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The Influence of Safety Culture, Leadership Behaviour, Risk Perception, and Training Compliance on Safety Management at Neyveli Lignite Mines in India

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Abstract:
This study examines the role of safety culture, leadership behaviour, risk perception, and training compliance in safety management practices at Neyveli Lignite Corporation India Limited's lignite mines. The study employs a descriptive methods approach, integrating quantitative surveys and qualitative interviews to explore the impact of safety influencers on safety management. The results indicate that safety culture emerged as a strong predictor of safety protocol adherence and risk perception among workers. Effective leadership, particularly transformational leadership styles, positively influenced workers' safety compliance by fostering a supportive environment for safety practices. The findings suggest targeted improvements in embedding safety values, enhancing leadership's role, and strengthening training could further solidify safety practices across the organization. Developing a novel quantitative approach to evaluate the organizational factors affecting occupational health and safety in the mining industry.

Keywords: Safety Management, Lignite Mines, Safety Culture, Leadership, Risk Perception

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1. INTRODUCTION

NLC India Limited's approach to all its threemine safety management was a synthesis of various advanced systems and methods. A comprehensive mine safety management system typically includes multiple subsystems such as safety monitoring, health monitoring, accident potential analysis, and prediction subsystems, which collectively enhance the prediction and management of mine accidents (Linxin, 2018). Additionally, the use of accident safety management systems that incorporate conventional reasoning and neural network expert systems significantly improve accident prediction and management by addressing the limitations of traditional forecasting methods (Qingming, 2018). Safety management refers to the systematic implementation of policies, procedures, and practices aimed at minimizing risks and ensuring worker protection (Hopkins, 2019). Various factors collectively known as safety influencers such as leadership behaviour, safety culture, and employee training, have been identified as critical to effective safety management (Zohar and Polachek, 2014). This study examines how these influencers affect safety management practices in lignite mines, seeking to identify actionable strategies that could enhance safety outcomes for mine workers. Effective safety management in lignite mines requires a comprehensive approach that addresses these multifaceted influences through strategic interventions, such as enhanced safety training, improved safety culture, and robust management systems, to ensure a safer working environment for miners (Yuan et al., 2023) (Chen et al., 2022) (Wei-y, 2013).

2. REVIEW OF LITERATURE

Safety culture, leadership, risk perception, and training compliance are interrelated factors that significantly influence workplace safety outcomes. Safety leadership plays a pivotal role in shaping safety culture and influencing safety behaviours, as demonstrated by its positive impact on safety compliance and participation through both transformational and transactional leadership styles Clarke, 2013). Safety culture, which is deeply intertwined with leadership, is essential for fostering an environment where safety is prioritized, and employees feel empowered to report hazards without fear (Rallapalli, 2024). Effective safety leadership enhances risk perception among employees, which is crucial for achieving safety performance, as seen in military contexts where clear risk perception is instilled through training (Wei and Kuo, 2023). In the manufacturing industry, safety behaviour, influenced by leadership and safety climate, is critical for reducing work accidents and enhancing productivity (Rahman et al., 2023). Training compliance is another vital component, as comprehensive safety training programs equip employees with the necessary skills to identify and mitigate risks, thereby reinforcing a positive safety culture

(Rallapalli, 2024). Moreover, safety compliance behaviours, categorized into deep and surface compliance, are influenced by safety leadership and climate, with deep compliance showing a stronger negative correlation with adverse safety outcomes (Omidi et al., 2023). The integration of safety culture and leadership is further emphasized in the chemical industry, where leadership commitment and behavioural safety initiatives are crucial for risk reduction (Rallapalli, 2024). Overall, the interplay between safety leadership, culture, risk perception, and training compliance forms a robust framework for enhancing workplace safety, underscoring the need for continuous improvement and stakeholder engagement to achieve zero incidents (Ukato et al., 2024).

3. METHODOLOGY

This study employs a descriptive methods approach, integrating quantitative surveys and qualitative interviews to explore the impact of safety influencers on lignite coal mine safety management. Surveys measured factors like safety culture, leadership, and risk perception using eight items each in accordance with validated scales (e.g., Zohar's Safety Climate Scale) (Zohar, 2002). Additionally, in-depth interviews with safety officers and miners were conducted to capture nuanced perspectives on safety challenges and management practices in the introduction of items. Quantitative data was analyzed using regression techniques to assess relationships between variables.

3.1 Statement of research problem

In the high-risk environment of lignite coal mines, such as those managed by NLC India Limited, effective safety management is crucial due to inherent hazards like combustible dust, gas explosions, and structural instabilities (Smith et al., 2021). Specifically, safety culture, leadership behaviour, employee training, and workers' risk perception are key factors that influence compliance with safety protocols and the reduction of incidents (Hopkins, 2019; Zohar Polachek, 2014). Therefore, understanding how these influencers impact safety management practices in lignite mines is essential to identify effective strategies for improving safety outcomes for mine workers.

3.2 Research Gap

Prior research has largely focused on the role of technology and safety monitoring systems in mine safety management, yet studies addressing the direct impact of safety influencers—particularly leadership behaviour, safety culture, and employee training—on compliance and risk perception in high-risk mining settings remain limited (Clarke, 2013; Guldenmund, 2000). Although safety culture is known to influence adherence to protocols, the specific ways in which leadership and training effectiveness interact with safety culture to affect workers' behaviour and perceptions in lignite mines is underexplored (Mearns et al., 2003). Addressing this gap is critical, as a comprehensive approach to mine safety should incorporate both technological solutions and robust organizational practices, placing emphasis on human factors that are central to maintaining a safe working environment (Burke et al., 2006; Zohar, 2002).

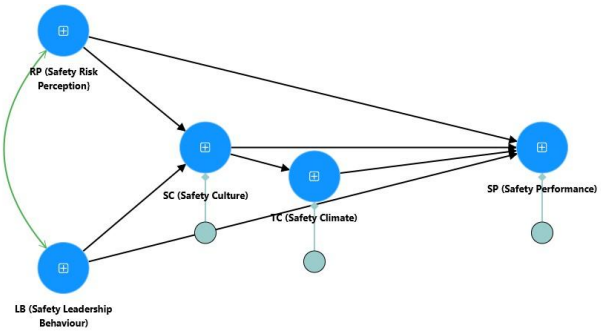

Figure 1: Mine's Safety Performance Framework

3.3 Research Questions

The following are potential research questions based on the study's focus on safety influencers in lignite mining safety management: What specific safety influencers (safety culture, leadership, training) have the most significant impact on reducing incidents in lignite mines? How can safety management practices in lignite mines be improved through targeted interventions in leadership, safety culture, and training? What are the challenges in fostering a proactive safety culture in lignite mining, and how can these be addressed to improve safety outcomes?

3.3.1 Objectives

There were five research objectives based on the study's focus on safety influencers in lignite mining safety management:

- To assess the influence of risk perception and leadership behaviour on safety culture and training compliance on safety management practices in mines of NLCIL.
- To find the association between safety management practices with the safety influencers of safety culture, effective leadership, risk perception, regular training and adherence of safety protocols.
- To provide practical recommendations for enhancing safety management through targeted improvements in safety influencers.

3.4 Hypothes

There were five research hypotheses proposed on the study's focus on safety influencers in lignite mining safety management:

H1: The right risk perception and leadership behaviour have significant strong safety culture within lignite mines.

H2: The strong safety culture has significant effect on the improved training compliance in safety management practices.

H3: Safety management practices has significant positive correlation with the safety influencers of safety culture, effective leadership, risk perception, regular training and adherence of safety protocols.

3.5 Description of Variables

The questionnaire is intended to provide a comprehensive evaluation of safety culture, leadership influence, risk awareness, training effectiveness, and management practices within the lignite mining industry. By analyzing responses, safety officers and management identifies strengths and areas needing improvement in their current safety framework. The results support targeted interventions to enhance overall safety performance, reduce incidents, and foster a proactive safety culture in lignite mines.

3.5.1 Measurable scale of safety influencers and safety management of Mimes

The averages around or just above 4 indicate generally positive but moderate perceptions across all areas of safety management. These values suggest that the organization has established a foundation for a safety culture, but some areas might benefit from additional focus or reinforcement, especially around making safety a core value (SC) and ensuring practical, impactful training (TC). Strengthening these aspects could lead to a more robust and universally recognized culture of safety across the organization. The higher variances (such as SC and LB) indicate more diverse responses, potentially showing areas with less consensus, while lower variances (like TC and SP) reflect more uniform agreement among respondents.

3.5.2 Safety Culture: General Safety Culture and Practices

The heatmap above visually represents the factor loadings of each item within Factor 1 across the five scales (SC, LB, RP, TC, and SP). Darker colours represent stronger loadings, indicating how closely each item aligns with the underlying factor for each scale. This graphical presentation allows for a quick comparison of how each item contributes to the overall factor structure. Factor 1 highlights key dimensions of organizational safety culture, leadership, risk perception, training, and safety practices, showing that safety is embedded across various organizational aspects: High loadings on items like core safety values (SC1), discussions about safety protocols (SC5), and enforcement/recognition (SC6, SC8) show a strong, shared commitment to safety, emphasizing regular dialogue and consistent standards as central to the organization's culture.

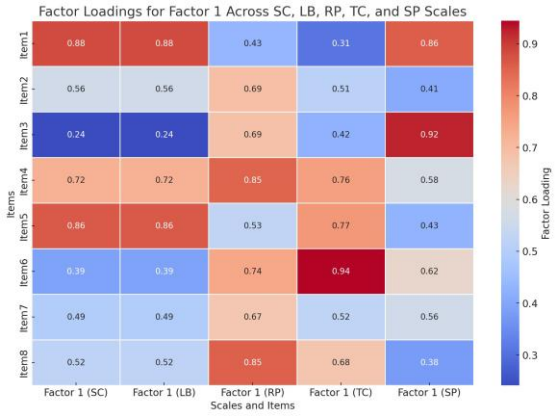

Figure 2: Heat Map Factor Loadings across SC, LB, RP, TC and SP Scales

Items related to leadership behaviours (LB1, LB5, LB4) reflect an active commitment to safety, demonstrated through support for safety training and openness to employee feedback, reinforcing leaders' role in promoting a safety-first environment. Items like confidence in risk assessments (RP4) and belief in safety audits (RP8) indicate that employees feel aware of hazards and trust in established safety protocols, supporting a culture of risk awareness. Items on training adequacy and preparedness (TC6, TC4) underscore the importance of regular, sufficient training in ensuring employees' readiness and adherence to safety protocols. High loadings on items related to protocol enforcement (SP1) and management support (SP3) reflect a strong organizational focus on consistently enforcing safety measures with solid managerial backing. Overall, Factor 1 suggests a cohesive approach to safety, where organizational culture, leadership, and practices collectively reinforce a strong commitment to safety standards and protocols.

3.6 Description of population: Employees of Mines in NLC India Limited

The population in this data is divided into different categories based on job roles, with proportions indicating the share each category holds in the total population. Executives comprising roles E1 to E9, this category has a population of 1,146 individuals, which accounts for 20 percent of the total population. Including roles S1 to S4, the Supervisors group has a population of 229, making up 4 percent of the total. The non-executive selection grade represented by roles SG1 to SG4, this group has a population of 1,440, which constitutes 25 percent of the total. The non-executive intermediate category, with roles W4 to W8, has the largest population at 2,522, representing 43 percent of the total. Finally, in the nonExecutive labour, including roles W0 to W3, this group has a population of 252, which is 9 percent of the total. The Grand Total population is 5,859, encompassing all roles and categories.

3.6.1 Sample Size Calculations and sample distribution

The sample size calculations for each group in a population of 5859 individuals is presented. The calculations are based on a 5 percent significance level and a 5 percent margin of error. This document provides the sample size calculations for each subgroup within a population of 5859 individuals, with a 5 percent margin of error and a 95 percent confidence level. The sample sizes for each subgroup was calculated using specific proportions to reflect their representation within the population. This approach ensures representation across different roles and shifts, enhancing the validity of results (Creswell and Plano Clark, 2017). The sample captured diverse experience levels, providing insights into safety practices across the workforce spectrum. The executive population size (N) of 1146 with a proportion (p)of 20 percent allowed the selection of 203 executives. Similarly, based on the supervisor population size (N) of 229 with a proportion (p) of 4.0 percent, 47 members were selected. The non-executive selection grade population size (N) of 1140 with a proportion (p) of 25.0 percent, favoured the selection of 230 of them. The non-executive intermediate population

size (N) of 2522 with a proportion (p) of 43.0 percent allowed the selection of 328 of them. The non-executive worker population size (N) of 252 with a proportion (p) of 9.0 percent ended in the selection of 84 workers. The overall sample size across all subgroups is 892. This sample size ensures that each subgroup is adequately represented, reflecting their specific proportions within the overall population. A sample of individuals, including miners, supervisors, and safety managers, was selected from three lignite mines using random sampling.

3.7 Limitations

• Generality: This study focuses on lignite coal mines, so findings may not be fully applicable to other mining types or industries. • Response Bias: Participants may underreport incidents or overstate compliance due to fear of repercussions, potentially skewing results (Podsakoff et al., 2003). • Data Access Constraints: Some mines may restrict access to detailed incident data, limiting the depth of quantitative analysis and comparison (Hopkins, 2019).

4. RESULTS AND INTERPRETATIONS

4.1 Reliability of dataset

This approach provides a structured framework for analyzing survey data and interpreting the impact of safety influencers on safety management in lignite coal mines. The calculated Cronbach's Alpha value for this sample dataset is 0.68, which is favourable, as Cronbach's Alpha should typically range from 0 to 1. A positive value suggests there were no potential issues with the dataset, such as high item inter-correlation or a consistent structure in the items measured. The reliability analysis shows that most constructs in the study exhibit strong internal consistency, as indicated by high Cronbach's Alpha values (above 0.97) for Safety Core Value (SC), Risk Perception (RP), Training Compliance (TC), and Safety Practices (SP). This reflects consistent responses across these scales. However, Leadership Behaviours (LB) has a lower Alpha of 0.56, suggesting variability in responses and a need for refinement. The Composite Reliability (CR) and Average Variance Extracted (AVE) for each construct further confirm this consistency. CR values are close to or above the acceptable threshold of 0.7, indicating reliability across the constructs. AVE values for each construct are above 0.5, meeting the standard for good convergent validity, which suggests that each construct effectively captures the variance in its indicators. High AVE values for Safety Management Performance (0.706) and Leadership Behaviour (0.673) indicate particularly robust construct validity, supporting the model's reliability in measuring safety performance outcomes. Overall, these results affirm the model's robustness and effectiveness in explaining safety management factors in a high-risk environment.

4.2 Descriptive Statistics

The average values for each scale (SC, LB, RP, TC, SP) represent the central tendency or general level of agreement among respondents about different aspects of workplace safety. Here's what these averages suggest about employee perceptions: The data analysis reveals moderately positive perceptions across all aspects of workplace safety, with some areas showing room for improvement: Employees moderately agree on safety as a core value (avg. 3.87, variance 1.10), though the score suggests it could be more deeply embedded in the culture. The higher variance indicates mixed views on the importance of safety. Leadership commitment to safety is seen positively (avg. 4.08, variance 1.06), reflecting supportive safety practices, though there is room for leadership to demonstrate even greater safety commitment. Variance suggests some inconsistencies in employee perceptions of leadership's safety approach. Employees generally understand risks and safety protocols (avg. 4.03, variance 0.94), but additional training could enhance risk awareness further. Lower variance indicates more consistent views on risk perception. Training is viewed positively (avg. 3.99, variance 0.80), though there is potential to improve practical training and preparedness. Lower variance suggests relatively uniform agreement on training effectiveness. Safety protocols are generally seen as effective (avg. 3.97, variance 0.74), though some employees feel they could be enforced more consistently. The low variance implies strong agreement on the organization's commitment to safety practices. In summary, while employees hold favourable views on safety aspects, targeted improvements in embedding safety values, enhancing leadership's role, and strengthening training could further solidify safety practices across the organization.

4.3 PLS-SEM Development

Path Coefficient Interpretation Summary

4.3.1 Leadership Behaviour → Safety Culture Coefficient: -0.608

Interpretation: This negative coefficient suggests that higher scores in Leadership Behaviour are associated with a lower perceived Safety Culture score. This counterintuitive result may indicate that certain leadership behaviour may inadvertently suppress aspects of safety culture, possibly due to overemphasis on control or procedural adherence without fostering a collaborative culture. Statistical Significance: p ¡ 0.001, indicating this relationship is statistically significant.

4.3.2 Risk Perception → Safety Culture Coefficient: 1.588

Interpretation: This positive coefficient signifies that an increase in Risk Perception is associated with a stronger Safety Culture. This implies that when employees perceive higher risk, they may engage more actively in maintaining and reinforcing safety culture norms. Statistical Significance: p ¡ 0.001, highlighting a strong, significant positive relationship.

4.3.3 Safety Culture → Training Compliance Coefficient: 0.794

Interpretation: The positive coefficient suggests that a robust Safety Culture promotes better Training Compliance. When safety culture is valued and emphasized, employees are more likely to comply with training protocols and safety guidelines. Statistical Significance: p ¡ 0.001, indicating this relationship is statistically significant.

4.3.4 Training Compliance → Safety Management Performance Coefficient: 0.906

Interpretation: This positive and substantial coefficient indicates that higher Training Compliance directly improves Safety Management Performance. This implies that adherence to training is critical for achieving optimal safety performance in the workplace. Statistical Significance: p ¡ 0.001, confirming the strong, significant impact of training compliance on safety management outcomes.

4.3.5 Path model

The path model illustrates that Risk Perception and Leadership behaviour on Safety Culture are essential for fostering Training Compliance, which in turn is a key driver of Safety Management Performance. All relationships are statistically significant, emphasizing the model's robustness and the interconnectedness of these factors in promoting workplace safety.

4.3.6 Model Fit Indices from the Current PLS-SEM Analysis

R-squared (R^2) Values:

Leadership Behaviour and Risk Perception (R^2 = 0.889) together explain 88.9 percent of the variance in Safety Culture, indicating a strong model fit. Safety Culture explains (R^2 = 0.965) 96.5 percent of the variance in Training Compliance, showing a robust predictive power of Safety Culture on Training Compliance. Training Compliance (R^2 = 0.892) explains 89.2 percent of the variance in Safety Management Performance (R2 = ¿ .929), highlighting a high predictive accuracy for this path (-0.378).

Overall Model Fit:

Based on the high R^2 values across paths, the model demonstrates strong explanatory power, particularly in linking constructs sequentially from Leadership Behaviour and Risk Perception through to Safety Management Performance. Given the statistical significance and high R^2 values, this PLS-SEM model demonstrates robust fit and effective predictive relationships among constructs. This PLS-SEM model shows strong explanatory power and a good fit, with each dependent construct's variance largely accounted for by its predictors. The high R^2 values suggest the model captures the relationships effectively, indicating the potential utility of improving Safety Culture and Training Compliance as interventions to enhance Safety Management Performance. For a complete evaluation of model fit, calculating SRMR and additional fit indices in dedicated SEM software would provide a more precise measure of model fit quality.

The RMSE values for each construct path in the PLS-SEM model are as follows: The predicted values for Safety Culture deviate from the observed values by an average of 0.068 units. The predicted Training Compliance scores differ from the observed scores by an average of 0.082 units. The model's predictions for Safety Management Performance deviate from the observed values by approximately 0.279 units on average. Lower RMSE values for Safety Culture and Training Compliance suggest that these constructs are well-represented by the model, while the higher RMSE for Safety Management Performance may indicate room for improvement in the model's predictive accuracy for this construct.

Standardized Root Mean Square Residual (SRMR) for the PLS-SEM model An SRMR value below 0.08 is generally considered to indicate a good model fit. However, with an SRMR of 0.327, this model has a higher-than-ideal residual discrepancy between observed and predicted correlations, suggesting room for improvement. This higher SRMR value indicates that the model may not fully capture the relationships among the constructs, and adding or adjusting variables could improve the fit.

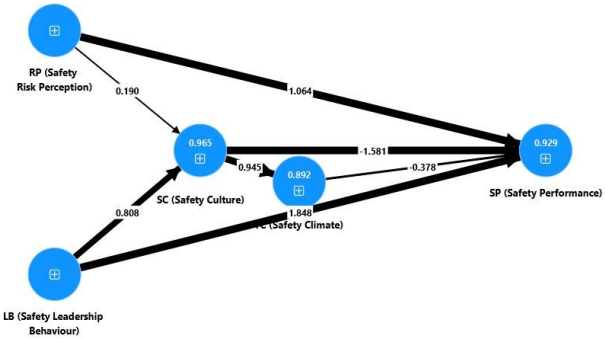

Figure 3: Mine's Safety PLS-SEM

5. FINDINGS, RECOMMENDATION AND CONCLUSION

The study identified several key safety influencers, including safety culture, leadership behaviour, risk perception, and training compliance, as significant determinants in safety management within lignite coal mines at NLC India Limited.

5.1 Findings

1. Safety culture emerged as a strong predictor of safety protocol adherence and risk perception among workers. 2. Effective leadership, particularly transformational leadership styles, positively influenced workers' safety compliance by fostering a supportive environment for safety practices. 3. Moreover, regular safety training reinforced risk awareness and compliance, contributing to a proactive safety culture. Additionally, technological advancements, such as real-time monitoring systems, have played a role in enhancing mine safety management by enabling early hazard detection and prompt response.

4. The findings from this study on safety influencers at NLC India Limited align closely with existing research on safety culture and leadership in high-risk industries, particularly mining. Previous studies underscore similar conclusions regarding the impact of safety culture, leadership, and risk perception on safety outcomes. 5. Safety Culture: This study identified safety culture as a crucial factor influencing safety

management practices. Research by Guldenmund (2000) and Mearns et al. (2003) similarly noted that safety culture is a primary predictor of safety compliance, particularly in high-risk industries. These studies emphasize that a strong safety culture not only reduces incidents but also fosters a proactive approach to risk management, corroborating findings at NLC India Limited that highlight the positive relationship between safety culture and compliance with safety protocols. 6. Leadership Influence: The current study found that effective leadership, especially transformational leadership styles, positively impacts worker compliance and risk awareness. Clarke (2013) also reported that transformational leadership styles contribute to a safer work environment by promoting supportive communication and safety-oriented behaviours. Similarly, Kines et al. (2010) found that leadership that actively promotes safety standards and communication can significantly reduce incidents. This alignment reinforces the importance of leadership behaviour in shaping safety practices, suggesting that NLC India Limited's approach to leadership development could enhance safety outcomes. 7. Risk Perception and Training:

The study noted that safety training improves risk perception and adherence to safety standards, a finding consistent with Burke et al. (2006), who demonstrated that frequent and targeted safety training enhances compliance with safety protocols. Wogalter (2006) also highlighted that heightened risk perception, often influenced by past incidents and situational awareness, encourages safer behaviours among employees. This supports the notion that increasing risk perception through targeted training can positively impact safety outcomes in high-risk settings like lignite mining. 8. Technological Integration: This study observed that advanced safety monitoring systems enhance safety management by enabling real-time hazard identification. Similar findings were reported by Zhigao et al. (2017), who noted that wearable devices and gas sensors significantly improve safety outcomes by providing personnel tracking capabilities. The use of predictive analytics, as highlighted in Qingming (2018), further supports the conclusion that technological tools are crucial for effective safety management in complex and high-risk environments like mining. 9. In summary, the study at NLC India Limited reflects broader findings in the safety management literature, particularly regarding the interplay between safety culture, leadership, training, and technology. These results affirm that a comprehensive approach, integrating both human and technological factors, is essential for reducing incidents and promoting a safety-conscious workforce in mining. Further, the alignment with other studies suggests that best practices in safety management are highly transferable across various high-risk industries, emphasizing the value of a well-rounded safety strategy that incorporates leadership, culture, and advanced technology.

5.2 Recommendations

1. Enhancing Safety Leadership: Leadership training programs should focus on integrating safety as a core value, emphasizing transformational leadership approaches that encourage open communication and active involvement in safety initiatives. This approach will help align leadership behaviour with safety culture, fostering an environment that prioritizes worker safety. 2. Strengthening Safety Training: Implement continuous, comprehensive training that emphasizes risk assessment and emergency preparedness. The training should be designed to enhance practical application and should be frequently updated to reflect the evolving challenges in mine safety. Periodic assessments should be conducted to gauge training effectiveness. 3. Technological Integration: Invest in and continuously improve safety technology, such as real-time monitoring and predictive analytics, to reduce the potential for incidents. Integrating wearable technology and geographic information systems (GIS) can improve personnel tracking and environmental monitoring, contributing to timely intervention in hazardous situations. 4. Fostering a Proactive Safety Culture: Promote a strong safety culture by encouraging open reporting of hazards without fear of repercussions. Recognize and reward compliance with safety protocols to embed safety values deeply within the organizational culture.

6. CONCLUSION

The study underscores the importance of a holistic safety management approach in lignite mines, combining robust leadership, effective training, a strong safety culture, and advanced technology to create a safe working environment. Addressing human and organizational factors, in addition to technological advancements, can lead to a more resilient safety framework, minimizing incidents and enhancing worker protection. Through continuous improvement in leadership, training, and safety culture, NLC India Limited can further strengthen its safety management practices, thereby fostering a safe, compliant, and proactive workforce.

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