THE IMPACT OF SAFETY FACTORS ON THE SAFETY SUSTAINABILITY OF OPERATORS IN MINING COMPANIES: A MANAGER'S PERSPECTIVE

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Abstract: The mining industry is a crucial driver of economic development, yet it faces significant challenges due to its hazardous nature. Safety and health at work are paramount for sustainable operations within this industry. This study focuses on managers' perceptions of workplace safety factors concerning mining machinery operators and explores how technical, human, and organisational factors influence mining operators' sustainable safety efforts. A survey was conducted in mining companies to analyse management opinions regarding factors influencing occupational safety and health in mining machinery operators. The data collected was statistically processed using the software package SPSS. Statistical tests were used based on the collected data and opinions of the managers. This research's implications are reflected in the identification of key factors that contribute to the effective implementation of security measures and practices. Despite its limitations, the results offer strong empirical support for the proposed theoretical model. These findings provide valuable guidance for researchers and practitioners seeking to enhance safety in the workplace for mining machinery operators. Through an in-depth analysis of these factors, mining company managers can identify key aspects contributing to the effective implementation of security measures and practices. Finally, a framework will be created that will enable the sustainable management of the safety activities of mining machinery operators, which will result in a reduction in the risk of injury and an improvement in the health of workers in the mining sector.

Keywords: Safety, Technical factor, Human factor, Organisational factor, Sustainability.

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1. INTRODUCTION

Mining is considered one of the most hazardous industries in the world, with a high rate of injuries and illnesses (Haas & Yorio, 2021). According to Marimuthu et al. (2023), mining jobs are among the most unsafe worldwide. The mining industry is characterised by constantly changing working conditions (Bayraktar et al., 2023). Nowadays, mining workplaces are experiencing rapid advancements in technology and techniques, which are affecting the lives of workers in terms of economic and social development. However, despite these developments, safety and health at work in the mining sector is still not up to satisfactory levels (Komljenovic et al., 2017). Mining workers are exposed to various hazards, including biological, chemical, mechanical, and emotional risks (Amponsah-Tawiah et al., 2013).

The entire process of mining exposes miners to many hazards, such as extreme temperatures, injuries caused by mining machinery and falls (Haas & Yorio, 2021). Also, work equipment, mechanization, working environment conditions, and outdated working methods are very critical and lead to accidents (Li et al., 2019).

In addition to all the unfavourable working conditions that cause accidents in mines, one of the biggest causes of accidents is still the human factor, which most often leads to accidents and tragedies (Wang et al., 2019). In this respect, carelessness, unprofessional work, and insufficient training of operators in many ways lead to tragedies (Bayraktar et al., 2023). Therefore, it is necessary to implement all the necessary measures in coordination in order to train, motivate and adapt mining operators to the changing conditions in the workplace.

This research aims to analyse and examine the managers’ opinions on the workplace safety factors of the operators of mining machinery. For this purpose, it is necessary to examine how the technical, human and organisational factors of occupational safety and health affect the sustainable safety activities of mining machinery operators. Through an in-depth analysis of these factors, the research will identify key points contributing to the effective implementation of security measures and practices. The aim is to develop a deeper understanding of the interactions between the above factors and their impact on the safety and health of mining machinery operators so that informed guidelines and recommendations can be applied to improve safety standards in mining. The ultimate goal is to create a framework that will enable the sustainable management of the safety activities of mining machinery operators, which will result in a reduction in the risk of injury and an improvement in the health of workers in the mining sector.

2. LITERATURE REVIEW

The available literature investigates safety and health at work, as well as work-related injuries, depending on the industries and the factors included in the analysis. The mining industry carries with it various dangers specific to that area, such as rock strikes and the sudden collapse of rock material, explosions of methane and coal dust, unexpected breakthroughs of water and material, etc. (Zhironkina & Zhironkin, 2023). Also, water pollution, massive waste from mining, soil erosion and land desertification threaten the environment and sustainability (Guo & Yang, 2023). These mining safety hazards threaten employees, equipment, and roadways, interrupt mine production systems, and negatively impact the mining industry’s economic benefits and sustainability (Guo & Yang, 2023).

Previous research on safety and health at work clearly shows that certain factors can have a greater impact on the occurrence of accidents or incidents. Zhang (2015) created a safety attitude scale that assesses the safety-related viewpoints of senior managers. Wu et al. (2017) proposed a four-dimensional structure for safety attitudes, including team safety climate, safety
commitment of management, fatalism, and job stress. Hale and Hovden (1998) suggest that managers need to provide both technical and human resources for safety but do not specify how this provision should be managed. In this context, as an essential technological factor, the working environment ensures the safety and health of mining machine operators (Komljenovic et al., 2017). It enables operators to feel more secure in carrying out their daily tasks, leading to a reduction in errors and defects. Also, a safe working environment increases productivity, which improves the quality of products or services, and this all leads to the sustainability of mining operations (Haas & Yorio, 2021). Providing a safe working environment for employees can increase their motivation and commitment, making them feel supported and valued by the company (Montibeller & Von Winterfeldt, 2015). Also, operators who work in a safe and healthy environment are more likely to be satisfied with their work and the company, which can increase operators' performance (Gowrisankaran et al., 2015).

Also, an important aspect of safety and health at work for mining machine operators is the support of managers. The interaction between management and operators involves several factors, including the overall climate of labour relations, the level of concern management shows for their workers, and the support workers receive for safety-related actions (Parker et al., 2017). Gaertner et al. (1987) discovered a direct correlation between poor communication and cooperation between managers and employees and workplace injuries. Their study revealed that companies with a negative labour relations climate have an injury rate that is almost twice as high as companies with a positive labour relations climate. In mines where management neglects employee well-being, accidents are common. Many studies have shown that in all mines with a low accident rate, the union supported the company's enforcement of safety rules (Beus et al., 2016). Coworker support in occupational safety and health indicates the degree of attention shown by coworkers (Parker et al., 2017).

Furthermore, Marimuthu et al. (2023), in their research, indicate that an organisation's performance is greatly influenced by the health and safety of its workers. If the workers' health and safety are compromised, their productivity may decrease. Therefore, it is vital to prioritise the well-being of employees and provide a safe and healthy work environment (Karuppih et al., 2020).

The engagement of mining machine operators in the work shows their commitment and concern about their work, which positively reflects on improving safety and productivity. Operators who know about safety and health at work know how to perform their work, how to use protective equipment, and how to preserve health, which leads to a reduction in accidents and injuries. Peters (1989) reveals that lack of job knowledge leads to more dangerous working conditions and contributes to a higher accident rate.

In the light of theoretical analysis, the following hypotheses were developed:

Hypothesis 1. Technical factors have a positive influence on sustainability factors in mining companies

Hypothesis 2. Human factors have a positive influence on sustainability factors in mining companies

Hypothesis 3. Organisational factors have a positive influence on sustainability factors in mining companies

In this study, the hypotheses were developed on the basis of previous research on the impact of safety factors on the sustainable safety activities of mining machinery operators.
3. DATA AND METHODOLOGY

A survey methodology was used to analyse management opinions about influential factors of occupational safety and health of mining machinery operators. For this purpose, the technical, human, and organisational factors and sustainability performance were employed using questionnaires that were initially developed in the previous phase under the project "Support Systems for Smart, Ergonomic and Sustainable Mining Machinery Workplaces - SmartMiner" supported by Science Fund of the Republic of Serbia.

The questionnaire was developed by grouping questions based on literature review and existing research in OSHAS. Companies in the mining sector were chosen to evaluate management's opinion on the current state of occupational safety and health for mining machinery operators. Prominent causal and theoretical models of workplace safety were consulted to identify relevant constructs. Most of the data was collected in the field through visits to the management of mining companies and conversations with them, while the other part was collected through an online questionnaire. The data collected was statistically processed using Excel tables and a specialised software package such as SPSS. Responders expressed their attitudes using a Likert five-level scale (1 to 5). Based on the collected data and opinions of the 34 managers, statistical tests were used. The software program SPSS was utilised to evaluate the consistency and correlation within the measurement scale and the impact of the safety factor on the sustainability of the mining companies.

4. RESULTS AND DISCUSSION

The first step in data analysis was descriptive statistics, which were used to describe the observed data and phenomena. Descriptive data on respondents showed that most respondents were male (76.47%). Regarding age, most respondents were between the ages of 26 and 35 (32.35%), as well as between the ages of 36 and 45 (32.35%). For working experience, approximately 44.11% of respondents have between 11 and 15 years or less of experience, which represents very relevant information for the particular topic of the research. Regarding education, the sample reported that most of the respondents, 64.70%, have a university degree, and 32.35% of respondents have a Master’s degree. These facts show that the respondents possess sufficient education levels to comprehend and implement safety measures during their management activities.
Furthermore, a correlation analysis presented the mutual relationship between the observed factors. The results indicate a strong correlation with statistical significance between all considered factors, as depicted in Table 1.

### Table 1. Correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>Technical factor</th>
<th>Human factor</th>
<th>Organizational factors</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical factor</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human factor</td>
<td>0.697</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organisational factors</td>
<td>0.790</td>
<td>0.947</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sustainability</td>
<td>0.838</td>
<td>0.798</td>
<td>0.880</td>
<td>1</td>
</tr>
</tbody>
</table>

Cronbach's alpha was used to evaluate the internal consistency of each factor in the scale, Table 2. The obtained results show that all the values of the Cronbach coefficient are over 0.7 (Cronbach, 1951), which fulfils the consistency condition.

### Table 2. Cronbach's alpha

<table>
<thead>
<tr>
<th></th>
<th>Technical factor</th>
<th>Human factor</th>
<th>Organizational factors</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cronbach Alfa</td>
<td>0.962</td>
<td>0.988</td>
<td>0.981</td>
<td>0.942</td>
</tr>
</tbody>
</table>

Regression analysis was used to test hypotheses and assess the relationship between independent and dependent variables. In this light, it was performed to determine the character and form of the relationship, that is, the regression model between two observed variables in a stochastic relationship (Hair et al., 1998; Ho, 2006). This research considered the impact of technical, human, and organisational factors on sustainability.

### Table 3. Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of Estimate</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.912a</td>
<td>0.831</td>
<td>0.814</td>
<td>0.317</td>
<td>0.831</td>
<td>49.124</td>
<td>3</td>
<td>30</td>
<td>0.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), Technical factor, Human factor, Organizational factor
b. Dependent Variable: Sustainability factor

Table 3 depicts the results of R Square Change, where 0.831, which means that 83.1% of the variation of the dependent variable "Sustainable factor" is explained by controlled variables such as the Technical, Human, and Organizational factors. Adjusted R Square is a coefficient used in multiple regression analysis to determine the goodness of fit of a model (Harel, 2009). It is introduced because R Square may increase incorrectly when new independent variables are added to the model. In this research, the Adjusted R Square coefficient is 0.814, which indicates that the regression model explains approximately 81.4% of the variance in the dependent variable.
The hypotheses were tested using regression analysis, and the results of the path coefficients are depicted in Table 3 and Figure 2. Path analysis depicts that the variables of the technical and organizational factors directly impact the sustainability factor with statistical significance, while the human factor has negative impacts without statistical significance on the sustainability factor.

**Table 4. Coefficients’ beta regression**

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized</th>
<th>Coefficients</th>
<th>Standardized Coefficients</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td>T</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>-0.012</td>
<td>0.399</td>
<td>-0.030</td>
<td>0.976</td>
</tr>
<tr>
<td>Technical factor</td>
<td>0.334</td>
<td>0.119</td>
<td>0.358</td>
<td>2.816</td>
</tr>
<tr>
<td>Human factor</td>
<td>-0.178</td>
<td>0.263</td>
<td>-0.165</td>
<td>-0.678</td>
</tr>
<tr>
<td>Organizational factor</td>
<td>0.895</td>
<td>0.339</td>
<td>0.753</td>
<td>2.645</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Sustainability factor

Regression analysis was utilised to determine if the influence of technical, human, and organisational factors has an important impact on the sustainability of mining companies. Table 4 presents the VIF value demonstrating the multi-collinearity level. The VIF value indicates the percentage of variation in the independent variable that is not accounted for by other independent variables. If the low VIF values are below 10, they indicate a division or overlapping of the predictive power of the independent variables (Cohen & Cohen, 1983). VIF values greater than 10 cannot be accepted, and that independent variable must be exposed for further analysis (Ho, 2006).

The obtained results of the regression analysis showed that technical and organisational factors have a positive influence on security sustainability, thus confirming hypotheses H1 and
H3. These findings are consistent with the findings of Haas and Yorio (2021), Montibeller and Von Winterfeldt (2015), Gowrisankaran et al. (2015), and Parker et al. (2017). However, a negative relation without statistical significance can be seen between the human factor and the sustainability factor and hypothesis H2 is rejected. These results link with the findings of Wang et al. (2019) and Bayraktar et al. (2023), who indicate that the biggest cause of injuries and accidents is the human factor, which cannot have the sustainable safety activities of mining machinery operators.

In this respect, managers must implement all necessary measures to train, motivate and adapt mining operators to changing workplace conditions to improve the sustainable safety activities of mining machine operators.

5. CONCLUSION

The mining industry plays a significant role in economic development. However, it is also among the most hazardous industries and faces great challenges. The mining industry is characterized by risks and challenges, making safety and health considerations crucial aspects of its sustainability operations. This study aimed to analyze managers’ perceptions of workplace safety factors for mining machinery operators. It was necessary to analyse how technical, human, and organisational factors impact the sustainable safety efforts of mining machinery operators in terms of occupational safety and health.

This research's implications are reflected in the identification of key factors that contribute to the effective implementation of security measures and practices. Despite its limitations, the results offer strong empirical support for the proposed theoretical model. These findings provide valuable guidance for researchers and practitioners seeking to enhance safety in the workplace for mining machinery operators. Mining company managers can use these findings as a roadmap to ensure that safety and health standards and procedures for mining machine operators are maintained.

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