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# Human Factors and Risk Analysis in Conventional System of Marble Mining: Using HFACS Framework and Structural Equation Modeling Technique

Saira Sherin*, Salim Raza, Sajjad Hussain, Zahid Ur Rehman
University of Engineering and Technology, Peshawar
***Corresponding Author:** sairasherin@uetpeshawar.edu.pk

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Accidents in mines can occur due to sources of hazards that lead to the loss of hundreds of precious lives every year. Among these sources, human error is considered one of the significant sources that contribute to human errors causing accidents. In this study, different risk factors were analyzed that contribute to human errors and subsequent accidents in the conventional marble mining system. Data was collected from marble mine workers through a questionnaire based on the Human Factors and Classification System framework. Structural equation modeling was applied to examine the interaction between contributory factors that trace back to mine accidents. Two structural models were developed, showing good fit for indices with chi-square to the degree of freedom values of 2.967 and 2.095, respectively, and root mean square error of approximation value below 0.08. The results indicate that the risks caused by individuals or systems have considerable effects on human performance and safety. The findings further explore that safety management at the managerial and supervisory levels is mostly associated with systematic risks, influencing safety policies, procedures, and oversight mechanisms. However, risk caused by lack of PPE, improper machinery, and lack of training has a direct effect on workers, leading to unsafe activities. These risk factors significantly contribute to the development of unsafe conditions that increase the probability and potential severity of accidents. For improving unsafe conditions, the implementation of mechanization can effectively decrease reliance on workers, thereby minimizing human errors and ultimately enhancing safety. The findings of this study will be helpful for the assessment the surface mines safety in a better way.

**Keywords:** Human Errors, Self-Inflicted Risks, Systematic Risks, HFACS, Mine Accidents, SEM.

**Introduction:**

The mining industry has been acknowledged for its inherent complexity and hazardous environment that affects safety, productivity, and overall operating performance. [1][2]. Among these factors, human-related issues are identified as significant contributors to incidents, accidents, and inefficiencies within the industry. [2][3]. Despite advancements in technology, human factors continue to pose significant challenges, alongside physical hazards, especially in mines that are not fully mechanized [4][5]. The prevalence of low mechanization in developing countries, driven by the low cost of labor, leads to greater reliance on workers and an increased likelihood of errors [6]. Human error is a major contributor to accidents, yet both the error and its underlying causes are often overlooked in risk assessments, despite their potential for serious consequences [7]. Therefore, thorough analysis and assessment of anthropological factors are necessary to improve operational effectiveness and reduce the probability of human errors in the workplace [8].

To address the critical safety concerns in mines with limited automation, researchers and safety experts have emphasized human factors analysis, along with other hazards and risks to understand the root causes of accidents and incidents [9][10]. Human elements, including the study of human behaviors, decision-making processes, and interactions within complex systems, are recognized as key contributors to safety outcomes in various industries [11]. Identifying factors influencing human error is crucial for safety management and accident reduction. Various models for the identification and evaluation of human errors have been developed but the most common is the Human Factors and Classification System (HFACS) by Shappell and Weigmann based on the Swiss Cheese Model [12]. Originally developed for aviation accidents, HFACS has been adapted for various fields, including maritime, medical, rail accidents, and mining, and consists of four hierarchical levels, including unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences [12][13][14][15][16][17][18].

In the complex environment of mining, focusing solely on identifying and analyzing factors related to human errors is inadequate [19]. It is essential to understand the specific interrelationships among the factors that contribute to human errors, which in turn lead to a higher frequency of accidents [20]. In some cases, it is not the individual factors themselves that are mainly responsible, but rather the interactions between these factors that exacerbate the situation [21]. Thus, a thorough understanding of these relationships and their combined effects within the system is essential. To analyze the impact of these factors, various methods such as Human Error Assessment and Reduction Technique (HEART), Structural Equation Modeling (SEM), Hierarchical Linear Modeling (HLM), and Bayesian Network Analysis (BNA) are used [3][22][23][24]. Among these, Structural Equation Modeling is a commonly utilized method for analyzing relationships among factors and is characterized by its ability to test both direct and indirect effects within hypothesized causal relationships [17]. This approach proves particularly advantageous for testing variables, as the model is assessed for the overall fit by using a range of fit indexes including chi-square ($\chi^2$), the degrees of freedom ratio ($\chi^2/df$), and the Root Mean Square Error of Approximation (RMSEA) [25][26][27]. SEM is widely applied across various industries including the mining sector, to study interactions between operational factors, safety measures, and environmental impacts, aiding process optimization and sustainability, which highlights its extensive value for insights and decision-making across various fields [22][28][29].

In developing countries such as Pakistan, marble mining is carried out using the conventional blasting method [30]. Common hazards in these traditional mining systems include falling rocks, landslides, steep slopes, and blasting-related hazards, which frequently lead to injuries and fatalities [31]. Therefore, this research considered a more comprehensive understanding of the risks associated with individual and system-based factors, that contribute to human errors and consequently lead to accidents in mines with inadequate mechanized processes [32][33]. This study employed the HFACS framework, SEM technique, and risk factors that contribute to human errors to evaluate the causes of frequent accidents. In the current study, SEM method is applied for the analysis of the relationship between the risk factors and the HFACS framework to effectively investigate the origins of human error and further, for the evaluation of the HFACS framework and accident factors to investigate the deficiencies at different levels of the HFACS framework that are responsible for accident causation [7], [34]. The objective of this research is to identify risk factors and causes of workers' unsafe behaviors in mining accidents using the HFACS framework and SEM. The findings offer practical insights for preventing accidents and enhancing mine safety management. They will help safety professionals and organizations develop targeted interventions that address the root causes of human error, reduce unsafe acts, and prevent accidents. Moreover, the research will inform the development of more effective safety protocols and policies, ultimately enhancing both worker safety and operational efficiency in the mining sector.

**Material and Methods:**

This study analyzed data obtained from workers of marble mines, focusing on the risks that lead to human errors and the factors influencing accidents in mining operations. The methodology followed in the study is given in Figure 1.

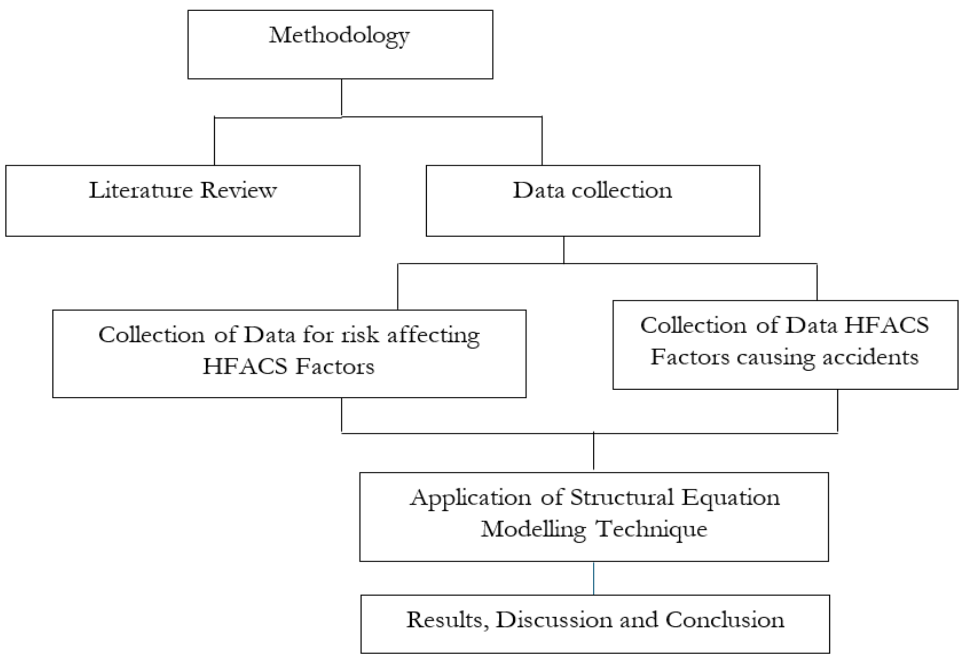


**Figure 1.** Methodology of the research

**Data Collection:**

Data collection was conducted using questionnaires distributed to workers in marble mines employing conventional mining methods in Buner, Khyber Pakhtunkhwa, Pakistan. A questionnaire structured on HFACS framework was developed to gather worker's perceptions, as detailed in Appendix-A. The first section addressed the risks contributing to human errors, while the second section focused on the human errors that lead to accidents. In the first section, risks identified as root causes for human errors were categorized into two groups: one related to systematic risks, including observed variables such as lack of safety culture, inadequate mechanized procedure, and enforcement gaps; and another related to self-inflicted risks, encompassing observed variables like lack of Personal Protective Equipment (PPE), improper machinery, and lack of training [2][9][33][35]. In the second section, accidents experienced by workers and their coworkers were classified into five observed variables such as near-miss accidents and injuries resulting in less than three days off work, three to seven days off, eight to twenty days off, and more than twenty days off. Table 1 explains HFACS factors cited in this research. Prior to conducting the interviews, the survey's purpose was explained to the workers, informed consent was secured, and then data was collected from 318 workers through questionnaires. A 5-point Likert scale was used in the questionnaire, continuing from 1 for strongly disagree to 5 for strongly agree.

**Table 1.** HFACS factors with explanation in the context of marble mine

| Factor | Sub-Factors | Code | Explanation with example |
|---|---|---|---|
| **Unsafe Act** | Decision Error | UA_11 | Failure to determine the risk with the situation. e.g., Failure to assess machinery risks near a high wall led to a rockfall injury. |
| | Skill-based Error | UA_12 | Human error due to lack of attention. e.g., Slip from the top or on same ground. |
| | Perceptual Error | UA_13 | Misjudged the risk of the situation. e.g., misjudging the rock stability and continuing drilling caused the accident. |
| | Routine Violations | UA_14 | Often breaking rules because they seem routine. E.g., Lack of PPE Use. |
| | Exception Violations | UA_15 | Procedure deviations in unusual circumstances. E.g., Taking a steep slope to save time while ignoring the risks. |
| **Pre-Condition** | Personal Readiness | PC_21 | Individuals inadequately prepare themselves physically or mentally for their responsibilities. E.g., Skipping rest breaks due to unavoidable circumstances led to errors and unsafe conditions. |
| | Crew Resource Management | PC_22 | Ineffective coordination. E.g., Poor team coordination during blasting caused timing and placement errors, resulting in a hazardous rockfall. |
| | Adverse Mental State | PC_23 | Mental and Physical Stress e.g., Stress, fatigue, and cognitive overload affect judgment and performance. |
| | Adverse physiological state | PC_24 | Unfavorable Physical conditions e.g., Extended work shifts without adequate rest affecting performance. |
| | Physical/ Mental Limitation | PC_25 | Circumstances affecting task performance. E.g., Long shift fatigue reduced the driller's strength and coordination, causing imprecise drilling. |
| | Physical Environment | PC_26 | Unfavorable working conditions. E.g., high noise level, uneven roads, extreme temperature etc. |
| | Technical Environment | PC_27 | Factors affecting the worker's performance. e.g., Using traditional drilling and blasting methods caused excessive rock fragmentation. |
| **Unsafe Supervisory** | Inadequate Supervision | US_31 | Inadequate oversight or enforcement of safety protocols. E.g., conducting infrequent site inspections and missing critical safety hazards and risks. |
| | Planned Inappropriate Operation | US_32 | Planning unsafe activities. E.g., extended shifts without breaks. |
| | Failed to Correct Problem | US_33 | Fail to remove hazards. E.g., Failing to clear loose rocks raises accident risk. |

| Factor | Sub-Factors | Code | Explanation with example |
|---|---|---|---|
| | Supervisory Violations | US_34 | Ignoring rules or permitting unsafe practices. E.g., Permit trucks to be overloaded beyond safety limits. |
| **Organization influence** | Resource Management | OI_41 | Inadequate staffing, training, and budget. E.g., Limited funds lead to outdated safety equipment, reducing safety. |
| | Organizational Climate | OI_42 | Lack of proper policies and procedures. E.g., Outdated procedures overlook new risks, leaving hazards unresolved. |
| | Operational Process | OI_43 | Lack of updated procedures. E.g., Using outdated machinery and procedures causes inefficiencies and safety hazards. |

**Data Analysis:**

Collected data through questionnaire was screened and verified for analysis by using SPSS software v. 24 [27]. The evaluation of questionnaire reliability yielded a Cronbach's alpha coefficient of 0.843 and 0.893 for sections 1 and 2 respectively, which signifies data consistency [29]. Prior to employing SEM, exploratory factor analysis was carried out to determine the suitable number of factors and their appropriate indicators. All factors had loadings exceeding the acceptable threshold of 0.5, indicating strong relationships between the items and their respective constructs and demonstrating strong convergent validity [22][27]. Table 2 and Table 3 provide evidence of factors with commonalities above 0.5 level, and factors of the pattern matrix exhibiting one-dimensionality, with each sub-factor producing a considerable contribution to its estimated factor, with Cronbach alpha values above 0.9 [22][36].

To achieve the objectives of the study, three hypotheses were initially formulated, and subsequently, two structural models were developed to ascertain the impact of the factors and validate the hypotheses. For assessing the influence of the factors, SEM was applied, using SPSS AMOS software v. 23. SEM, a powerful multivariate regression technique, allows for the simultaneous testing of multiple regression equations, making it ideal for uncovering complex relationships between variables. In addition, SEM considerably facilitates the estimation and testing of causal sequences involving theoretical constructs rather than measured variables.

**Hypotheses:**

- **H1:** It is hypothesized that all the factors of the HFACS are significantly affected by the exogenous variables of systematic risks and self-inflicted risks.
- **H2:** All the categories of HFACS have a positive significant effect on the variable accidents faced by workers due to human errors.
- **H3:** The category of organizational influence has a positive and significant effect on supervisory factors, which then affect preconditions for unsafe acts and ultimately influence the occurrence of unsafe acts in both models.

**Results:**

This study employed several overall fit indices to evaluate the models, including chi-square ($\chi^2$), the $\chi^2$/df ratio, the Normed Fit Index (NFI), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Parsimony Comparative Fit Index (PCFI), the Incremental Fit Index (IFI), and the Root Mean Square Error of Approximation (RMSEA) as recommended by SEM experts [27][37] The results from Structural Model-1 and Structural Model-2 indicate a good fit: the chi-square value is acceptable, with NFI, CFI, and TLI all exceeding 0.9; PCFI is above 0.8; and the RMSEA is below 0.08, as presented in Table 4 [17][25][26]. Further, the details of regression weight for Structural Model-1 and Structural Model-2 are given in Appendix-B in Table A and Table B respectively.

**Table 2.** Communalities, Cronbach alpha, and Pattern Matrix for HFACS & Risk Factors

| Sub-Factors | Communalities | | *Cronbach alpha and Pattern Matrix | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Pre-conditions | Unsafe Act | Unsafe Supervision | Self-Inflicted Risk | Organizational Influence | Systematic Risk |
| | Initial | Extraction | 0.921* | 0.943* | 0.951* | 0.957* | 0.942* | 0.930* |
| UA_11 | .837 | .858 | | .933 | | | | |
| UA_12 | .804 | .837 | | .930 | | | | |
| UA_13 | .688 | .666 | | .796 | | | | |
| UA_14 | .690 | .661 | | .795 | | | | |
| UA_15 | .810 | .829 | | .907 | | | | |
| PC_21 | .540 | .473 | .665 | | | | | |
| PC_22 | .540 | .479 | .691 | | | | | |
| PC_23 | .682 | .701 | .833 | | | | | |
| PC_24 | .745 | .786 | .885 | | | | | |
| PC_25 | .620 | .525 | .722 | | | | | |
| PC_26 | .666 | .684 | .818 | | | | | |
| PC_27 | .742 | .790 | .902 | | | | | |
| US_31 | .807 | .746 | | | .865 | | | |
| US_32 | .760 | .683 | | | .821 | | | |
| US_33 | .905 | .959 | | | .971 | | | |
| US_34 | .874 | .888 | | | .943 | | | |
| OI_41 | .848 | .884 | | | | | .946 | |
| OI_42 | .854 | .896 | | | | | .952 | |
| OI_43 | .810 | .803 | | | | | .881 | |
| Lack of PPE | .924 | .946 | | | | .971 | | |
| Improper Machinery | .930 | .972 | | | | .982 | | |
| Lack of Training | .752 | .747 | | | | .858 | | |
| Enforcement Gaps | .720 | .743 | | | | | | .854 |
| Inadequate Mechanized Procedure | .807 | .880 | | | | | | .938 |
| Lack of Safety Culture | .787 | .843 | | | | | | .914 |

Structural Model-1 was designed to assess the impact of the exogenous variables, systematic risks, and self-inflicted risks, on HFACS factors as hypothesized in H1 and depicted in Figure 2. The results revealed that the effects of all the exogenous variables are statistically significant ($p < 0.05$), except for the effect of systematic risks on the unsafe act variable, and the effects of self-inflicted risks on the organizational influence and supervisory factors variables, which were not significant and were therefore excluded from the model. Moreover, the highest standardized effects of the variables systematic risks and self-inflicted risks are β = 0.39 and β = 0.38, respectively, with $p < 0.05$ for the variable pre-condition for unsafe acts; an increase in one variable will lead to an increase in the other, and vice versa.

**Table 3.** Communalities, Cronbach alpha, and Pattern Matrix for HFACS & Accidents Factors

| Sub-Factors | Communalities | | *Cronbach alpha and Pattern Matrix | | | | |
|---|---|---|---|---|---|---|---|
| | | | Pre-Conditions | Accidents | Unsafe Act | Unsafe Supervision | Organizational Influence |
| | Initial | Extraction | 0.921* | 0.967* | 0.963* | 0.945* | 0.946* |
| UA_11 | .920 | .947 | | | .974 | | |
| UA_12 | .862 | .875 | | | .936 | | |
| UA_13 | .731 | .680 | | | .827 | | |
| UA_14 | .777 | .753 | | | .854 | | |
| UA_15 | .920 | .939 | | | .968 | | |
| PC_21 | .674 | .664 | .798 | | | | |
| PC_22 | .669 | .635 | .768 | | | | |
| PC_23 | .762 | .784 | .833 | | | | |
| PC_24 | .749 | .755 | .835 | | | | |
| PC_25 | .690 | .610 | .784 | | | | |
| PC_26 | .585 | .499 | .725 | | | | |
| PC_27 | .641 | .578 | .793 | | | | |
| US_31 | .834 | .794 | | | | .898 | |
| US_32 | .741 | .678 | | | | .807 | |
| US_33 | .885 | .946 | | | | .973 | |
| US_34 | .815 | .828 | | | | .908 | |
| OI_41 | .858 | .907 | | | | | .949 |
| OI_42 | .863 | .916 | | | | | .956 |
| OI_43 | .722 | .742 | | | | | .857 |
| Near Miss | .888 | .888 | | .942 | | | |
| Days-off<3 | .869 | .859 | | .931 | | | |
| Days-off 3-7 | .843 | .814 | | .896 | | | |
| Days-off_8-20 | .821 | .807 | | .901 | | | |
| Days-off >20 | .892 | .910 | | .945 | | | |

**Table 4.** Goodness of Fit

| Model | $X^2$ | DF | $X^2$/DF | NFI | CFI | TLI | PCFI | RMSEA |
|---|---|---|---|---|---|---|---|---|
| Measurement Model-1 | 771.24 | 260 | 2.967 | 0.903 | 0.933 | 0.923 | 0.809 | 0.079 |
| Measurement Model-2 | 494.41 | 236 | 2.095 | 0.942 | 0.969 | 0.964 | 0.828 | 0.059 |

Structural Model-2 was developed to examine the impact of HFACS factors on the accidents faced by workers due to human errors, as hypothesized in H2 and depicted in Figure 3. The results indicated that all exogenous factors in this model, which correspond to the HFACS factors, had a positive and statistically significant effect on the endogenous variable. The most significant standardized effects on the variables related to accidents caused by human errors come from the pre-condition for unsafe acts and supervisory factors, with values of β = 0.25 and β = 0.20, respectively.

The third hypothesis (H3) was formulated to evaluate the sequential influence of factors within the HFACS framework, where each factor influences the next, starting from organizational influence and culminating in unsafe acts, as depicted in Structural Models 1 and 2. Structural Model- and Structural Model 2 fully support H3, demonstrating that each factor positively and significantly affects the subsequent factor in the sequence. In Model-1, the strongest standardized effect is the influence of the pre-condition of unsafe acts on unsafe acts, with a coefficient of β = 0.15. Whereas, Model-2 identifies the most significant effect as the impact of supervisory factors on the pre-condition for unsafe acts, with a coefficient of β = 0.40.

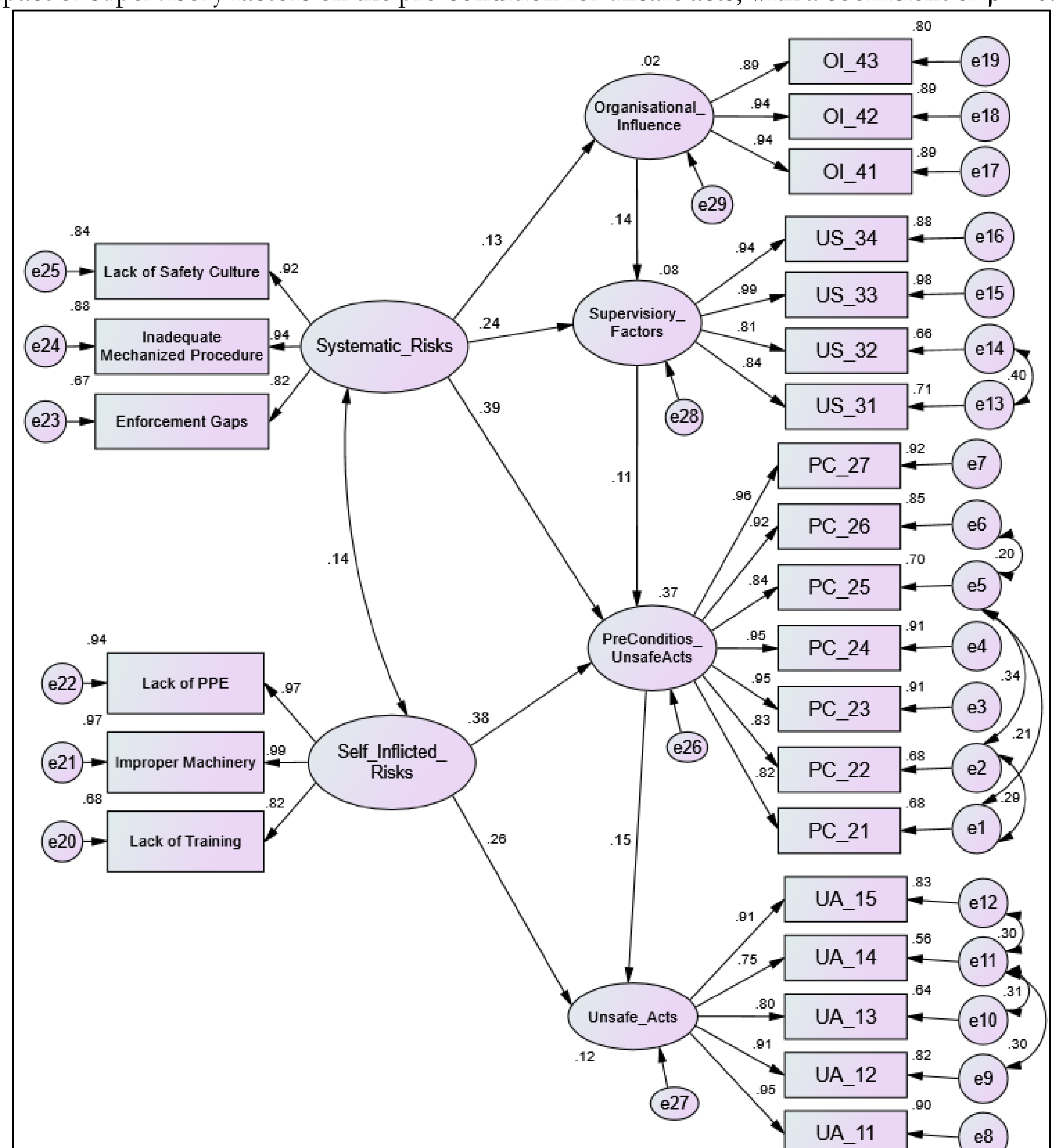


**Figure 2.** Structural Model-1

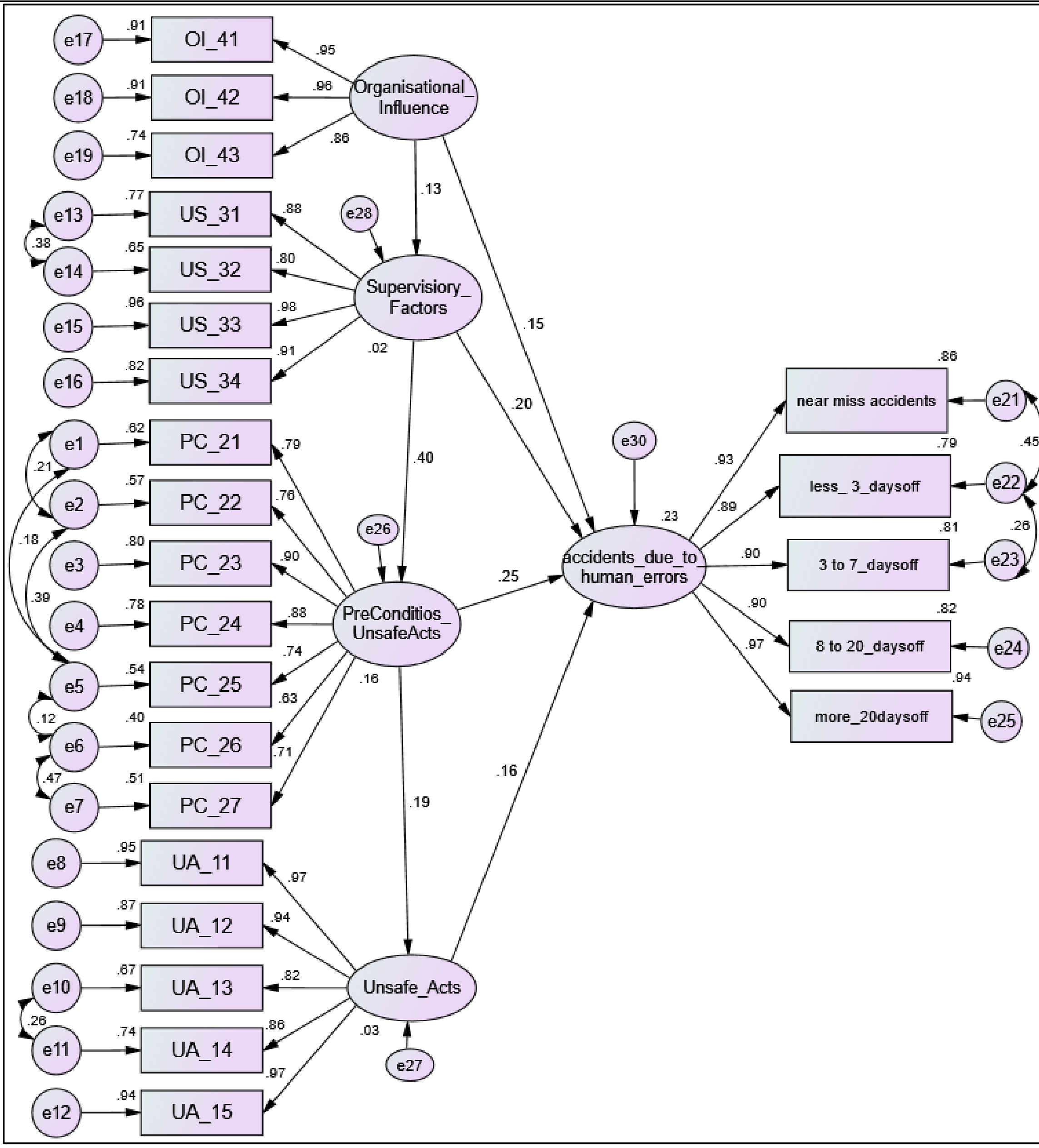


**Figure 3.** Structural Model-2

**Discussion:**

This study assesses the human aspects that contribute to unsafe circumstances in marble mines that employ conventional mining techniques. The assessment utilizes the Human Factor Analysis and Classification System (HFACS) framework for analyzing the factors that influence human errors and contribute to the occurrence of accidents in mines [38]. In mining operations, certain human errors impact only individuals, while others, frequently associated with management and supervisory responsibilities, can have wider consequences that contribute to a hazardous environment, as recognized in various studies [34][39]. Workers reported that the preconditions for unsafe acts, including the physical and technical environment, are more influenced by management and supervision issues rather than by the acts of individual workers. In addition, the study also indicated that managerial practices and organizational culture have a more substantial impact on the preconditions for unsafe acts that are responsible for accident causation in mining, suggesting that addressing systematic concerns is essential in enhancing safety in the mining industry, as reported by Quiroz et al. [40].

Moreover, it has been assessed that the increased probability of self-inflicted risk is significantly influenced by individual lack of PPE, improper machinery, and lack of training [41][42]. These factors greatly impact the unsafe acts themselves and the preconditions for them, such as the mental and physical well-being of workers that make them more susceptible to errors. Although these factors do not directly impact organizational regulations or supervisory roles, strengthening them can greatly enhance safety and effectiveness [43]. Consequently, this approach will effectively address the enforcement gaps, adopt managerial and policy-related concerns, as well as promote a safety culture and individual attitude [39].

Analysis of the direct effects at different levels of the HFACS framework, considering both the self-inflicted risks and systematic risks, it is evident that every tier has a substantial impact on the next one, starting with organizational factors and finally influencing the potentially harmful acts of workers. Understanding this interdependence highlights the necessity of addressing the root causes of risks that influence all levels to successfully reduce human errors and enhance safety results [7]. Analysis of HFACS variables in the second model of the study revealed that all levels within the framework significantly contribute to the occurrence of accidents ranging from near misses to severe accidents. Preconditions for unsafe acts and supervisory factors have a higher impact on accident causation, highlighting their critical importance in the frequency of accidents [37]. Moreover, the unsafe acts of workers and the influence of management also play an integral part in the occurrence of accidents. It is essential to consider all aspects of HFACS, particularly unsafe conditions and supervision on priority, to minimize the number and severity of incidents and accidents in mining operations, this finding supports the results of Joe-Asare et al., [18] that the workplace condition and leadership deficiencies are the most frequently identified contributing factors.

The findings of this study emphasize the importance of improving safety management and reducing human errors in the mining industry through comprehensive training programs that focus on operational competency and leadership abilities. Setting clear work standards, conducting regular workplace examinations, and developing safety culture that encourages reporting unsafe behaviors are important, the implementation of safe and mechanized mining techniques can significantly reduce workload, fatigue, and stress as described by Flores-Castañeda et al., [5] and Hattingh et al., [44]. Furthermore, implementing such findings into regulatory frameworks and working with industry stakeholders to develop standardized safety indicators helps drive continuous improvement and increase responsibilities across the industry.

**Conclusion:**

In mines with limited mechanization, addressing human errors and their root causes along with the assessment of physical hazards is important to effectively reduce the probability of accidents. This study analyzed the complexities of safety management in mines with the conventional system of mining by determining the different ways through which the risk factors affect safety practices. The findings revealed a strong relationship among the root causes of human errors, HFACS factors, and accidents faced by the workers. Deficiencies in mechanized procedures, safety culture, enforcement, and individual behavior due to lack of PPE, machinery, and training have a higher influence on human errors that result in minor to fatal accidents in mines. It is illustrated that the high influence of managerial and supervisory practices on workplace conditions, as well as the unsafe environment and individual behaviors that contribute to unsafe acts of workers, needs attention to reduce the associated risks. The unsafe conditions of the mine are dependent upon its physical and technological factors, which can be efficiently controlled by a mechanized system. It is recommended that mining operations should be mechanized to reduce the probability of human errors and improve safety [44].

**Conflict of Interest:** All the authors declare no conflicts of interest for publication of this paper. All authors have contributed to the paper.

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## Appendix - A

**Questionnaire for Workers' Interviews:**

The purpose of this survey is to gather insights from workers in the mining industry regarding safety practices, challenges, and human factors that influence workplace incidents. By understanding the experiences and perceptions of workers, we aim to identify critical areas for improvement in safety measures and training programs. Your feedback will help us enhance safety culture, reduce risks, and create a safer working environment for all employees. Participation in this survey is crucial for developing strategies that address the unique safety concerns faced in mining operations. In response to the following statement, please tick (✓) in the appropriate block with a scale ranging from Strongly Disagree with the value of 1 to Strongly Agree with the value of 5.

**Demographic:**

- Name (optional) ______________________________
- Age ________________________________________
- Level of education __________________________________________
- Current job position _______________________________________
- Total experience _____________________________________________

**Section-1:**

**1a: Safety Risk Factors in Mining Operations:**

Please choose one response from the scale, the risks factors in mining operations that contribute to human errors and lead to accidents.

| S. No | Statement/Question | Strongly Disagree (1) | Disagree (2) | Up to some extent Agree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|---|
| a. | Lack of PPE | | | | | |
| b. | Improper Machinery | | | | | |
| c. | Lack of Training | | | | | |
| d. | Enforcement Gaps | | | | | |
| e. | Inadequate Mechanized Procedure | | | | | |
| f. | Lack of Safety Culture | | | | | |

**1b: Human Factors/Errors Affecting Mining Operation:**

Please choose one response from the scale, which ranges from "Strongly Disagree" to "Strongly Agree," about the HFACS factors influenced by the risks factors in mining operations that contribute to human errors.

| S. No | HFACS Factors | Strongly Disagree (1) | Disagree (2) | Up to some extent Agree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|---|
| 1 | Decision Error | | | | | |
| 2 | Skill-based Error | | | | | |
| 3 | Perceptual Error | | | | | |
| 4 | Routine Violations | | | | | |
| 5 | Exception Violations | | | | | |
| 6 | Physical Environment | | | | | |
| 7 | Technical Environment | | | | | |

| S. No | HFACS Factors | Strongly Disagree (1) | Disagree (2) | Up to some extent Agree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|---|
| 8 | Adverse Mental State | | | | | |
| 9 | Adverse physiological state | | | | | |
| 10 | Physical Mental Lt | | | | | |
| 11 | Crew resource management | | | | | |
| 12 | Personal readiness | | | | | |
| 13 | Inadequate supervision | | | | | |
| 14 | Planned inappropriate operation | | | | | |
| 15 | Failed to correct known problem | | | | | |
| 16 | Supervisory violations | | | | | |
| 17 | Resource management | | | | | |
| 18 | Organizational climate | | | | | |
| 19 | Operational process | | | | | |

**Section-2:**

**2a: Human Factors/Errors Affecting Mining Operation:**

Please choose one response from the scale, which ranges from "Strongly Disagree" to "Strongly Agree," regarding the HFACS factors that are contributing to mine accidents.

| S. No | HFACS Factors | Strongly Disagree (1) | Disagree (2) | Up to some extent Agree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|---|
| 1 | Decision Error | | | | | |
| 2 | Skill-based Error | | | | | |
| 3 | Perceptual Error | | | | | |
| 4 | Routine Violations | | | | | |
| 5 | Exception Violations | | | | | |
| 6 | Physical Environment | | | | | |
| 7 | Technical Environment | | | | | |
| 8 | Adverse Mental State | | | | | |

| S. No | HFACS Factors | Strongly Disagree (1) | Disagree (2) | Up to some extent Agree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|---|
| 9 | Adverse physiological state | | | | | |
| 10 | Physical Mental Lt | | | | | |
| 11 | Crew resource management | | | | | |
| 12 | Personal readiness | | | | | |
| 13 | Inadequate supervision | | | | | |
| 14 | Planned inappropriate operation | | | | | |
| 15 | Failed to correct known problem | | | | | |
| 16 | Supervisory violations | | | | | |
| 17 | Resource management | | | | | |
| 18 | Organizational climate | | | | | |
| 19 | Operational process | | | | | |

**2b: Information About Mine Accidents You Faced:**

| S. No | Statement/Question | 0 time | 1 time | 2-3 times | More than 3 times |
|---|---|---|---|---|---|
| a. | Average number of near miss accidents you faced during last one year. | | | | |
| b. | Number of accidents you faced with having minor injury having less than 03 days off from work. | | | | |
| c. | Number of injuries you faced with having at least 03 to 07 days off from work. | | | | |
| d. | Number of injuries you faced with 08 to 20 days off from work. | | | | |
| e. | Number of accidents you faced with more than 20 days off from work. | | | | |

## Appendix-B

**Table A.** Regression Weights of Structural Model - 1

| Factors | | Influencing factors | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| Organisational__Influence | <--- | Systematic_Risks | .184 | .086 | 2.134 | .033 |
| Supervisiory__Factors | <--- | Systematic_Risks | .376 | .091 | 4.144 | *** |
| Supervisiory__Factors | <--- | Organisational__Influence | .151 | .061 | 2.478 | .013 |
| PreConditios__UnsafeActs | <--- | Supervisiory__Factors | .171 | .075 | 2.280 | .023 |
| PreConditios__UnsafeActs | <--- | Self_Inflicted__Risks | 1.000 | | | |

| Factors | | Influencing factors | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| PreConditios__UnsafeActs | <--- | Systematic_Risks | 1.000 | | | |
| Unsafe_Acts | <--- | Self_Inflicted__Risks | .397 | .093 | 4.274 | *** |
| Unsafe_Acts | <--- | PreConditios__UnsafeActs | .082 | .035 | 2.380 | .017 |
| PC_23 | <--- | PreConditios__UnsafeActs | 1.000 | | | |
| PC_24 | <--- | PreConditios__UnsafeActs | .808 | .021 | 39.261 | *** |
| PC_25 | <--- | PreConditios__UnsafeActs | .667 | .028 | 24.204 | *** |
| PC_26 | <--- | PreConditios__UnsafeActs | .804 | .024 | 33.173 | *** |
| PC_27 | <--- | PreConditios__UnsafeActs | .825 | .020 | 40.294 | *** |
| UA_11 | <--- | Unsafe_Acts | 1.030 | .036 | 28.946 | *** |
| UA_12 | <--- | Unsafe_Acts | 1.000 | | | |
| UA_13 | <--- | Unsafe_Acts | .864 | .044 | 19.599 | *** |
| UA_14 | <--- | Unsafe_Acts | .859 | .044 | 19.467 | *** |
| UA_15 | <--- | Unsafe_Acts | .993 | .038 | 26.076 | *** |
| US_31 | <--- | Supervisiory__Factors | .813 | .031 | 25.944 | *** |
| US_32 | <--- | Supervisiory__Factors | .819 | .035 | 23.161 | *** |
| US_33 | <--- | Supervisiory__Factors | 1.000 | | | |
| US_34 | <--- | Supervisiory__Factors | .943 | .024 | 38.825 | *** |
| OI_41 | <--- | Organizational__Influence | 1.000 | | | |
| OI_42 | <--- | Organisational__Influence | 1.020 | .032 | 31.863 | *** |
| OI_43 | <--- | Organisational__Influence | .968 | .035 | 27.339 | *** |
| F13 | <--- | Self_Inflicted__Risks | 1.000 | | | |
| F12 | <--- | Self_Inflicted__Risks | 1.342 | .053 | 25.438 | *** |
| F11 | <--- | Self_Inflicted__Risks | 1.324 | .053 | 24.920 | *** |
| F21 | <--- | Systematic_Risks | 1.000 | | | |
| F22 | <--- | Systematic_Risks | 1.222 | .057 | 21.366 | *** |
| F23 | <--- | Systematic_Risks | 1.292 | .062 | 20.854 | *** |
| PC_21 | <--- | PreConditios__UnsafeActs | .609 | .026 | 23.184 | *** |
| PC_22 | <--- | PreConditios__UnsafeActs | .616 | .026 | 23.306 | *** |

**Table B.** Regression Weights of Structural Model -2

| Factors | | Influencing Factors | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| Supervisiory__Factors | <--- | Organisational__Influence | .141 | .060 | 2.338 | .019 |
| PreConditios__UnsafeActs | <--- | Supervisiory__Factors | .352 | .049 | 7.126 | *** |
| Unsafe_Acts | <--- | PreConditios__UnsafeActs | .196 | .061 | 3.188 | .001 |
| accidents_due_to__humanerrors | <--- | Unsafe_Acts | .142 | .046 | 3.116 | .002 |
| accidents_due_to__humanerrors | <--- | PreConditios__UnsafeActs | .230 | .055 | 4.212 | *** |
| accidents_due_to__humanerrors | <--- | Supervisiory__Factors | .157 | .046 | 3.396 | *** |
| accidents_due_to__humanerrors | <--- | Organisational__Influence | .129 | .044 | 2.934 | .003 |
| PC_23 | <--- | PreConditios__UnsafeActs | 1.000 | | | |
| PC_24 | <--- | PreConditios__UnsafeActs | .930 | .042 | 22.095 | *** |
| PC_25 | <--- | PreConditios__UnsafeActs | .825 | .052 | 15.916 | *** |
| PC_26 | <--- | PreConditios__UnsafeActs | .682 | .054 | 12.700 | *** |
| PC_27 | <--- | PreConditios__UnsafeActs | .729 | .048 | 15.167 | *** |

| Factors | | Influencing Factors | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|---|---|
| UA_11 | <--- | Unsafe_Acts | 1.026 | .026 | 39.195 | *** |
| UA_12 | <--- | Unsafe_Acts | 1.000 | | | |
| UA_13 | <--- | Unsafe_Acts | .874 | .040 | 21.976 | *** |
| UA_14 | <--- | Unsafe_Acts | .947 | .038 | 24.998 | *** |
| UA_15 | <--- | Unsafe_Acts | 1.039 | .027 | 38.393 | *** |
| US_31 | <--- | Supervisiory__Factors | .835 | .030 | 28.237 | *** |
| US_32 | <--- | Supervisiory__Factors | .793 | .036 | 22.089 | *** |
| US_33 | <--- | Supervisiory__Factors | 1.000 | | | |
| US_34 | <--- | Supervisiory__Factors | .930 | .029 | 31.770 | *** |
| OI_41 | <--- | Organisational__Influence | 1.000 | | | |
| OI_42 | <--- | Organisational__Influence | 1.006 | .029 | 34.752 | *** |
| OI_43 | <--- | Organisational__Influence | .896 | .035 | 25.264 | *** |
| F21 | <--- | accidents_due_to__human _errors | 1.000 | | | |
| F23 | <--- | accidents_due_to__human _errors | 1.051 | .041 | 25.525 | *** |
| F22 | <--- | accidents_due_to__human _errors | 1.043 | .034 | 30.937 | *** |
| PC_21 | <--- | PreConditios__UnsafeActs | .833 | .047 | 17.730 | *** |
| PC_22 | <--- | PreConditios__UnsafeActs | .806 | .049 | 16.546 | *** |
| F13 | <--- | accidents_due_to__human _errors | .981 | .034 | 28.513 | *** |
| F12 | <--- | accidents_due_to__human _errors | 1.019 | .037 | 27.346 | *** |