

OPERATIONAL RISK MANAGEMENT IN THE MINING TRANSITION: A CASE STUDY OF PT FREEPORT INDONESIA'S GRASBERG BLOCK CAVE (GBC) IMPLEMENTATION

**Cleyvains Fresly Wulandari^{1*}, Dita Fadila Artamiye C. S², Rifasya Nurul Ramadanti³,
Alvianus Kristian Sumual⁴, Riva Ananda Br Pelawi⁵**
^{1,2,3,4,5}Kalimantan Institute of Technology
***Email Correspondence: 17231014@student.itk.ac.id**

Abstract

The transition from the Grasberg open pit to the Grasberg Block Cave (GBC) underground mine has placed PT Freeport Indonesia in a phase of high operational risk, while its risk management assessment within the ISO 31000 framework remains limited. This study aims to identify the key operational risks associated with the transition and implementation of GBC, as well as to analyze the mitigation strategies applied and their alignment with ISO 31000 principles. A qualitative case study approach was employed through content analysis of PT Freeport Indonesia/Freeport-McMoRan's sustainability and annual reports from 2019 to 2024, supported by relevant technical literature. The findings indicate that PT Freeport Indonesia has established a relatively comprehensive risk management cycle; however, the occurrence of fatalities and recurring incident rates suggests that non-geotechnical risks particularly those related to transportation, supporting activities, and the management of new workers and contractors have not yet been fully controlled.

Keywords: Operational Risk Management, Underground Mining, Block Caving, Grasberg Block Cave, ISO 31000.

INTRODUCTION

PT Freeport Indonesia (PTFI) operates one of the world's largest copper and gold reserves located in Mimika, Papua, with the Grasberg open pit serving as the backbone of production until its official closure in 2019 (Casten et al., 2020). Following this closure, the continuity of PTFI's production depends on the successful transition to the *Grasberg Block Cave* (GBC) underground mine, which is designed as one of the world's largest block caving operations and plays a strategic role in maintaining production output and the company's economic contribution (Melati et al., 2023). This transition phase from the Grasberg open pit to GBC represents a critical period from an operational risk management perspective.

The block caving method carries significantly different risk characteristics compared to open-pit mining, as it is highly dependent on rock mass behavior and the controlled success of cave propagation (Melati et al., 2023). Potential hazards such as ground collapse, cave propagation failure, wet muck flow, and inrush events may disrupt long-term production and elevate the risk of occupational accidents (Pereira et al., 2023). In the context of GBC, technical studies have shown that the configuration of the undercut ventilation system, the placement of auxiliary fans, and the design of vent bags directly influence the smoke-clearing rate after blasting and the safe re-entry duration for workers

(Cahyono, 2020).

Underground mining operations in general are categorized as high-risk industries, requiring the implementation of structured and consistent risk management systems (Novaryan et al., 2021). From a theoretical standpoint, operational risk management in high-risk sectors can refer to the ISO 31000 framework, which emphasizes a series of integrated stages establishing context, identifying, analyzing, evaluating, treating, and monitoring risks aligned with organizational decision-making processes (ISO, 2018). This framework provides a foundation to assess the extent to which operational risk management practices applied in the Grasberg–GBC transition have been systematically designed and implemented in accordance with internationally recognized risk management principles.

A gap analysis of previous studies reveals that research related to Grasberg and GBC has been dominated by geotechnical, design, and technical optimization aspects, as well as block caving production ramp-up analyses, without specifically evaluating the operational risk management system during the company's strategic transition phase (Campbell et al., 2018). Meanwhile, literature on underground mine safety at PTFI has largely focused on behavioral interventions and individual-level safety practices, rather than on system-level operational risk management explicitly referenced to the ISO 31000 framework (Novaryan et al., 2021).

The novelty of this study lies in its in-depth analysis of specific operational risks emerging during the transition and implementation of GBC, along with a systematic review of the technical and managerial mitigation strategies adopted by PTFI through the lens of ISO 31000 (ISO, 2018). Therefore, the purpose of this research is to identify the key operational risks in the transition and implementation of GBC, analyze the operational risk mitigation strategies employed by PTFI, and assess their alignment with the principles and stages of risk management as outlined in the ISO 31000 framework (ISO, 2018).

METHOD

This study employs a qualitative research design using a case study approach focusing on the operational risk management of PT Freeport Indonesia during the transition period from the Grasberg open pit to the Grasberg Block Cave (GBC) underground mining operation, from 2019 to the present. The research population comprises all operational risk management practices and policies related to PTFI's underground operations during this transitional phase, while the research subject is the operational risk management system of the GBC mine, encompassing geotechnical, ventilation, production, and occupational safety aspects.

The study utilizes secondary data obtained through document analysis of PT Freeport Indonesia's sustainability and annual reports, as well as scientific articles and mining engineering journals discussing the design and geotechnical challenges of GBC, along with scholarly publications on underground mine safety and risk management (Campbell et al., 2018). Document selection was conducted purposively based on relevance to the topic of GBC operational risk management and its relation to the 2019–present transition period. The collected data were analyzed using content analysis guided by categories derived from

the ISO 31000 framework namely, establishing context, risk identification, risk analysis, risk evaluation, and risk treatment and monitoring to generate key themes on GBC's operational risk profile and the mitigation patterns implemented by PTFI (ISO, 2018).

RESULTS AND DISCUSSION

Content analysis of PT Freeport Indonesia's (PTFI) and Freeport-McMoRan's (FCX) sustainability and annual reports for the 2019–2024 period indicates that the transition from the Grasberg open pit to full-scale underground operations has placed the company in a phase of heightened operational risk pressure. Between 2019 and 2022, the company's Total Recordable Incident Rate (TRIR) ranged from 0.69 to 0.77 per 200,000 working hours, with the percentage of high-risk events showing a declining trend and stabilizing at around 7%, while the number of fatalities fluctuated between one and five per year (FCX, 2022). These data suggest that the quality of control over high-risk activities has improved; however, the overall frequency of incidents and the continued occurrence of fatalities indicate that operational risks have not yet been fully mitigated.

Table 1. Summary of FCX Safety Performance, 2019 – 2022

Year	TRIR	Fatalities	High-Risk Events (%)
2019	0,71	3	11
2020	0,69	5	7
2021	0,70	2	7
2022	0,77	1	7

At the site level, the 2019 report recorded a *mud rush* incident that resulted in the deaths of two Grasberg workers, while in 2020 five fatalities occurred related to vehicle accidents, heavy equipment movement exposure, an explosion on a survey vessel, and falls from height. In 2021, one contractor was killed after losing control of a vehicle on the main supply road (PTFI, 2019; PTFI, 2020; PTFI, 2021). This pattern indicates that, in addition to typical block caving hazards such as wet muck and rock mass instability, non-geotechnical risks associated with logistics chains and supporting activities remain significant sources of fatal exposure. This aligns with the inherent risk characteristics of block caving operations, which depend heavily on controlled rock mass behavior and cave propagation (Melati et al., 2023).

Regarding the implementation of the ISO 31000 framework, the analysis reveals that PTFI has developed a relatively comprehensive operational risk management system. The stages of risk identification, analysis, and evaluation are operationalized through the use of a corporate risk register that classifies incidents based on consequence levels and fatality potential, accompanied by the monitoring of leading and lagging indicators such as high-risk events and TRIR (FCX, 2022). The risk treatment stage is reflected in the strengthening of the Fatality Risk Management program, field verification of critical controls supported by digital applications, intensive underground hazard training for GBC workers, the use of autonomous and remote-operated equipment to minimize direct

exposure to ground failure and wet muck, and the implementation of a Ground Control Management Plan developed by geotechnical experts (PTFI, 2020; Campbell et al., 2018). On the environmental dimension, the company has implemented the ModADA and Tailings Management Roadmap systems in collaboration with the government, allocated significant expenditures for environmental monitoring, obtained Copper Mark validation, and begun transitioning its Grasberg operational energy mix from coal to natural gas. These measures demonstrate the integration of environmental and climate-related risks into PTFI's broader operational risk management framework (PTFI, 2019; PTFI, 2024).

The application of ISO 31000 at PTFI has contributed to strengthening the structure of operational risk management during the transition to GBC; however, its effectiveness is reflected mainly in the reduction of high-risk event proportions rather than in the elimination of fatalities. This finding is consistent with block caving literature, which emphasizes that the success of underground operations is determined not only by technical design and geotechnical control but also by human resource capability, supervision quality, and contractor management within the complexity of large-scale operations (Casten et al., 2020; Novaryan et al., 2021).

The limitation of this study lies in its reliance on aggregated secondary data, which does not allow for the quantitative separation of PTFI's specific contribution from other FCX operations; therefore, interpretations should be made with caution. The practical implication is that PTFI management should sharpen its focus on non-geotechnical risks particularly those related to transportation and supporting activities strengthen programs for new workers and newly appointed supervisors, and continue integrating technical, organizational, and environmental controls within a single risk management framework aligned with ISO 31000 principles.

CONCLUSION

Based on the analysis of PT Freeport Indonesia's (PTFI) and Freeport-McMoRan's (FCX) sustainability and annual reports for the 2019–2024 period, it can be concluded that the implementation of operational risk management during the transition from the Grasberg open pit to the Grasberg Block Cave (GBC) underground mine has been carried out in a systematic manner and, in many respects, aligns with the ISO 31000 framework. PTFI has established a risk management cycle encompassing risk identification, analysis, evaluation, and treatment through the use of a corporate risk register, the implementation of the Fatality Risk Management program, reinforcement of geotechnical and ventilation designs, the adoption of automation technologies, and the integration of tailings and environmental management consistent with regulatory commitments and global standards. These efforts have contributed to a decline in the proportion of high-risk incidents and a strengthening of technical, organizational, and environmental risk governance during the underground ramp-up phase. However, the persistence of fatalities and the stable TRIR indicate that operational risks are not yet fully controlled particularly in non-geotechnical domains such as transportation, supporting activities, and the management of new workers and contractors.

Accordingly, this study underscores that the success of large-scale underground mining transitions depends not only on the sophistication of block caving technical solutions but also on the depth of ISO 31000 implementation within human and organizational dimensions. The findings provide a comprehensive overview of the strengths and areas for improvement in PTFI's operational risk management system, offering valuable insights for practitioners and stakeholders. Furthermore, the results serve as a reference for policy development and future research on risk management in similar mining transition projects, ensuring the practical relevance and broader implications of this study.

BIBLIOGRAPHY

- Campbell, R., Banda, H., Fajar, J., & Brannon, C. (2018). Optimising for success at the Grasberg Block Cave. In Y. Potvin & J. Jakubec (Eds.), *Caving 2018: Proceedings of the Fourth International Symposium on Block and Sublevel Caving* (pp. 3–18). Australian Centre for Geomechanics.
- Casten, T., Johnson, M., Zimmer, C., & Mahayasa, M. (2020). PT Freeport Indonesia – The transition to underground production. In *Proceedings of MassMin 2020* (pp. 1–12).
- Cahyono, Y. D. G. (2020). Technical planning of ventilation system to support development W undercut in 2021 at PT Freeport Indonesia underground mining. *Journal of Earth and Marine Technology*, 1(1), 1–6. <https://doi.org/10.31284/j.jemt.2020.v1i1.1141>
- Freeport-McMoRan Inc. (2019). 2019 annual report on sustainability: Building on strength. Freeport-McMoRan Inc.
- Freeport-McMoRan Inc. (2020). 2020 annual report on sustainability: Charging ahead responsibly, reliably, relentlessly. Freeport-McMoRan Inc.
- Freeport-McMoRan Inc. (2021). 2021 annual report on sustainability: Electrifying the future. Freeport-McMoRan Inc.
- Freeport-McMoRan Inc. (2022). 2022 annual report on sustainability. Freeport-McMoRan Inc.
- Freeport-McMoRan Inc. (2024, April 25). Freeport-McMoRan publishes 2023 annual report on sustainability [Press release]. Freeport-McMoRan Inc.
- International Organization for Standardization. (2018). *ISO 31000:2018 risk management Guidelines*. ISO.
- Melati, S., Wattimena, R. K., Sahara, D. P., Syafrizal, Simangunsong, G. M., Hidayat, W., Riyanto, E., & Felisia, R. R. S. (2023). Block caving mining method: Transformation and its potency in Indonesia. *Energies*, 16(1), 9. <https://doi.org/10.3390/en16010009>
- Novaryan, O. Y., Setyaningsih, Y., & Suroto. (2021). Intervensi pemaparan modul resiko utama tambang bawah tanah terhadap peningkatan pengetahuan, sikap, dan praktik kontrol kritis resiko fatal pada petugas safety lapangan. *Jurnal Sains Terapan*, 7(1), 33–40.
- Pasaribu, F., & Anggono, A. H. (2012). Resolving accommodation deficit at PT Freeport Indonesia: An analysis approach using NPV calculation. *The Indonesian Journal of Business Administration*, 1(7), 452–456.
- PT Freeport Indonesia. (2024). *Keberlanjutan PT Freeport Indonesia 2023/2024*. PT Freeport Indonesia.
- Rahmi, R., Dewi, S. N., & Oktaria, Y. (2025). *Literatur review: Occupational health and*

safety impact assessment in underground mining operations. *Journal of Healthcare Technology and Medicine*, 11(1), 573–582.

Pereira, M., Castro, R., & Manríquez, F. (2023). Improving block caving production by incorporating operational risks in short-term scheduling. *International Journal of Rock Mechanics and Mining Sciences*, 170, 105537. <https://doi.org/10.1016/j.ijrmms.2023.105537>