implemented is significantly dependent on the underlying managerial and workforce related factors.

The most important driving factor identified was working hours. In Pakistan, construction sites frequently have strict deadlines and limited resources, which can lead to long working hours and fatigue among workers. Fatigue leads to poor concentration, increased human error and poor adherence to safety practices, thereby increasing the risk of workplace accidents. The same findings have been suggested by other studies **that** have found that long working hours and physically demanding working conditions are significant risk factors for work injuries. The results indicated that adherence to the standard working hours should be considered not only as a requirement for labour welfare but also as an essential part of safety management in construction.

The results also suggest that safety management is an important organizational factor that impacts on the success of other OHS practices. To ensure safety is managed effectively, hazards are identified, safety checks are made on a regular basis, regular employee training and education is conducted and regulatory requirements are met. Organizations that have well developed safety management systems are therefore more likely to have high compliance for the use of PPE, emergency preparedness and worker welfare programs. This finding is in line with previous studies, which have identified management commitment as one of the most influential factors affecting construction safety.

The other key finding relates to the effect of the composition of the workforce, including the way in which permanent and temporary workers are managed. Temporary workers are commonly hired for construction sites in Pakistan, and are often inadequately trained on safety procedures and lack consistent oversight. The status of employment can lead to disparities in safety practices and exposure to occupational risk. Promoting consistent safety

practices, regular induction training and equal access to safety resources for all workers can then help to improve the overall safety performance of the project.

Protocols related to personal protective equipment (PPE), first aid facilities, employee insurance, minimum wage compliance, social welfare, child labour prevention, and inclusion of persons with disabilities, were considered effect factors. While these protocols still play a crucial role in occupational health and safety practices, the results suggest that their effective application requires strong organizational engagement and good health and safety management. So, organizations need to focus on improvements in the driving factors that were identified, because these will likely result in more widespread and lasting improvements across the occupational health and safety system.

The results also have significant implications for financial and managerial constraint construction organizations. Contractors should not allocate the same number of resources to each safety activity, but should focus resources on the factors identified. This should ensure that the limited available resources are used to their greatest effect and compliance with multiple occupational health and safety requirements will be achieved. This systems-based prioritization technique could help construction companies minimize accidents, boost employees' health and safety, boost project productivity, and boost their company's long-term success.

In general, the results of this study illustrate that workplace health and safety should not be perceived as a set of individual safety measures, but as an integrated management system. Knowing the cause-and-effect relationships between safety measures can be used to design more strategic and evidence-based interventions that will help tackle the root causes of poor safety performance, rather than just addressing individual safety issues.

Critical Interpretation of Differences from Previous Studies:

The findings showed that organizational safety management is important, but with different extent as the 8-hour work shift is the most dominant one while international studies emphasized management commitment, supervision and safety planning. The disparity could be attributed to the labor-intensive nature of the construction industry in Pakistan, which often involves long working hours and deadlines that can lead to fatigue, less focus and poor adherence to safety protocols. Likewise, the significance of permanent and project/temporary workforce management could stem from the high number of temporary and project workers that are utilized, which may not be consistent in training, supervision, provision of PPE or welfare provision.

The following factors were considered as effect factors: PPE, First-aid facilities, Employee insurance, Minimum wage compliance, social welfare, Child-labour prevention, Disability inclusion, all of which are dependent on the implementation through organizational commitment, governance of the workforce and the allocation of resources. But this doesn't imply that the protocols are not important, it means that they are more influenced by the underlying managerial factors. Some differences with other studies can also be due to differences in the national context, criteria used, the target groups and methods of analysis. So, the present findings are causal rather than ranking relationships.

Practical Implications:

The results of this research will lead contractors, project managers, safety practitioners and construction companies in Pakistan towards implementing effective measures to enhance the occupational health and safety (OHS) performance in the construction industry. The study describes causal relationships between important OHS protocols, allowing decision-makers to focus on implementing interventions that lead to the highest overall improvements in the safety of the workplace, and not on implementing individual safety measures.

DEMATEL analysis revealed a total of eight driving factors in the occupational health and safety system, which included the eight-hour work shift, workforce composition and

safety management. Based on this discovery, it is recommended that construction organizations pay more attention and invest more in these areas as improvement of these protocols will likely improve the effectiveness of several dependent safety measures. Ensuring proper working hours, for instance, helps to decrease worker fatigue, increase focus and lessen the risk of human error, which in turn brings about safer construction sites and greater project productivity.

Likewise, enhancing organizational safety management must be taken up as a strategic matter instead of just a regulatory obligation. Construction companies should implement comprehensive safety management systems, which will include regular hazard identification, regular safety inspections, toolbox meetings, ongoing safety training and monitoring of safety compliance. The senior management's leadership in having a positive attitude to safety, engaging workers and embedding safety within project planning and delivery is also essential in developing a good safety culture.

The results also emphasize the significance of handling the permanent as well as the temporary employees well. Employers need to make sure induction, training, supervision and provision of PPE for all workers (permanent and casual) are the same when carrying out construction work. Standardized safety procedures can help minimize variability of work practice and enhance compliance to the overall OHS requirements.

While protocols like personal protective equipment (PPE), first aid facilities, employee insurance, minimum wage compliance, social welfare, child labor prevention and inclusion of persons with disabilities were considered effect factors, they are still very much a part of a comprehensive occupational health and safety system. The results indicate that with strong organizational leadership and good safety management, areas that need improvement are more likely to be sustainable. So, rather than safety programs being tackled as stand-alone projects, organizations should take a holistic view, incorporating managerial commitments along with worker protection programs.

The proposed prioritization framework can also help contractors to make better investment decisions, especially under resource constraints. Decision makers do not necessarily need to allocate safety budgets evenly across all safety activities, but rather the first step should be prioritizing those driving factors that make the greatest impact on the overall occupational health and safety system. It is expected that the allocation of resources by this evidence-based approach will result in better safety performance, lower costs of the accidents, lower project delay and more productivity for the organization.

The three driving factors identified by DEMATEL should be the starting point for implementation. The first step is to limit the hours worked through duty rosters and attendance records (relatively low resources), which is a step that should be taken by contractors. The next step is equipping permanent and temporary workers with equal induction, training, supervision and PPE, which will require medium levels of investment in training, equipment and safety personnel. The resources for a qualified safety staff, inspections, documentation, and corrective actions will be relatively greater in establishing a formal safety-management system. Progress should be tracked monthly in the following ways: overtime record; training attended; PPE compliance; incident rate; safety audit results; and closure of corrective actions.

Overall, the prioritization framework developed in this study offers a practical decision support tool to construction organizations that wish to improve their occupational health and safety performance by proactively planning, efficiently allocating resources and systematically implementing safety management practices.

Policy Implications:

The results of this study have implications for the policymakers or regulatory bodies working on the improvement of occupational health and safety (OHS) in the construction

industry of Pakistan. Finding causal relationships between OHS protocols creates a scientific basis for developing policies that will focus on interventions that create the most workplace improvements.

The results show that working hours, workforce management and organizational safety management are the main drivers for the overall OHS system. As such, it is recommended that the regulatory bodies enforce current labour laws regarding working hours, work safety and worker welfare. To ensure compliance with the national occupational health and safety regulations, regular inspections, periodic safety audits and effective monitoring mechanisms should be put in place, especially for medium and large-scale construction projects.

The findings also indicate that institutional support for safety management in construction industry needs to be strengthened. There is a significant role that can be played by Pakistan Engineering Council (PEC), and relevant government departments to promote standardized safety management practices, update construction safety guidelines and encourage contractors to implement internationally recognized occupational health and safety management systems. The mandatory safety training and certification programs for engineers, site supervisors, and safety officers would further enhance the competency of professionals and promote a culture of safety within the industry.

In Pakistan, where many workers in the construction industry are employed on a temporary or contract basis, it would be beneficial to implement policies that guarantee all workers – temporary and contractual – equal access to safety training, personal protective equipment, medical care, and welfare. This would help to decrease the variety of workplace security issues which would assist in attaining workplace safety guidelines throughout construction projects.

The study also highlights the need to bolster labor welfare policies by ensuring good compliance with minimum wages, employee insurance policies, child labor laws and medical preparedness for emergencies. The identified dependent variables in the DEMATEL framework are still of paramount importance to ensure workers' rights are protected and to enhance the overall occupational health and safety performance if they are implemented successfully. So, rather than having these considered as individual compliance obligations, regulatory agencies should incorporate these within a broader national construction safety strategy.

Medium and large size construction projects should be the priority for regulatory bodies and the minimum requirements need to be compliance with working hours, worker status, safety training, provision of PPE, insurance, wages compliance, and welfare facilities. The Pakistan Engineering Council (PEC) and concerned labour departments should keep a check on compliance by conducting periodic inspections, quarterly compliance reports, and annual inspections based on the performances of contractors. This requires moderate administrative resources including auditors, audit checklists, and a simple reporting system, and can then be expanded to smaller contractors based on available administrative capacity.

The prioritization framework that was designed in this study can also help the policymakers to allocate financial and administrative resources more effectively. Implementation of OH and S measures can be targeted to maximize benefits and can include consideration of the identified driving factors as a way of improving the safety, productivity and sustainability of the construction industry. Such an evidence-based approach can help reduce workplace accidents, improve worker well-being, and improve performance and competitiveness of the construction industry in Pakistan in the long term.

Limitations: The findings of this study have important implications for the prioritization of occupational health and safety (OHS) protocols in the construction industry of Pakistan; however, certain limitations are noted.

The study was conducted based on the expert opinion gathered from construction industry professionals in Pakistan, which is in itself a strength. Although the respondents had the relevant industry knowledge and experience, their views do not necessarily reflect the experiences and practices of other countries and regions that have various regulatory environments and construction practices. So, the findings cannot be extrapolated to other situations outside the Pakistani construction industry.

Second, the DEMATEL analysis was applied to data from a single point in time, cross-sectional data. Occupational health and safety procedures can shift with time as construction safety procedures and regulations evolve. Further understanding of the temporal nature of these relationships and assessment of long-term effectiveness of safety interventions could come from a longitudinal study.

Furthermore, the relationship matrix is built from pairwise score of the respondents. The results are sensitive to each expert's individual perception, professional background, and possible common method bias. The reliability analysis cannot eliminate systematic different views of certain groups.

Finally, this study concentrated on the identification and analysis of causal relationships between selected occupational health and safety policies. These protocols were developed using a comprehensive literature search and tested and accepted by industry specialists, however other protocols could also affect OH&S performance including organizational culture, technology uptake, project complexity and economic factors. The inclusion of these factors may be able to give a more accurate view of the construction safety management.

Lastly, the DEMATEL method was used to analyze the interactions of OH&S protocols. Future research can benefit from complementing DEMATEL with other multi-criteria decision-making techniques and/or quantitative risk assessment methods, as this can bring further insights and enhance the decision-making process.

The limitations notwithstanding, the study offers a systematic and evidence-based framework to prioritize OHS protocol in the construction industry in Pakistan. The results are informative and can serve as a reference for future research and give practical suggestions for developing the occupational health and safety management of construction.

Future Research:

The study establishes a basis for further research on occupational health and safety (OHS) management in construction industry. Based on the current results, several research directions can be developed to further improve the understanding of the complexity of the relationship between OH and S.

First, the proposed prioritization framework may be validated in future studies by data from other developed and developing countries. Comparative analyses in different regulatory, economic and cultural settings would allow determining if the causal relationships could be considered to be generalizable or if there are context specific factors that influence construction safety performance.

Second, future research can be conducted using the DEMATEL method along with other multi-criteria decision making (MCDM) techniques like Analytic Network Process (ANP), Best–Worst Method (BWM) and Decision-Making Trial and Evaluation Laboratory-based Analytic Network Process (DEMATEL–ANP). Hybrid decision making approaches can be used to provide a more general evaluation of hazards and risks in the area of occupational health and safety (OHS), using a causal analysis and a factor weighting and prioritization.

Third, digital technologies are penetrating the construction sector, creating opportunities for improving construction safety. Investigations into the incorporation of Building Information Modelling (BIM), Internet of Things (IoT) technologies, wearable safety

devices, artificial intelligence, and real-time monitoring systems into occupational health and safety management can be explored in future studies. These techniques may help to make predictive risk assessments, continuous security screening, and timely decisions about construction sites.

Lastly, more research is needed using longitudinal study designs to assess the long-term impact of safety interventions. A long-term tracking of the construction projects would yield useful data to understand the effect of the enhancements of the identified driving factors on accident reduction, worker health, and organization performance. Such research would also support the evidence base of the built environment sector for creating sustainable OH and S approaches.

All these research directions will help to further develop occupational health and safety management and further develop safer, more resilient and more sustainable construction practices in developing economies such as Pakistan.

Conclusion:

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach was adopted to identify the most critical occupational health and safety (OHS) protocols in the construction industry in Pakistan based on a causal relationship between the ten most important safety factors. The results showed that, eight-hour work shift, workforce management and safety management are the major driving factors which significantly affect the overall OHS system. In contrast, dependent factors like personal protective equipment, first aid institutions, employees' insurance, minimum wage compliance, social welfare, child labour prevention, inclusion of persons with disability, etc. were identified whose effectiveness is more related to improvement in the driving factors.

In the study, construction safety management is illustrated as a whole management system instead of a single intervention. The suggested prioritization framework allows construction firms to pinpoint the most impactful safety measures, make the best use of resources, and improve their occupational health and safety strategies. Additionally, the results offer valuable recommendations for policymakers and regulatory bodies to enhance safety standards and foster a proactive safety culture in the Pakistani construction sector.

The overall contribution of this research is that it is one of the first attempts to use DEMATEL in construction safety management and contributes to the systemization of the understanding of the inter-relationships between OHS protocols. It is hoped that the proposed framework will aid in evidence-based decision making and enable safer and sustainable construction practices in Pakistan.

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