Optimizing Cost and Project Management in Zambia's Mining Infrastructure Projects: A Case of Lubambe Copper Mine Limited

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DOI: https://dx.doi.org/10.47772/IJRISS.2026.10200545

Received: 28 February 2026; Accepted: 05 March 2026; Published: 19 March 2026

ABSTRACT

The mining sector remains a cornerstone of Zambia's economy through its contribution to gross domestic product, export earnings, and employment. Despite this importance, mining infrastructure projects continue to experience persistent cost inefficiencies and project management challenges that undermine operational performance. This study investigated the factors influencing the optimization of cost and project management in Zambia's mining infrastructure projects, using Lubambe Copper Mine as a qualitative case study. The research adopted a qualitative case study design and purposively engaged ten expert participants drawn from engineering, project management, cost control, and senior management roles directly involved in project planning, implementation, and financial oversight. Primary data were collected through semi structured questionnaires and analyzed using a thematic analysis approach. The analysis followed a systematic coding process that involved initial familiarization with the data, open coding to identify meaningful units of information, axial coding to group related codes, and selective coding to consolidate these groups into higher order themes. Themes were derived inductively based on patterns of recurrence, emphasis, and explanatory strength across participant responses, ensuring that findings were grounded in participants' lived experiences and professional insights. The findings revealed five dominant and interrelated themes influencing cost and project management optimization. The most prominent themes were procurement and supply chain inefficiencies and weak scope definition, both of which were consistently identified as primary drivers of cost overruns and project delays. These were followed by workforce competence gaps and limited integration of technological systems, which constrained coordination and real time cost control. Leadership discipline and accountability emerged as a cross-cutting theme shaping the effectiveness of all other factors. Integration between cost and project management was found to be further constrained by institutional rigidity, fragmented information systems, poor interdepartmental communication, and cultural resistance to change. Based on these prioritized themes, the study developed a four-stage optimization framework comprising collaborative planning, synchronized execution, real time monitoring, and continuous feedback. The study recommends policy and regulatory support from the Ministry of Mines and Minerals Development, the Zambia Public Procurement Authority, and the Engineering Institution of Zambia, alongside the adoption of integrated enterprise resource planning systems and sustained capacity building within mining firms. The study contributes to knowledge by offering an empirically grounded and context specific framework for integrating cost and project management in mining infrastructure projects within developing economies.

INTRODUCTION

Mining infrastructure projects involve the development of critical facilities and systems that support mineral extraction, processing, and transportation, including roads, railways, power supply systems, water management facilities, processing plants, and ports (Signé, 2021). These projects are essential for ensuring efficient mining operations by providing the logistical and structural backbone required for production and distribution. Inadequate infrastructure leads to increased operational costs, heightened safety risks, and reduced production efficiency, thereby constraining the performance and competitiveness of mining firms (Azubuike, et al., 2022).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

Consequently, effective planning and management of mining infrastructure are fundamental to sustaining productivity and operational stability.

Mining infrastructure projects play a crucial role in national economic development, particularly in resource-rich countries. They stimulate economic growth by generating employment, attracting foreign direct investment, and supporting downstream industries dependent on mineral inputs (Du, et al., 2022). Furthermore, these projects promote the development of rural and remote regions by improving connectivity, energy access, and essential social amenities. Well-established infrastructure also facilitates efficient mineral exports, thereby enhancing foreign exchange earnings and contributing to broader national development goals (Kaiser & Barstow, 2022). Optimally functioning infrastructure benefits both mining companies and the nation by reducing operational costs, improving productivity, ensuring safety, and increasing public revenues for socio-economic development (Weldegiorgis, 2023).

Zambia's mining sector remains the backbone of its economy, contributing approximately 12.9 percent to the national GDP in 2022 and accounting for about 69 percent of total export earnings, largely driven by copper production (Sinkamba, 2024; Aurélien, et al., 2022). Major mining activities are concentrated in the Copperbelt and North-Western Provinces, with key operations including Mufulira and Nkana Mines, alongside significant emerald mining in Ndola Rural and coal production in Sinazongwe District (Kolala & Dokowe, 2021; Pardieu, et al., 2021). Substantial investments in mining infrastructure, such as the rehabilitation of rail and road networks, have been prioritised, with notable allocations made in the 2024 national budget to enhance transportation efficiency and support mining operations (Zambia Railways Limited, 2024). [See figure 1].

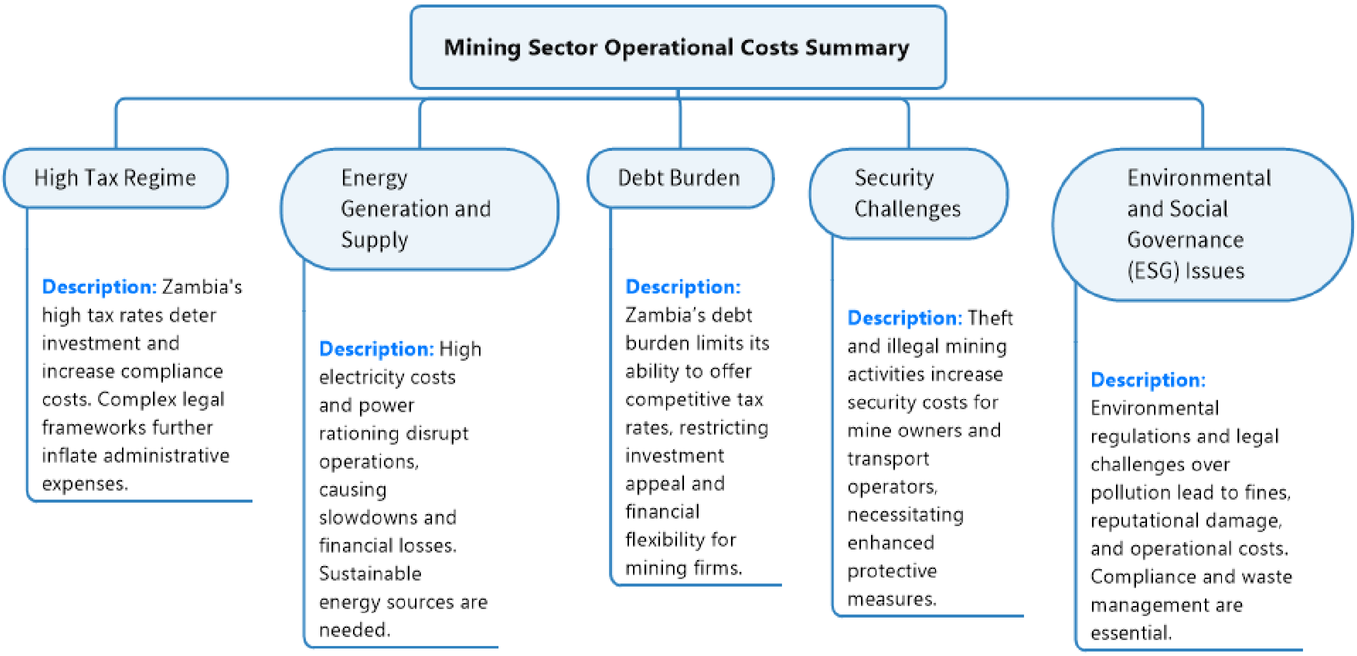

Figure 1. Summary of documented operational costs in the mining sector

Despite its economic significance, Zambia's mining sector faces persistent challenges that undermine operational efficiency and cost management. High tax rates and complex regulatory frameworks increase administrative burdens and deter investment, necessitating reforms to enhance competitiveness and attract capital inflows (Jalasi, et al., 2024; Steenkamp, 2024). Energy shortages and high electricity costs further constrain production efficiency, underscoring the need for sustainable power solutions and improved project management strategies (Kasoma, 2024; Malama & Mutale, 2024). Additionally, Zambia's debt burden limits fiscal flexibility, compelling mining firms to adopt innovative cost optimisation strategies to maintain financial viability (Christou, et al., 2024). Security challenges, including theft and illegal mining, alongside stringent environmental and social governance requirements, further escalate operational costs, highlighting the urgent need for robust project and cost management frameworks to ensure sustainable mining infrastructure development (Buzinkay, 2024; Chitemba, et al., 2025). (See figure 1).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

Given the capital-intensive and high-risk nature of mining projects, cost and project management optimization is crucial. Cost management involves controlling expenditures to keep projects financially viable, while project management ensures that scope, timelines, and quality standards are met (Buthelezi & Naidoo , 2024). In Zambia's mining industry, where cost overruns and delays are common, integrating these two functions can lead to enhanced productivity, risk mitigation, and sustainability. However, the literature reveals that while both aspects have been studied independently, their integration—particularly in the Zambian context—has not been fully explored. This study responds to this gap by investigating key cost drivers and project management inefficiencies, addressing Objective (i): to establish variables associated with cost and project management optimization.

Additionally, barriers such as inconsistent tax policy, energy shortages, environmental obligations, and inadequate security measures present significant integration challenges. The study will examine how these constraints impact the operational environment of mining infrastructure projects, addressing Objective (ii): to determine barriers associated with the integration of cost and project management.

Furthermore, while Zambia has made notable investments in mining-related infrastructure, such as allocating K234.4 million to road and rail transport services (Zambia Railways Limited, 2024), the return on these investments is hindered by weak project management practices and rising operational costs. This study, therefore, seeks to develop a context-specific, holistic framework to guide mining companies in integrating cost optimization into project execution. This aligns with Objective (iii): to develop a flow of integrated strategies for optimizing cost and project management in Zambia's mining infrastructure projects.

In summary, the need for this study stems from the growing financial and operational challenges in Zambia's mining sector, the fragmented treatment of cost and project management in existing literature, and the sector's pivotal role in national development. By identifying key variables, diagnosing integration barriers, and proposing practical strategies, this study aims to contribute meaningfully to both academic understanding and policy-making for mining infrastructure optimization in Zambia.

Lubambe Copper Mine Limited owns and operates the Lubambe underground copper mine situated in Chililabombwe District of Zambia's Copperbelt Province. The mine commenced operations in 2012 and is located approximately 468 kilometres north of Lusaka, 152 kilometres from Ndola, and about 40 kilometres from Chingola (Lubambe Copper Mine, 2025). The mining area covers approximately 58.1 square kilometres and includes an underground mining operation with two distinct ore bodies, namely the East and South Limbs, as well as a processing plant with an annual capacity of up to 2.4 million tonnes.

Lubambe Copper Mine forms part of the Konkola Musoshi Basin, which lies within one of the world's largest copper-producing regions. Mineralisation occurs within organic-rich siltstone and shale formations known locally as the Ore Shale, forming the basal unit of the Kitwe Formation (Lubambe Copper Mine, 2025). The deposit has a global average grade of 1.95 percent total copper, with ore thickness varying between 2.0 and 6.0 metres across a strike length of approximately five kilometres. The mine produces high grade copper concentrate averaging 40 percent copper, which is sold to local smelters. The total workforce is estimated at 2,650 full time equivalents, supported by key transport infrastructure connecting Chingola to Kasumbalesa.

Historically, Lubambe has faced considerable cost challenges that have affected operational performance. In 2018, production increased by 16 percent, reaching 5,545 tonnes in the third quarter, although management emphasised the continued need for cost containment and operational efficiency improvements to meet annual production targets (The Eagle, 2018). Investments in modern safety equipment and productivity enhancing technologies were implemented to reduce operational costs and improve efficiency. In 2019, additional metallurgical upgrades were introduced to improve concentrate quality and reduce smelter penalties, which had previously cost up to US$2 million annually. These upgrades led to significant improvements in concentrate purity and reduced treatment and transport expenses (The Eagle, 2019).

Despite these interventions, Lubambe continues to experience persistent operational and cost management challenges. Production shortfalls, declining ore grades, and geotechnical instability, particularly sinkhole formation, have disrupted mining activities and increased operational risks and expenses. Between 2020 and

2021, several sinkholes were recorded, leading to increased safety concerns and higher costs associated with stabilization and monitoring (Mutambo, et al., 2024). Ownership transitions have also introduced restructuring costs and operational disruptions. These ongoing challenges highlight the necessity for improved cost optimization and project management strategies to enhance efficiency, sustainability, and long-term profitability within Zambia's mining infrastructure sector.

Research problem

The mining sector plays a pivotal role in Zambia's economy, contributing approximately 10% to GDP, 70% to export earnings, and providing direct employment to over 90,000 people (Bank of Zambia, 2023). However, despite its economic significance, the sector faces persistent operational inefficiencies and cost management challenges that hinder its full potential. Lubambe Copper Mine's experience serves as a microcosm of these industry-wide struggles. Following EMR Capital's acquisition in 2017, the mine implemented various cost optimization measures, including a US$457,000 investment in emergency refuge chambers and installation of a second flotation column to reduce US$2 million in annual smelter penalties (The Eagle, 2018; 2019). While these interventions improved concentrate quality and reduced some operational costs, the mine continued to face fundamental challenges including production shortfalls, lower-than-expected ore grades, and unexpected geotechnical issues. Between 2020-2021, six sudden sinkholes disrupted operations, highlighting the complex interplay between geological risks and cost management in Zambia's mining sector (Mutambo et al., 2024).

The broader Zambian mining industry contends with additional systemic challenges that compound these operational difficulties. The sector operates under one of the world's highest tax regimes, with mineral royalty rates reaching 10% and corporate income tax at 30%, creating significant financial burdens for operators (Jalasi, Simbeye & Chinyemba, 2024). Energy supply issues further exacerbate costs, with electricity tariffs increasing by over 200% since 2017 and frequent power outages forcing mines to rely on expensive diesel generators (Kasoma, 2024). Security concerns add another layer of expense, with mining companies spending an estimated US$50 million annually on combating theft and illegal mining activities (Buzinkay, 2024). Environmental compliance has also emerged as a major cost driver, as evidenced by the high-profile US$1.5 billion lawsuit against Vedanta Resources and Konkola Copper Mines for environmental damage (Chitemba, Bwalya & Kalanda, 2025).

These multifaceted challenges underscore the critical need for comprehensive research into cost optimization and project management in Zambia's mining sector. While individual mines like Lubambe have implemented targeted solutions, there remains a lack of systematic analysis of industry-wide cost drivers and best practices for mitigation. This study addresses this gap by pursuing three key objectives: first, identifying the primary cost drivers affecting Zambian mining infrastructure projects; second, evaluating current cost management and project management practices; and third, developing an integrated framework for operational and financial optimization. The research will draw on Lubambe's case study experience while incorporating broader sector analysis to provide actionable insights for both mining operators and policymakers (see figure 2).

The significance of this study extends beyond academic interest. For mining companies, the findings will offer evidence-based strategies to improve cost efficiency and project execution. For policymakers, the research will provide data-driven recommendations for regulatory reforms that balance fiscal objectives with industry competitiveness. With Zambia's mining sector facing increasing pressure from global market fluctuations and domestic economic challenges, this study's recommendations could contribute to the sector's long-term sustainability and its continued role as Zambia's economic backbone (ZCCH-IH, 2024). By addressing both micro-level operational challenges and macro-level policy constraints, the research aims to enhance the sector's productivity and profitability while ensuring its positive contribution to national development (see figure 2).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

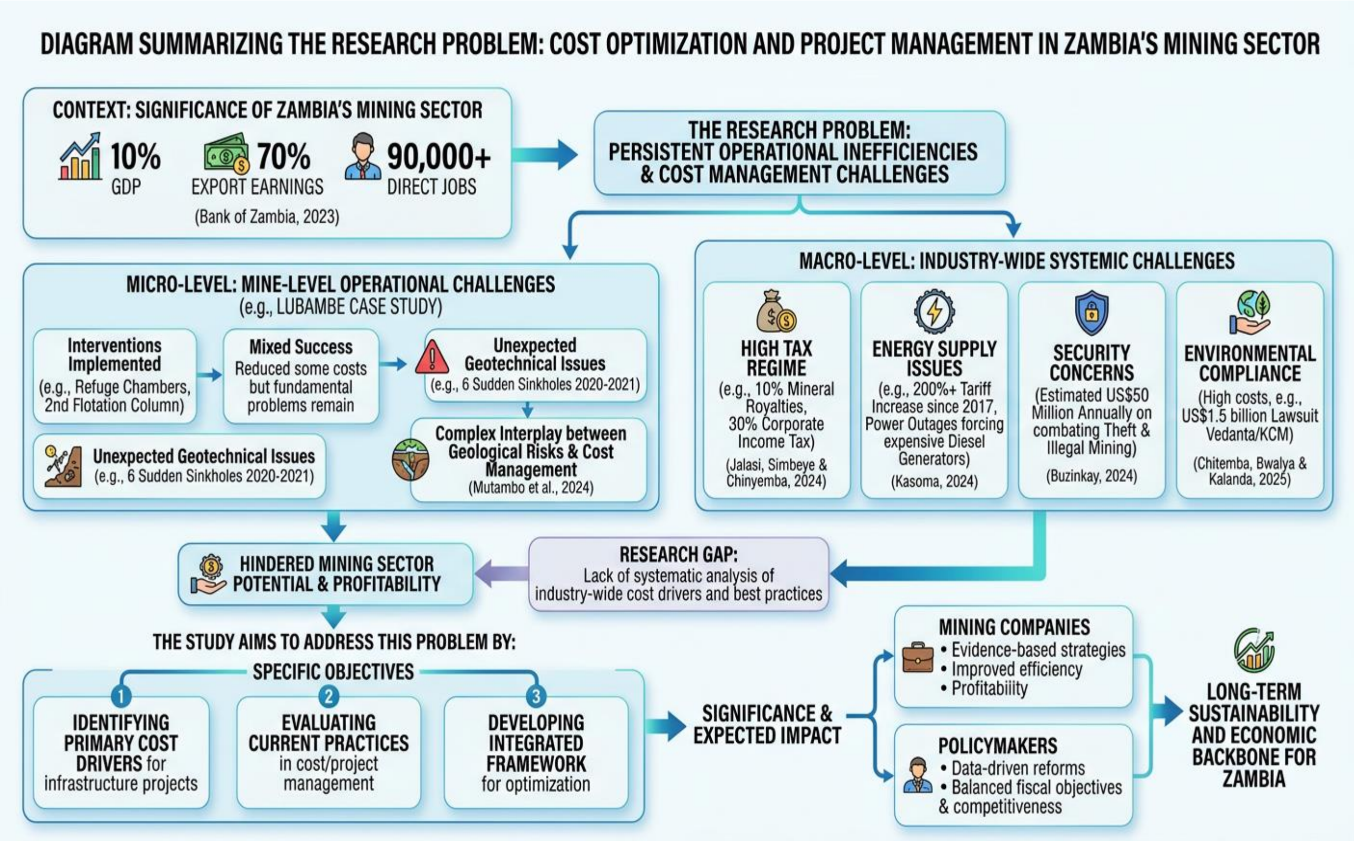

Figure 2. Problem diagram analysis

Significance and objectives of the study

The aim of this research is to investigate the factors associated with the optimisation of cost and project management in Zambia's mining infrastructure projects and to develop a comprehensive framework for enhancing cost and project management practices in the sector, with specific reference to Lubambe Copper Mine in the Copperbelt Province. This aim is guided by the need to improve operational efficiency, reduce project-related inefficiencies, and strengthen strategic planning and execution within mining infrastructure development.

To achieve this aim, the study seeks to establish key variables associated with the optimisation and integration of cost and project management practices. It further aims to determine the major barriers that hinder effective integration of these two critical management functions. In addition, the study intends to develop a systematic flow of integrated strategies that will inform the formulation of a structured framework for optimising cost and project management in mining infrastructure projects. These objectives are designed to generate practical insights that can support improved decision-making, enhance project delivery, and promote sustainable infrastructure development in Zambia's mining sector. In line with these objectives, the study is guided by three central research questions. The first seeks to determine the variables associated with cost and project management optimisation or integration. The second aims to establish the barriers that impede the effective integration of cost and project management processes. The third focuses on how a coherent flow of integrated strategies can be developed to support a robust framework for cost and project management optimisation.

This study is of critical significance to Zambia's mining sector, which contributes substantially to national economic development, accounting for 12.9 percent of GDP and 69 percent of export earnings in 2022 (Sinkamba, 2024; Aurélien et al., 2022). Despite its importance, the sector continues to face persistent inefficiencies in project execution and cost control, particularly in mining infrastructure development. By addressing these challenges through an integrated analytical framework, the study will generate practical and policy-relevant insights. The findings are expected to guide mining companies, project managers, and policymakers in enhancing operational efficiency, reducing project costs, improving resource utilisation, and supporting sustainable mining infrastructure development in line with national development priorities.

LITERATURE REVIEW

Theoretical literature

The theoretical framework of this study is anchored on three key theories, namely Transaction Cost Economics (TCE) Theory, Parkinson's Law, and the Efficient Market Hypothesis (EMH), which collectively provide a comprehensive lens for understanding cost and project management optimisation in Zambia's mining infrastructure projects. These theories offer insights into how organisational structures, administrative behaviour, and external market forces influence project costs, efficiency, and execution outcomes. Transaction Cost Economics (TCE) Theory, originally developed by Ronald Coase and later expanded by Oliver Williamson, explains how firms organise themselves to minimise transaction costs associated with coordination, contracting, and exchange processes (Rindfleisch, 2019; Sent & Kroese, 2022). Transaction costs include search and information costs, bargaining and decision-making costs, and enforcement costs, all of which significantly affect project performance. The theory argues that effective governance structures can reduce these costs, thereby improving efficiency and project management outcomes. However, TCE also recognises the influence of systematic risks such as inflation, interest rate changes, and currency fluctuations, which often exert a greater impact on project costs than internal managerial interventions, particularly in volatile economic contexts like Zambia (Woo et al., 2020). In mining infrastructure projects, where contractual complexity and stakeholder interdependence are high, TCE suggests that structured governance mechanisms, strategic partnerships, and supplier relationship management can minimise transaction costs, reduce inefficiencies, and enhance project outcomes (Adebayo & Werker, 2021; Adam & Fazekas, 2023). The theory further advocates vertical integration, digitalisation, and hybrid governance structures as strategies to lower uncertainty, enhance coordination, and improve cost efficiency (Chang et al., 2023; González-Ruiz et al., 2021). Parkinson's Law, introduced by C. Northcote Parkinson, asserts that work expands to fill the time available for its completion, leading to inefficiencies, wasted resources, and extended project durations (Sebestyén, 2022). This principle explains how excessive time allocation, bureaucratic layers, and administrative complexity can inflate costs and delay project execution. In Zambia's mining sector, prolonged approval processes, regulatory compliance procedures, and rigid bureaucratic systems often contribute to project delays and budget overruns. Parkinson's Law highlights the risks of budget inflation and "gold-plating," where projects expand beyond their original scope simply because resources are available (Balyuk, 2025). The theory underscores the importance of strict project controls, time management, and disciplined budgeting to prevent inefficiencies and ensure optimal resource utilisation (Sebestyén, 2022).

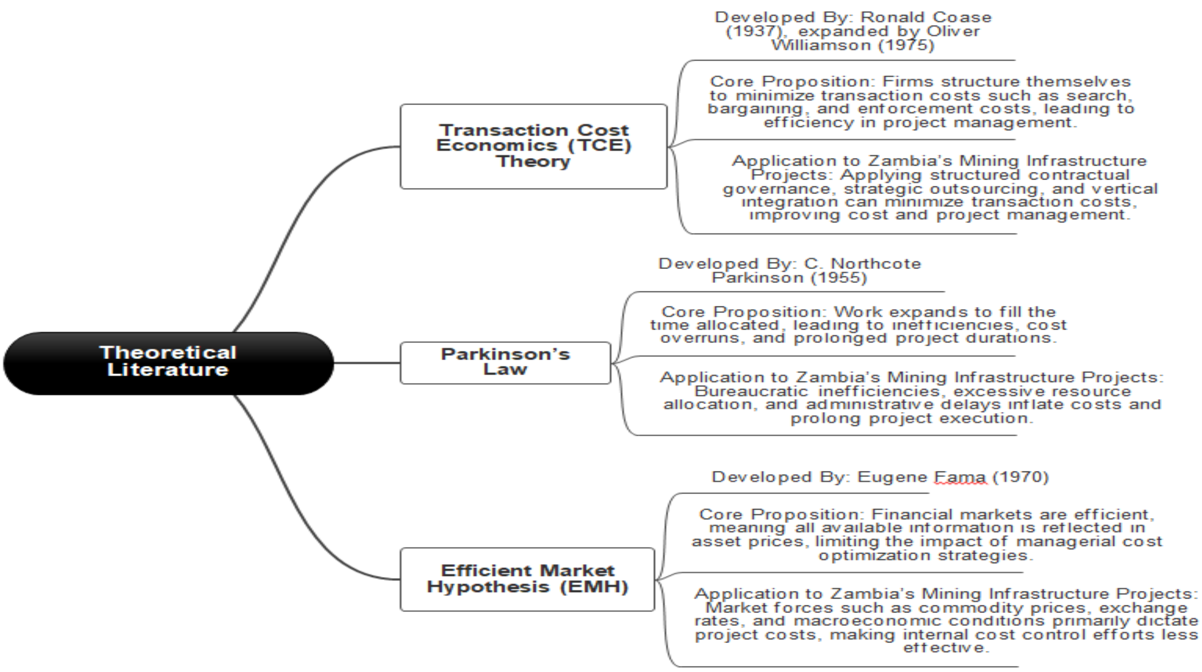

Figure 3. Summary of reviewed theories

The Efficient Market Hypothesis (EMH), proposed by Eugene Fama, posits that financial markets are informationally efficient, meaning that asset prices and investment costs reflect all available information, thereby limiting the effectiveness of managerial interventions in cost optimisation (Ţiţan, 2015). Applied to mining infrastructure projects, EMH suggests that project costs are largely determined by external market forces, including commodity prices, exchange rates, and geopolitical dynamics, rather than internal management strategies (Chen et al., 2022). In Zambia, fluctuations in global copper prices significantly influence project financing, investment decisions, and cost structures, limiting the scope for internal cost control (Boyle & Jiwon, 2022). Consequently, while project management practices may enhance internal efficiency, EMH implies that external economic conditions ultimately shape project cost outcomes. Collectively, these theories provide a multidimensional framework for analysing cost and project management optimisation in Zambia's mining infrastructure sector by integrating organisational, administrative, and market-based perspectives (see figure 3).

Empirical literature

The empirical literature on cost and project management optimization in the mining sector demonstrates that effective management of resources, processes, and technologies is essential for enhancing efficiency and reducing operational expenditures. Cost management optimization is defined as the strategic integration of budgeting, forecasting, cost estimation, and control mechanisms to ensure projects are delivered within budget while maintaining quality and scope (Martins, 2022; Girma & Patel, 2020). In mining infrastructure projects, these practices are particularly critical due to the sector's capital-intensive nature, high operational risks, and exposure to volatile material, labour, and energy costs (Bratus, 2024; Olvera, 2019). Optimized cost management enables firms to improve financial planning, monitor expenditures effectively, and enhance sustainability by minimizing waste and ensuring efficient resource utilisation.

Several empirical studies have proposed innovative frameworks and methodologies to enhance cost efficiency in mining operations. Botin and Vergara (2015) introduced a bottom-up cost management model combining Activity-Based Costing and the PDCA cycle to promote continuous improvement and operational accountability. Their findings from the Andina underground mine demonstrated that this approach enhanced decision-making and improved cost control. Similarly, Callaca et al. (2024) identified critical cost drivers through a thematic review of 40 studies, including resource management, supervision, equipment selection, time control, and continuous training, concluding that innovation and efficient resource utilisation are essential for sustainable mining operations. Maregedze et al. (2022) focused on energy cost optimisation, demonstrating that operational rescheduling, power factor correction, and renewable energy integration could reduce energy costs by up to 21.81 percent. Gubanov (2023) and Teplická and Kadarova (2018) analysed cost structures in coal and Slovakian mining firms, respectively, highlighting the importance of internal management mechanisms and cost control strategies in improving profitability. Marinin et al. (2021) further established that effective management of ore quality, mining losses, and dilution could significantly reduce production costs, while Qwathekana and Masilela (2023) demonstrated that Lean and Six Sigma methodologies supported data-driven cost optimisation and operational efficiency in gold mining.

Project management optimization literature emphasizes improving planning, execution, monitoring, and control to enhance efficiency and reduce waste (Dağgöl & Özsoy, 2024). Infrastructure mining projects require precise coordination, effective scheduling, risk management, and adaptability due to their complexity and uncertainty (Raman, 2023; Irfan et al., 2021). Studies by Ali and Rafique (2024) and Callaca et al. (2024) highlighted the strategic value of real options in enabling flexible and adaptive decision-making under uncertainty. Mazzaro et al. (2024) demonstrated that Business Intelligence tools, particularly Power BI, significantly enhanced real-time decision-making, reducing project management time by 50 percent and reporting time by 83 percent. Pelders et al. (2021) underscored the importance of optimizing shift systems to enhance productivity and worker well-being, while Buthelezi and Naidoo (2024) identified leadership support and organisational readiness as critical for successful digital transformation in mining project management (see table 1).

The integration of cost management and project management optimization is increasingly recognised as essential for improving performance in mining projects (Vrchota et al., 2020; Varajão et al., 2014). Advanced technologies, including artificial intelligence and machine learning, offer significant potential for enhancing efficiency, forecasting costs, and improving safety (Hyder et al., 2019; Zhang et al., 2020). Osei (2015) further demonstrated that weak cost management practices result in significant project overruns, reinforcing the need for structured

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

control mechanisms and integrated management frameworks. Collectively, the empirical evidence underscores the importance of adopting holistic, data-driven, and technology-enabled approaches to optimize cost and project management in the mining sector (see table 1).

Table 1. Summary of Empirical Literature on Cost and Project Management Optimisation in the Mining Sector

Author(s) & Year	Focus of Study	Methodology / Approach	Key Findings / Contributions
Martins (2022); Girma & Patel (2020)	Definition and scope of cost management optimization	Conceptual analysis	Cost management optimization integrates budgeting, forecasting, estimation, and control to enhance efficiency, value, and decision-making across project lifecycles.
Bratus (2024); Olvera (2019)	Cost management in infrastructure mining projects	Sectoral and empirical analysis	Capital-intensive nature and high risks make optimized cost control critical for efficiency, sustainability, and financial planning.
Botin & Vergara (2015)	Activity-Based Costing and PDCA integration	Case study at Andina underground mine	Bottom-up cost management using ABC and PDCA improves operational accountability, cost control, and continuous improvement.
Callaca et al. (2024)	Cost optimization drivers in mining	Systematic literature review (40 studies)	Identified key variables: resource management, supervision, equipment selection, time control, planning, and training for sustainable cost efficiency.
Maregedze et al. (2022)	Energy cost optimization	Modelling and NPV analysis	Energy rescheduling, power factor correction, and renewable integration reduced costs by up to 21.81%.
Gubanov (2023)	Cost structures in coal mining	Financial statement analysis	Internal management mechanisms and cost classification improve cost control and profitability.
Teplická & Kadarova (2018)	Cost trends in Slovakian mining firms	Economic cost trend analysis	Cost control strategies significantly affect financial sustainability, particularly in large firms.
Marinin et al. (2021)	Mine-to-mill cost optimization	Case study and cost engineering	Managing ore quality, mining losses, and dilution improves production efficiency and reduces cost per ton.
Qwathekana & Masilela (2023)	Lean and Six Sigma in gold mining	Quantitative benchmarking analysis	Lean/Six Sigma improves equipment efficiency, reduces waste, and supports sustainable cost reduction.
Dağgöl & Özsoy (2024)	Project management optimization	Conceptual framework	Effective planning, monitoring, stakeholder engagement, and risk management improve project efficiency.
Raman (2023); Irfan et al. (2021)	Infrastructure mining project execution	Empirical studies	Coordination, scheduling, adaptability, and risk control are essential for complex mining projects.

Ali & Rafique (2024); Callaca et al. (2024)	Real options in project planning	Systematic review	Real options introduce flexibility and enhance decision-making under uncertainty.
Mazzaro et al. (2024)	Business Intelligence in project management	Case study using Power BI	BI tools reduced project management time by 50% and reporting time by 83%.
Pelders et al. (2021)	Shift system optimization	Case studies and framework development	Optimized shift systems enhance productivity, asset utilization, and worker well-being.
Buthelezi & Naidoo (2024)	Digital transformation in project management	Qualitative interviews	Leadership support and organizational readiness are critical for successful digitalization.
Vrchota et al. (2020); Varajão et al. (2014)	Integration of cost and project management	Conceptual synthesis	Integrated management improves efficiency, decision-making, and project outcomes.
Hyder et al. (2019)	AI and automation in mining	Interviews and industry analysis	AI improves productivity, safety, and efficiency but faces financial and workforce challenges.
Zhang et al. (2020)	AI-based capital cost forecasting	Hybrid AI modelling	AI models significantly improve accuracy of mining capital cost predictions.
Osei (2015)	Project cost management in Ghanaian mining	Surveys and project analysis	Weak cost control leads to cost overruns, highlighting need for structured project controls.

The reviewed literature identifies a broad spectrum of variables associated with optimizing both cost management and project management in the mining sector. These variables reflect practical approaches and strategic tools that address operational, financial, and managerial challenges in mining projects. In terms of cost management, Callaca et al. (2024) highlighted key operational variables such as resource management, supervision and control, time control, equipment selection, continuous training, and planning, emphasizing their relevance to improving productivity and minimizing operational expenses. Similarly, Maregedze et al. (2022) focused on energy-related cost variables, including shift rescheduling, equipment usage, load crippling, power factor correction, and renewable energy integration, which directly influence electricity costs in mining operations.

From a structural and financial perspective, Gubanov (2023) identified variables like cost causative factors, responsible units, and risk factors, while Teplická and Kadarova (2018) emphasized the influence of company size, cost trends, and cost control strategies. Marinin et al. (2021) noted technical variables such as mining losses, dilution, ore quality, and transportation that affect cost efficiency. Qwathekana and Masilela (2023) introduced operational inefficiencies, benchmarking, and Lean/Six Sigma tools as core variables for cost reduction (see figure 3). Regarding project management optimization, Dağgöl and Özsoy (2024) pointed to fundamental managerial elements like goal setting, stakeholder communication, risk mitigation, and KPIs. Raman (2023) and Irfan et al. (2021) stressed coordination, budgeting, scheduling, and regulatory adaptability. Ali and Rafique (2024) along with Callaca et al. (2024) emphasized strategic flexibility and scenario-based planning through real options. Mazzaro et al. (2024) identified technological tools like BI software and data visualization for real-time decision-making, while Pelders et al. (2021) and Buthelezi and Naidoo (2024) addressed human-centered factors such as shift length, morale, and digitalisation readiness (see figure 2.2). Integrated studies such as Hyder et al. (2019) and Zhang et al. (2020) contributed technological and predictive variables, while Osei (2015) focused on practical cost control frameworks using EPCM contracts and value engineering. Together, these variables form a comprehensive base for optimizing mining project delivery (see figure 4).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

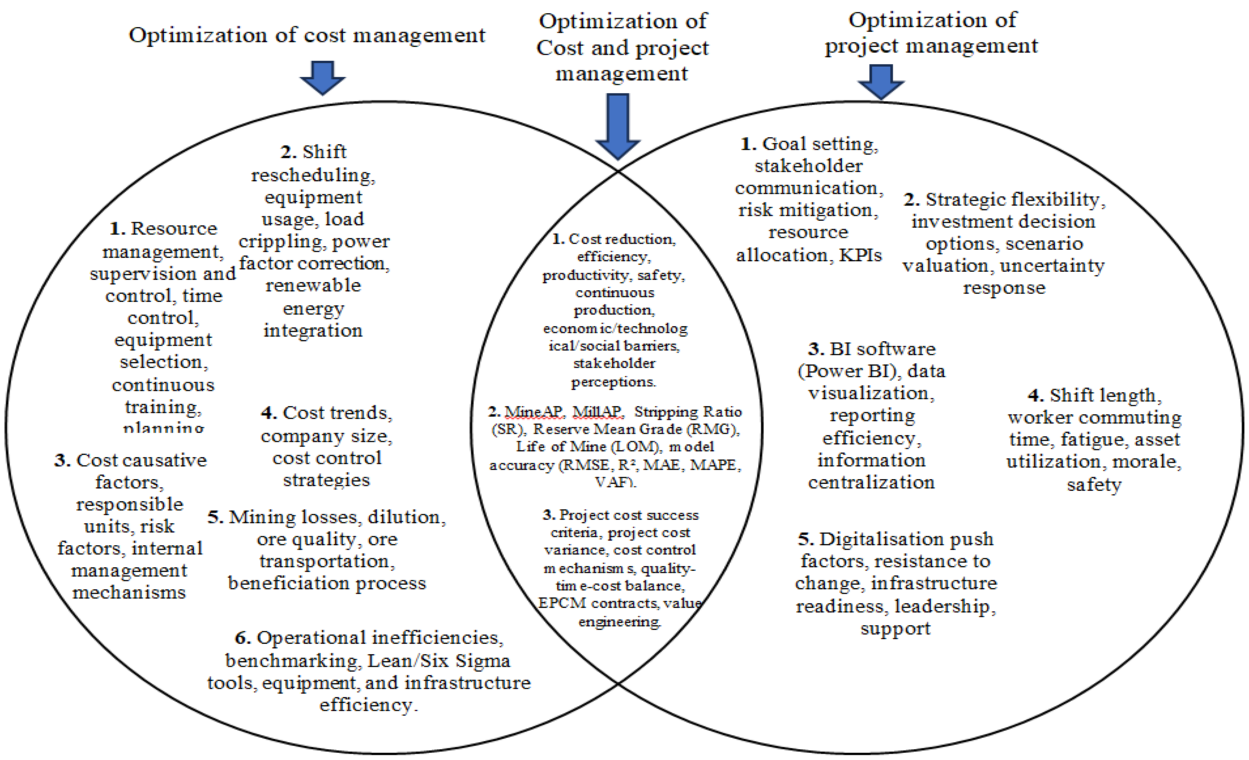

Figure 4. Identified variables associated with cost and project management optimization in reviewed empirical literature

Literature review by region

Global Studies

Several studies conducted outside Africa have explored cost structures, project scheduling, and digitalization in project management within the mining and construction sectors. Gubanov (2023) analyzed cost structures in Russian coal mining companies, identifying variations in cost management strategies and proposing a classification system for cost optimization. The study emphasized the role of internal management practices in improving financial performance. Similarly, Teplická and Kadarova (2018) investigated cost trends in Slovakian mining companies, finding that large firms experienced rising costs while small and medium-sized firms reduced expenses. The study highlighted the importance of cost control for profitability. Marinin, Marinina, and Wolniak (2021) examined the impact of declining gold grades and increasing excavation depths on mining efficiency, proposing tailored cost optimization strategies to improve production efficiency. Their findings confirmed that managing ore quality parameters could significantly reduce costs across the production chain.

African Studies

Research in other African countries has focused on project risk management, digital transformation, and cost optimization in mining operations. Bag (2016) investigated project risk elements in South Africa's mining industry, identifying corruption, poor time and cost management, and procurement inefficiencies as major risks affecting firm performance. The study recommended prioritizing risk mitigation to prevent cost overruns. Buthelezi and Naidoo (2024) explored digitalization in project management within a South African mining context, finding that leadership support and organizational readiness were crucial for successful implementation. However, resistance to change and infrastructure limitations posed significant challenges. In Botswana, Baleni and Gande (2023) assessed the impact of project planning and scheduling on capital project success, concluding that best practices in planning significantly contributed to project outcomes, whereas scheduling techniques had a lesser impact. Qwathekana and Masilela (2023) studied cost optimization in South African gold mining, advocating for Lean/Six Sigma methodologies to enhance operational efficiency and reduce costs without compromising long-term sustainability.

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Zambian Studies

Research within Zambia has examined project management practices, infrastructure financing, and scheduling techniques in construction and mining projects. Daka (2024) investigated the influence of project management practices on construction project success, identifying comprehensive planning, risk management, and stakeholder engagement as critical factors. The study recommended improved training programs and better performance monitoring mechanisms. Sailota and Chibomba (2025) analyzed project scheduling techniques in a Zambian mining project, finding that modern scheduling methods improved cost management and resource allocation. The study emphasized the importance of stakeholder communication and leadership support in project execution. Musonda (2023) explored project finance as a solution to Zambia's infrastructure financing gap, highlighting political will and policy consistency as key enablers. However, challenges such as unclear regulations and limited expertise in public-private partnerships were identified as barriers to growth. These studies collectively underscore the need for enhanced project management frameworks, better financial strategies, and policy reforms to improve project outcomes in Zambia. This thematic review provides a structured understanding of global, African, and Zambian perspectives on project management and cost optimization, highlighting both common trends and region-specific challenges.

Literature Gaps

The reviewed empirical literature provides substantial insights into cost and project management optimisation within the global mining sector. However, significant gaps remain, particularly regarding the integrated application of these practices within Zambia's mining infrastructure projects. Most studies adopt fragmented perspectives by concentrating either on cost management or project management in isolation, with limited attention to their combined influence on project performance. Furthermore, the majority of the existing empirical evidence is derived from developed or emerging economies outside sub-Saharan Africa, thereby limiting its contextual relevance to Zambia. Consequently, there remains a critical need for a context-specific and integrated framework that identifies key variables, barriers, and strategic interventions for optimising both cost and project management in Zambia's mining sector. Several studies have emphasised technical and operational approaches to cost efficiency, yet they rarely incorporate comprehensive project management dimensions.

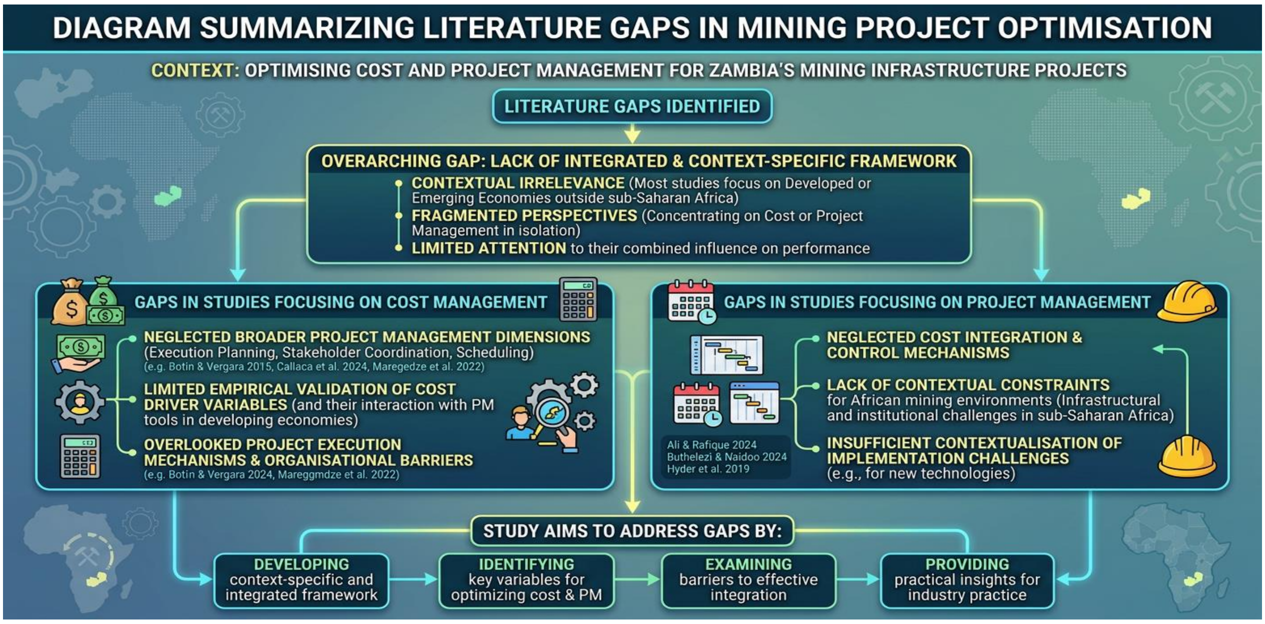

Figure 5. Summary of contemporary gaps in the reviewed literature

For instance, Botin and Vergara (2015) proposed the integration of Activity-Based Costing and the PDCA cycle to enhance cost control in Chilean mines, but their work overlooked broader project management aspects such as execution planning, stakeholder coordination, and scheduling. Similarly, Callaca et al. (2024) identified critical cost drivers through a systematic review but did not empirically validate these variables or explore their interaction with project planning tools in developing economies.

Maregedze et al. (2022) narrowed their analysis to energy cost optimisation, excluding holistic project management processes, while Gubanov (2023) and Teplická and Kadarova (2018) focused primarily on internal cost structures without examining project execution mechanisms or organisational barriers. These limitations indicate the need for a more comprehensive approach that integrates both cost and project management dimensions within a unified analytical framework (see figure 5).

In addition, studies addressing project management optimisation often neglect cost integration and contextual constraints prevalent in African mining environments. Research by Ali and Rafique (2024), Mazzaro et al. (2024), and Pelders et al. (2021) demonstrated the value of real options, business intelligence tools, and shift system optimisation, respectively, yet these studies largely excluded cost control mechanisms and did not adequately address infrastructural and institutional challenges typical of sub-Saharan Africa. Furthermore, Buthelezi and Naidoo (2024) examined digital transformation barriers in project management but did not integrate cost-related considerations, while Hyder et al. (2019) and Zhang et al. (2020) highlighted the potential of artificial intelligence without sufficiently contextualising implementation challenges and project execution realities (see table 2).

Collectively, these gaps underscore the absence of an integrated, empirically grounded, and context-specific framework tailored to Zambia's mining infrastructure projects. This study addresses these deficiencies by identifying key variables influencing cost and project management optimisation, examining barriers to their effective integration, and developing a structured framework suited to Zambia's institutional, economic, and operational environment. In doing so, the research provides practical insights that advance both academic understanding and industry practice in the optimisation of mining infrastructure project performance (see table 2).

Table 2. Summary of empirical literature by methodologies and identified gaps

Study	Research Focus	Methodology	Key Findings	Identified Gaps	How This Study Fills the Gap
Daka (2024)	Project management practices in construction projects in Zambia.	Qualitative approach; interviews; thematic analysis.	Comprehensive planning, risk management, and communication are crucial for success. Identified stakeholder engagement issues.	Lacks focus on mining infrastructure projects and cost drivers.	Investigates key cost drivers in Zambia's mining infrastructure projects.
Sailota & Chibomba (2025)	Effectiveness of project scheduling techniques in a mining project at Kalumbila.	Quantitative approach; structured questionnaires; SPSS analysis.	Baseline schedules and optimized resource allocation improve project completion. Scheduling techniques alone are insufficient.	Does not address broader cost management practices in mining.	Extends analysis to broader cost and project management challenges in mining.
Musonda (2023)	Role of project finance in addressing infrastructure	Qualitative approach; interviews;	Project finance is effective in closing infrastructure financing gaps.	Does not analyze cost drivers or inefficiencies in	Identifies key cost drivers and inefficiencies in

	financing gaps in Zambia.	thematic analysis.	Political will and policy consistency are crucial.	project execution.	mining infrastructure.
Gubanov (2023)	Cost structures and financial performance of Russian coal mining companies.	Vertical and horizontal analysis of financial statements; cost estimation matrix.	Internal management mechanisms influence cost optimization. Cost minimization impacts financial performance.	Findings are geographically limited to Russia and do not address project management challenges.	Focuses on Zambia's mining sector and integrates project management strategies.
Teplická & Kadarova (2018)	Cost structures and optimization strategies in Slovakian mining companies.	Economic cost analysis using a chain index method.	Decreasing costs in small/medium firms; rising costs in large firms. Cost management is critical for sustainability.	Does not evaluate project management challenges in Zambia's mining industry.	Proposes a tailored framework integrating cost and project management for Zambia.
Marinin, Marinina & Wolniak (2021)	Cost optimization in the mine-to-mill process for gold mining.	Case study approach; factor analysis; cost engineering methods.	Losses and dilution influence cost savings. Managing ore quality parameters reduces processing costs.	Does not explore broader project management challenges affecting mining infrastructure.	Examines a comprehensive range of cost and project management factors in mining.
Qwathekana & Masilela (2023)	Cost optimization strategies in gold mining using Lean/Six Sigma methodologies.	Quantitative approach; benchmarking and Lean/Six Sigma methodologies.	Structured cost management improves efficiency. Lean/Six Sigma methodologies reduce operational costs.	Lacks focus on infrastructure-related cost and project management challenges.	Develops a cost management framework incorporating multiple control mechanisms.
Bag (2016)	Risk factors affecting project performance in South African mining industry.	Total Interpretive Structural Modeling (TISM) approach.	Corruption, poor planning, and procurement inefficiencies are top risk factors. Eliminating these is essential	Does not analyze cost management practices or propose optimization frameworks.	Integrates cost and project management optimization strategies for Zambia.

			for project success.		
Buthelezi & Naidoo (2024)	Role of digitalization in project management in a mining organization.	Qualitative approach; interpretive lens; face-to-face interviews.	Leadership and organizational support are key to digitalization success. Resistance to change and infrastructure issues hinder adoption.	Does not explore cost management or optimization strategies in mining infrastructure.	Incorporates digitalization into cost and project management framework.
Baleni & Gande (2023)	Impact of project planning and scheduling on capital project success in Botswana.	Quantitative approach; structured questionnaires; multiple regression analysis.	Project planning and front-end planning significantly impact capital project success. Scheduling techniques have limited impact.	Does not investigate cost management challenges in Zambia's mining infrastructure sector.	Develops a tailored cost and project management framework for Zambia's mining sector.

METHODOLOGY

The study adopted a qualitative case study research approach centred on Lubambe Copper Mine in Zambia's Copperbelt Province. This approach was justified by the complexity and context-specific nature of cost and project management challenges within mining infrastructure projects. A qualitative design allowed for the collection of rich, in-depth data that captured the experiences, perspectives, and decision-making processes of key stakeholders. By focusing on a single, information-rich case, the study sought to develop a holistic understanding of operational and financial management practices and to generate insights that could inform the development of an integrated optimisation framework suited to the Zambian mining context. An exploratory qualitative research design was employed to examine existing cost and project management practices, challenges, and strategies within Lubambe Copper Mine. Data were collected at a single point in time to provide a focused assessment of current operational realities shaped by recent developments such as changes in tax policy, rising energy costs, and increasing environmental compliance requirements. This design facilitated the identification of key cost drivers and management challenges, while also allowing the study to explore adaptive strategies adopted in response to emerging industry pressures. The exploratory nature of the design supported a deeper investigation into under-researched areas, particularly the integration of cost and project management functions within mining infrastructure development.

The study population comprised expert stakeholders who were directly involved in cost and project management activities at Lubambe Copper Mine. Participants were purposively selected based on their professional roles, responsibilities, and depth of experience in project planning, execution, financial management, and operational oversight. Targeted participants included junior engineers or site supervisors, project engineers, project managers, senior project managers, cost engineers, planning engineers, contracts managers, and senior executives such as the head of projects and operations directors. This diverse representation ensured the collection of comprehensive perspectives that reflected both strategic and operational dimensions of project delivery and cost control within the mine. A purposive sampling technique was used to select a sample of ten expert participants. This sample size was considered appropriate for qualitative inquiry, where emphasis was placed on depth of understanding and thematic saturation rather than statistical generalisation. By engaging a limited number of knowledgeable informants, the study prioritised information richness and analytical depth, ensuring that the findings meaningfully contributed to the development of a practical and context-sensitive optimisation framework.

Primary data were collected through semi-structured questionnaires, which allowed participants to provide detailed narratives on key thematic areas. These themes included the identification of critical cost drivers and project management challenges, evaluation of existing management practices, and suggestions for effective strategies and frameworks for optimisation. The semi-structured format offered flexibility to probe emerging issues, thereby capturing both explicit practices and tacit knowledge that shaped decision-making within the mining environment. Data analysis followed a thematic analysis approach, involving systematic coding, categorisation, and interpretation of qualitative data to identify recurring patterns and themes. This method enabled the integration of participants' experiences with broader operational and financial considerations, producing insights that directly addressed the study's objectives. Ethical considerations underpinned all stages of the research, with informed consent, confidentiality, voluntary participation, and secure data handling ensuring adherence to established ethical standards. This study employed FitzStatistics to generate data visualizations based on the coded qualitative data. FitzStatistics provided a single platform for qualitative analysis, allowing the researcher to transform thematic codes into visually rich, decision-oriented representations of patterns and relationships (RES, 2025). The software facilitated rapid pattern recognition and enhanced interpretability of the qualitative findings, supporting a deeper understanding of key cost and project management issues. Its visual-first approach allowed the study to communicate complex themes effectively, ensuring that insights could be readily analyzed, interpreted, and applied within the context of Zambia's mining sector. The use of FitzStatistics justified the study's focus on producing rigorous, visually compelling outputs from qualitative data (RES, 2025).

Data saturation was used as the guiding principle to determine the adequacy of the sample and the completeness of the qualitative data collected in this study. Saturation was assessed during the coding and thematic analysis stages of the research process. After each completed questionnaire was reviewed and coded, the emerging concepts and categories were compared with those identified in previous responses. The analysis indicated that by the eighth participant, the majority of themes had already begun to recur with minimal introduction of new information. The final two responses confirmed the stability of these themes, as no additional substantive categories emerged. This repetition and confirmation of previously identified patterns signified that thematic saturation had been achieved, indicating that the dataset was sufficiently rich to support reliable interpretation and the development of a coherent analytical framework.

FitzStatistics played a central role in supporting the analysis and interpretation of the coded qualitative data. Following the thematic coding process, the identified codes and categories were entered into the FitzStatistics environment where they were converted into structured datasets representing the frequency and relationships among thematic elements. The software enabled the generation of network diagrams, hierarchical visualizations, and relational charts that illustrated how different cost and project management factors interacted within the operational environment of the mine. These visual outputs enhanced pattern recognition and facilitated the identification of dominant themes and interconnections among variables. By translating coded textual responses into visual analytical structures, FitzStatistics improved the clarity, transparency, and analytical depth of the qualitative findings.

Several measures were implemented to strengthen the credibility and trustworthiness of the study. Member checking was conducted by sharing summarized interpretations of the findings with selected participants to confirm that the interpretations accurately reflected their perspectives and experiences. Reflexivity was maintained through reflective notes that documented the researcher's analytical decisions and awareness of potential biases during data interpretation. In addition, a peer audit process was undertaken in which independent academic colleagues reviewed the coding structure, thematic grouping, and analytical interpretations to ensure logical consistency and methodological rigor throughout the study.

RESULTS

Demographic analysis

The composition of participants in this study reflected a well-balanced representation of professional roles within

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

Lubambe Copper Mine, which allowed for a holistic understanding of cost and project management practices. Out of the ten experts interviewed, two were Project Engineers, while one each represented the roles of Junior Engineer or Site Supervisor, Cost Engineer or Estimator, Planning Engineer, Contracts Manager, Project Manager, Senior Project Manager, Head of Projects, and General Manager or Operations Director (see Figure 6).

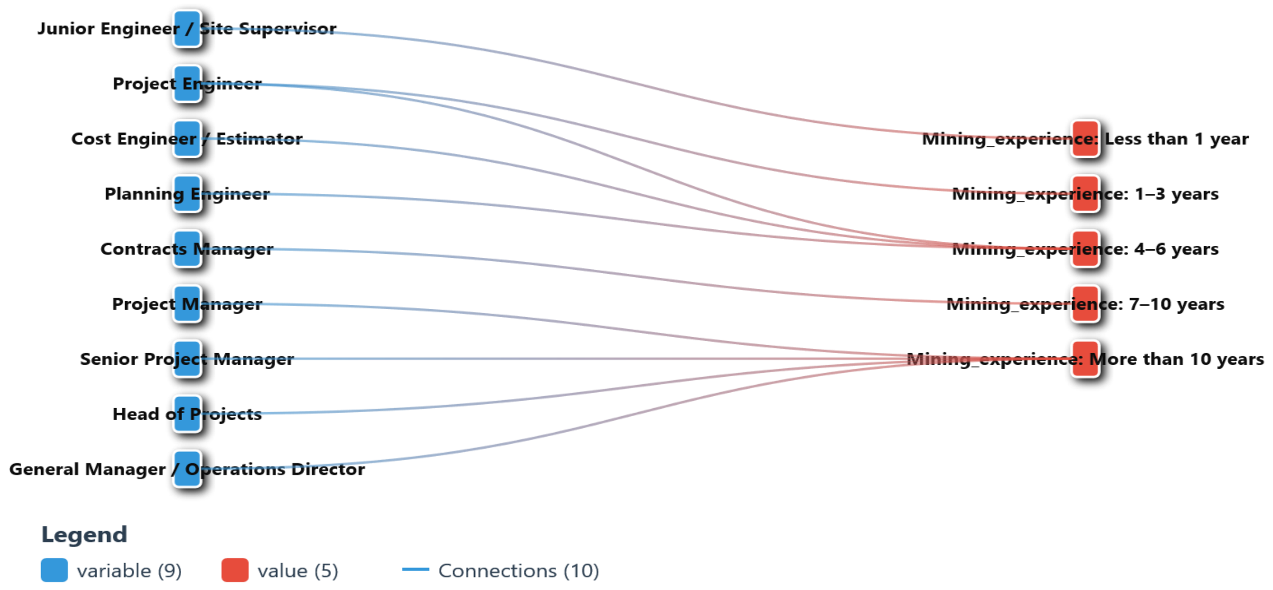

Figure 6. Current professional role and years of experience in mining infrastructure projects of respondents

The study engaged participants occupying a wide range of operational and managerial roles across the project lifecycle, from Junior Engineers and Site Supervisors to Project Managers and Directors, providing depth and triangulation to the qualitative findings. Junior personnel offered insights into on-the-ground challenges, including compliance with timelines, technical delays, and cost overruns, while Cost and Planning Engineers highlighted budgeting, forecasting, and scheduling variables affecting efficiency. Senior participants contributed strategic perspectives on integrating cost control with project management systems. Participants' experience in mining infrastructure projects ranged from less than one year to over ten years, ensuring a rich mix of contemporary operational insights and long-term institutional knowledge. Those with extensive experience reflected on systemic issues such as cost escalation, project delays, and regulatory barriers, whereas less experienced individuals provided perspectives on emerging technologies and evolving practices. This diversity of roles and experience supported the study's objectives of identifying variables and barriers to effective cost and project management integration in Zambia's mining sector (see figure 6). The study revealed that participants possessed diverse academic qualifications and professional tenures at Lubambe Copper Mine, which enriched the quality and depth of qualitative insights obtained. In terms of education, one participant held a Diploma, three held Bachelor's Degrees, another three possessed Postgraduate Diplomas or Certificates, two had Master's Degrees, and one held a Doctorate. This academic diversity ensured that the discussions on cost and project management optimization were informed by individuals with both practical technical knowledge and advanced theoretical understanding. Participants with postgraduate and doctoral qualifications provided analytical reflections on strategic planning, risk mitigation, and policy alignment, while those with diplomas and bachelor's degrees offered grounded operational perspectives shaped by hands-on project experience. Regarding tenure, the participants' work experience at Lubambe ranged from less than one year to more than ten years, with representation across all levels. This mix provided a balance between institutional memory and fresh viewpoints (see figure 7).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

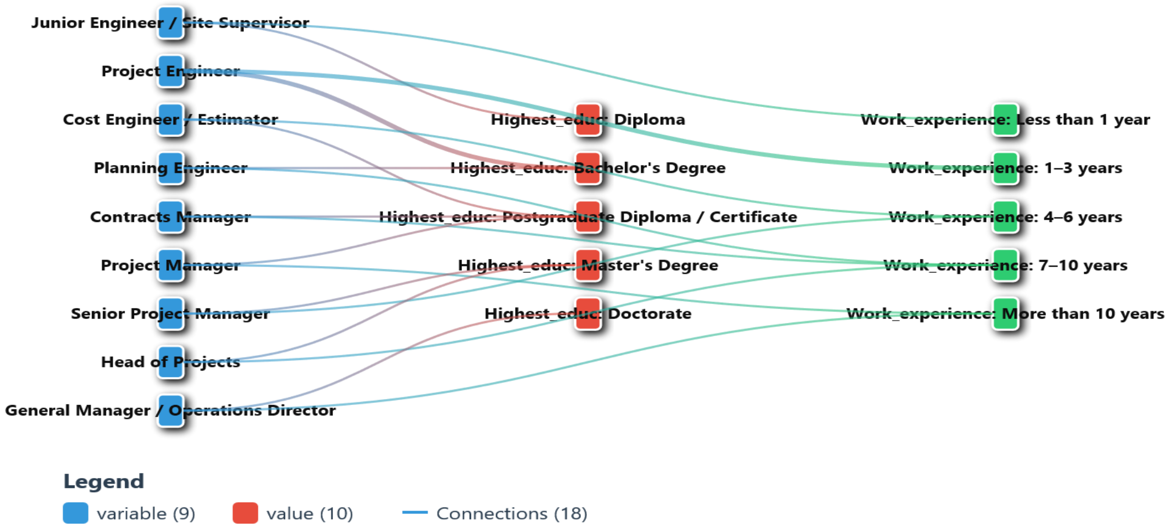

Figure 7: Educational and Professional Background of Participants in Relation to Cost and Project Management Practices at Lubambe Copper Mine

The findings also indicate that participants' levels of involvement in decision-making and familiarity with cost control strategies varied across different professional roles, reflecting a well-rounded pool of expertise within Lubambe Copper Mine. Out of the ten participants, three reported being always involved in cost and project management decisions, two were frequently involved, three participated occasionally, while two had no direct decision-making role. This diversity demonstrates that perspectives were drawn from both strategic leaders and technical personnel, ensuring a balanced understanding of how decisions are formulated, implemented, and experienced at different organizational levels. The inclusion of participants with varying degrees of authority enriches the study's qualitative insights by capturing both policy-level and operational viewpoints that influence project performance (see figure 8).

Regarding familiarity with cost control strategies, four participants described themselves as very familiar, two as experts, while the remainder expressed moderate to limited familiarity. This range highlights that while some participants possess advanced technical and managerial knowledge, others engage more from an implementation standpoint (see figure 8). Furthermore, the results indicate that participants demonstrated varying levels of confidence and influence in cost and project management activities, reflecting a balanced mix of operational and strategic expertise across Lubambe Copper Mine.

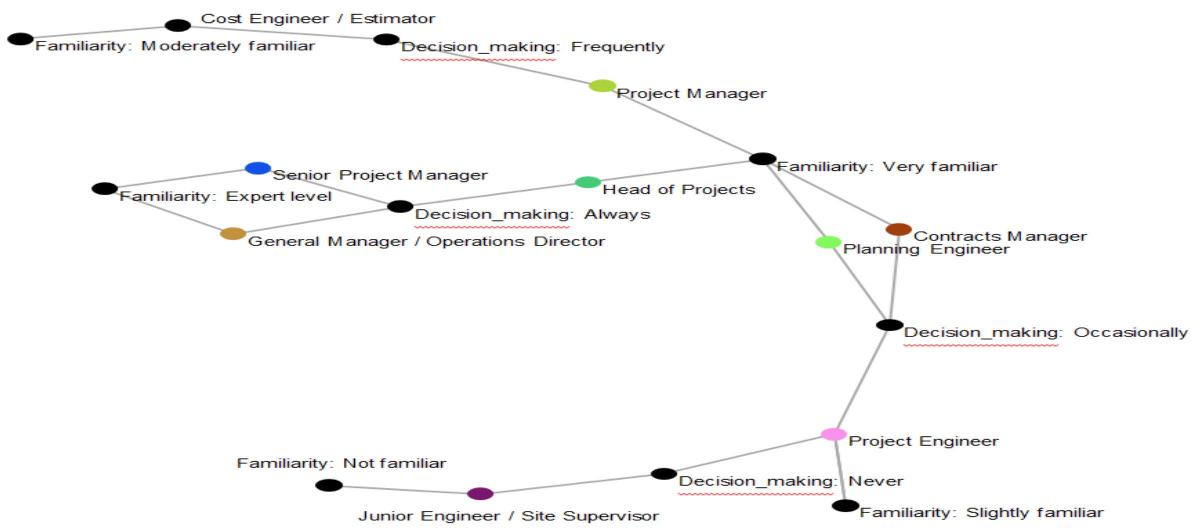

Figure 8: Levels of Decision-Making Involvement and Familiarity with Cost Control Strategies Among Participants at Lubambe Copper Mine

Among the ten experts, most described themselves as confident or very confident in identifying key cost drivers, while a few expressed moderate assurance. This range suggests that participants possessed strong experiential knowledge of mining infrastructure projects, grounded in both technical execution and managerial oversight. Their confidence levels illustrate the presence of practical competence and contextual understanding necessary to diagnose cost inefficiencies and propose realistic optimization measures.

When asked about their influence over project outcomes, responses ranged from minimal to full influence, showing that the participants represented different hierarchical levels within the organization. Those in leadership roles highlighted their capacity to shape project direction, while others emphasized their contributions to operational implementation and feedback mechanisms. The study revealed that participants expressed mixed perceptions regarding the effectiveness of project management practices and the level of integration between financial planning and operational execution at Lubambe Copper Mine.

Figure 9: Perceptions of Project Management Effectiveness and Financial-Operational Integration at Lubambe Copper Mine

Among the ten experts interviewed, opinions varied across the spectrum—from those who perceived the current systems as effective to others who viewed them as ineffective in addressing recurring cost and schedule overruns. This diversity of perspectives reflects the complex realities of managing large-scale mining infrastructure projects, where operational efficiency is influenced by multiple interdependent factors, including resource allocation, regulatory constraints, technical uncertainties, and managerial communication.

Participants who considered current practices effective highlighted improvements in structured planning, monitoring tools, and risk mitigation strategies. Conversely, those who perceived inefficiencies emphasized recurring issues such as delayed decision-making, weak interdepartmental coordination, limited resource forecasting, and inconsistent supervision, which collectively contribute to cost escalation and time delays.

Regarding the integration between financial planning and operational execution, most participants described the linkage as poor or only fair. They noted that while financial frameworks and budgets are well-developed, they often fail to align with operational realities on the ground. This disconnect creates inefficiencies in resource utilization and reduces responsiveness to dynamic project conditions. Participants further explained that the lack of real-time financial oversight and the absence of integrated project management systems hinder proactive cost control (see figure 9).

Variables associated with cost and project management optimization (or integration)

The qualitative responses gathered from ten participants holding key technical and managerial positions at Lubambe Copper Mine, ranging from *Junior Engineer* to *General Manager*, offered a vivid account of how cost and project management integration influences infrastructure development outcomes. Each participant shared their experiences, frustrations, and observations about the factors shaping cost performance and project timelines, and the systems used to manage them. The diversity of roles among respondents enriched the discussion, as perspectives spanned both operational and strategic levels of project execution.

The first question asked participants, *"In your experience, what specific factors most significantly influence cost performance and project timelines in infrastructure development at Lubambe Copper Mine?"* The responses revealed a shared concern about procurement inefficiencies, weak planning coordination, and unpredictable external conditions. The *Junior Engineer* reflected that *"most delays start with late delivery of materials, especially imported equipment that gets stuck due to customs clearance or supplier issues."* This sentiment was echoed by the *Project Engineer*, who elaborated that *"procurement delays often cascade into idle labor costs and rescheduled activities, pushing up overall project expenses."* From a financial perspective, the *Cost Engineer* noted that *"cost escalation is also driven by currency fluctuations and unanticipated variations in material prices, especially for steel and fuel."* Meanwhile, the *Planning Engineer* highlighted poor scope management, explaining that *"frequent design changes after project commencement disturb timelines and budgets because they alter the critical path."* The *Contracts Manager* offered a complementary view, stating that *"some contractors underestimate resource needs during bidding, leading to claims and disputes once cost overruns begin to appear."*

At the managerial level, the *Project Manager* emphasized workforce inefficiencies, noting that *"limited skilled artisans and inconsistent subcontractor performance often disrupt continuity, forcing extensions and additional supervision costs."* The *Senior Project Manager* reinforced this by saying, *"coordination between departments still needs improvement—sometimes engineering, procurement, and construction teams operate in silos, causing duplication of efforts and delays."* Environmental constraints also featured prominently, with the *Head of Projects* adding that *"during heavy rains, open-pit and access road projects are almost impossible to progress on schedule, yet costs continue accumulating."* Finally, the *General Manager* summarized the overarching issue by observing that *"cost and time performance ultimately depend on proactive planning, risk anticipation, and strong leadership discipline."* (see table 3).

Table 3. Thematic Summary of Qualitative Findings on Cost and Project Management Optimization at Lubambe Copper Mine

Theme	Description / Summary of Findings	Illustrative Quotes (in italics)	Implications for Project Optimization
1. Procurement and Supply Chain Delays	Delays in acquiring critical materials, especially imported equipment, were highlighted as a key driver of time and cost overruns. Inefficient procurement processes and customs delays disrupt project scheduling.	*"Most delays start with late delivery of materials, especially imported equipment that gets stuck due to customs clearance or supplier issues."* – Junior Engineer *"Procurement delays often cascade into idle labor costs and rescheduled activities."* – Project Engineer	Streamlining procurement, improving supplier coordination, and forecasting import timelines can significantly improve project efficiency.
2. Cost Escalation and	Fluctuating material prices and exchange rate changes affect budget stability. Projects are	*"Cost escalation is driven by currency fluctuations and variations in material prices,*	Strengthening cost forecasting models and including contingency

Market Volatility	vulnerable to unanticipated cost increases during long execution periods.	*especially for steel and fuel."* – Cost Engineer	budgets can mitigate exposure to market volatility.
3. Inadequate Scope Definition and Design Changes	Frequent alterations in project scope after initiation lead to rework, rescheduling, and cost inflation. Poor coordination between design and construction teams worsens the problem.	*"Frequent design changes after project commencement disturb timelines and budgets."* – Planning Engineer *"Lack of communication between teams leads to rework and duplication of efforts."* – Senior Project Manager	Comprehensive pre-project planning and improved interdisciplinary communication can prevent unnecessary redesigns and rework.
4. Workforce and Contractor Inefficiencies	Shortages of skilled artisans and inconsistent subcontractor performance slow project delivery. Staff turnover increases supervision costs and reduces productivity.	*"Limited skilled artisans and inconsistent subcontractor performance often disrupt continuity."* – Project Manager	Investing in workforce training, contractor evaluation, and retention strategies can enhance stability and performance.
5. Environmental and External Constraints	Adverse weather conditions, particularly during the rainy season, hinder progress in open excavation projects. Such disruptions contribute to idle time and cost overruns.	*"During heavy rains, open-pit projects are almost impossible to progress, yet costs continue accumulating."* – Head of Projects	Incorporating seasonal risk analysis and adaptive scheduling into project plans can minimize disruptions.
6. Systems and Tools for Project Management	Tools like Primavera P6, SAP, and Microsoft Project are used for scheduling and budgeting. However, weak integration and inconsistent usage reduce their effectiveness.	*"Primavera P6 is our primary scheduling tool—it gives visibility of progress and helps forecast slippages."* – Planning Engineer *"SAP is used for budgeting, but it doesn't always align with Primavera data."* – Cost Engineer	Full integration between cost and scheduling systems and continuous staff training are vital for system optimization.
7. Reporting and Monitoring Practices	Weekly reports and dashboards promote transparency and accountability, though manual compilation and data delays remain challenges.	*"Weekly dashboards and cost variance reports help everyone see where we stand."* – Junior Engineer	Automating reporting processes and ensuring real-time updates can improve monitoring accuracy.
8. Leadership, Coordination, and Institutional Discipline	Strong leadership and cross-departmental coordination were viewed as decisive for success. A disciplined project culture enhances the impact of digital tools and systems.	*"Cost and time performance depend on proactive planning, risk anticipation, and strong leadership discipline."* – General Manager	Building a culture of collaboration and accountability across all project levels ensures sustained optimization.

Team collaboration was repeatedly highlighted as the invisible thread that binds cost and performance outcomes. The Contracts Manager remarked that *"when engineers, accountants, and procurement officers communicate openly, it prevents duplication and confusion."* The Head of Projects offered a broader reflection, stating that *"the biggest cost inefficiencies arise not from lack of tools, but from lack of collaboration—teams working in silos end up solving the same problem twice."* The General Manager summarized this human-centered discussion by asserting that *"a well-trained, cohesive team can deliver a project within cost and time even under external pressure; fragmented teams, no matter how skilled, will always fall short."*

This second theme of human resource capability revealed the Mine's recognition that optimization is not merely a financial or technological challenge but a cultural and managerial one. The integration of cost systems and tools, while important, achieves its full value only when driven by competent, motivated, and well-coordinated personnel.

The final question examined the role of external influences: *"How do external variables such as regulatory changes, supply chain disruptions, or community engagement influence the optimization of cost and project outcomes?"* Participants offered a nuanced understanding of these variables, acknowledging that even the most well-planned projects operate within environments shaped by forces beyond their control. The Project Manager began by stating that *"regulatory changes can instantly shift cost baselines, especially when new environmental or safety standards are introduced mid-project."* The Cost Engineer expanded on this by explaining that *"compliance costs are sometimes underestimated, and when new regulations demand additional reporting or materials, the project must absorb that burden."*

Supply chain disruptions were among the most cited external challenges. The Planning Engineer recounted that *"during global shipping delays, delivery of imported valves and pumps took months longer than planned, forcing us to re-sequence project tasks."* Similarly, the Contracts Manager noted that *"when suppliers fail to deliver on time, it causes idle labor and equipment costs that are difficult to recover."* The Head of Projects described how the mine now adopts risk-based procurement strategies, stating that *"we identify critical materials early and source alternates locally where possible to minimize dependency on foreign suppliers."*

Community engagement emerged as both a cost risk and an opportunity. The Junior Engineer shared that *"projects located near settlements face unplanned stoppages when communities raise grievances about employment or environmental impacts."* The Senior Project Manager, however, saw community involvement as a potential enabler, observing that *"when communities are consulted early, they become partners in the process, and this reduces delays from resistance or protest."* The General Manager contextualized this by noting that *"Lubambe operates under social license expectations—community relations are not just a moral issue but a cost and time management factor."*

Across all responses, participants agreed that external variables require flexible and anticipatory management. While regulations ensure safety and sustainability, they also raise compliance costs; while global supply chains enable quality sourcing, they expose projects to volatility; and while communities can challenge operations, they can also provide stability when effectively engaged (see table 4).

Table 4. Thematic Summary of Qualitative Findings on Cost Integration, Human Resource Capabilities, and External Influences in Project Optimization at Lubambe Copper Mine

Theme	Description / Summary of Findings	Illustrative Quotes (in italics)	Implications for Cost and Project Optimization
1. Integration of Cost Considerations in Planning and Execution	Participants emphasized that cost planning begins at the feasibility stage and is integrated through budgeting, scheduling, and monitoring systems such as Primavera P6 and SAP. However, incomplete alignment between design, procurement, and finance often leads to deviations from initial cost projections.	*"Cost planning starts at the feasibility stage, but maintaining alignment between budget and evolving design is a challenge."* – Project Engineer *"We use cost-loaded schedules to track financial performance, but rework and delays distort planned figures."* – Planning Engineer	Strengthening cross-departmental coordination and maintaining real-time data synchronization between financial and scheduling tools can enhance cost control during execution.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

2. Impact of Cost Integration on Project Outcomes	Integration of cost into project planning has both improved and hindered outcomes. When done early, it prevents overruns; when reactive, it causes inefficiencies. Participants gave examples of both scenarios.	*"Early budgeting and cost simulation prevented overruns by identifying material risks early."* – Senior Project Manager *"Sometimes focusing too much on cost savings compromises quality when cheaper materials are chosen without proper testing."* – Head of Projects	Balanced cost integration—considering quality, safety, and sustainability—yields better results than purely cost-driven decision-making.
3. Role of Human Resource Capabilities	All participants agreed that skilled and experienced personnel are the backbone of cost optimization. Training, technical competence, and teamwork improve forecasting accuracy and execution efficiency. Weak human capacity leads to reactive decision-making and cost leakages.	*"Even the best systems and plans fail without competent people executing them."* – Junior Engineer *"After training on Primavera and SAP integration, reporting accuracy improved significantly."* – Senior Project Manager	Continuous professional training, mentorship, and fostering collaborative work culture are essential for sustainable cost optimization.
4. Influence of Team Collaboration and Leadership	Collaboration across engineering, finance, and procurement teams is critical. Leadership and communication determine whether cost control frameworks succeed or fail. A siloed culture leads to duplicated work and inefficiencies.	*"When engineers, accountants, and procurement officers communicate openly, it prevents duplication and confusion."* – Contracts Manager *"Strong leadership and a cohesive team can deliver a project within cost and time, even under pressure."* – General Manager	Promoting integrative leadership and interdepartmental collaboration enhances accountability, reduces delays, and optimizes project performance.
5. Impact of External Variables (Regulations, Supply Chain, and Community Engagement)	Participants recognized that regulatory changes, supply chain disruptions, and community factors have a major impact on cost and timelines. Global shipping delays, new compliance standards, and local grievances were cited as major external risks.	*"Regulatory changes can instantly shift cost baselines, especially when new standards are introduced mid-project."* – Project Manager *"When communities are consulted early, they become partners, reducing delays from resistance."* – Senior Project Manager	Proactive risk management, flexible budgeting, and early community engagement help mitigate external shocks and stabilize project outcomes.

Barriers associated with the integration of cost and project management

The questionnaire responses obtained from project personnel at Lubambe Copper Mine revealed deep insights into the barriers that hindered the effective integration of cost and project management processes. The responses to the three open-ended questions—focused on operational challenges, institutional and technological constraints, and the effects of communication gaps—unveiled a complex reality where systems, human factors, and organizational culture all play interdependent roles in shaping project outcomes. The participants, representing different professional levels from Junior Engineer to General Manager, narrated their experiences vividly, painting a clear picture of the structural and behavioral challenges facing project integration at the mine.

The first question asked participants, *"What major challenges have you encountered in trying to align cost control mechanisms with project execution plans at Lubambe Copper Mine?"* This question provoked a shared sense of frustration and realism among respondents who deal daily with the task of maintaining cost discipline while ensuring timely project delivery. The Project Engineer was quick to note that *"the main challenge is that cost control frameworks are developed separately from project execution plans, so by the time we start implementing, some cost assumptions are already outdated."* The Cost Engineer expanded on this by emphasizing that *"budgetary figures are often static, while project execution is dynamic; any design change or delay immediately throws off the cost alignment."*

The Planning Engineer added a more technical dimension, explaining that *"although we use Primavera P6 to link costs and schedules, delays in data updates and inconsistent reporting make it hard to get a real-time picture of the project's financial health."* Meanwhile, the Junior Engineer described the problem from the field perspective, stating that *"some cost overruns arise from operational realities—like equipment breakdowns or weather interruptions—that aren't fully anticipated in the cost model."* The Project Manager echoed these concerns, noting that *"execution pressure sometimes leads to decisions made for speed rather than cost efficiency, and reconciling those decisions afterward becomes difficult."* As the discussion deepened, the Head of Projects summarized the situation poignantly: *"Our biggest challenge is achieving synchronization between what finance tracks and what engineering executes. The two systems speak different languages and work on different timelines."* The General Manager concurred, describing the root of the issue as a structural one, where *"cost control is treated as an accounting function rather than an integral part of project execution."* Together, these reflections exposed a recurring theme: cost and project management are technically connected but operationally misaligned, with gaps arising from timing, data integration, and differing departmental priorities.

The second question explored institutional and technological factors: *"Are there institutional, technological, or policy-related barriers that make it difficult to integrate cost and project management effectively? Please elaborate with examples."* The responses reflected a nuanced understanding of how organizational systems and corporate procedures sometimes create bottlenecks instead of efficiencies. The Contracts Manager explained that *"procurement policies are rigid and often too centralized, so getting approvals for variations or urgent purchases takes too long, even when project realities demand quick action."* The Senior Project Manager added that *"this rigidity discourages flexibility and makes teams hesitant to adapt plans to real-time changes."* From a technological standpoint, several participants highlighted the limitations of digital systems used at Lubambe. The Planning Engineer pointed out that *"Primavera and SAP are powerful tools, but they aren't fully integrated; information flows manually between them, and that creates delays and data mismatches."* The Cost Engineer reinforced this, saying *"sometimes the data in SAP doesn't reflect the current progress recorded in Primavera, so when management reviews cost reports, the figures appear inconsistent."* (see table 5).

Table 5. Thematic Summary of Barriers to Cost and Project Management Integration at Lubambe Copper Mine

Theme	Description / Summary of Findings	Illustrative Quotes (in italics)	Implications for Cost and Project Integration
1. Misalignment Between Cost Control and Project Execution Plans	Participants consistently highlighted that cost control mechanisms and execution plans are often developed separately. This results in outdated cost assumptions, inconsistent updates, and reactive adjustments when design or operational realities change.	*"The main challenge is that cost control frameworks are developed separately from project execution plans, so by the time we start implementing, some cost assumptions are already outdated."* – Project Engineer *"Budgetary figures are static while project execution is dynamic; any design change or delay immediately throws off*	Integrated planning between cost, scheduling, and operations teams is necessary to ensure real-time consistency and flexibility in adapting to changing project conditions.

		the cost alignment." – Cost Engineer	
2. Institutional and Policy-Related Constraints	Rigid procurement policies, bureaucratic approval procedures, and lack of unified integration policies were major barriers. Participants noted that current structures discourage quick decision-making and prevent cost alignment with operational needs.	*"Procurement policies are rigid and too centralized, so getting approvals for urgent purchases takes too long."* – Contracts Manager *"There's still no unified policy enforcing integration between cost and project teams; each department has its own templates."* – Head of Projects	Policy reforms that promote agility, decentralization, and shared accountability would enable faster and more coordinated decision-making between cost and project functions.
3. Technological and Systemic Limitations	Although advanced tools like Primavera P6 and SAP are used, poor integration between them leads to data inconsistencies, delays, and duplication of work. Many participants pointed out that system silos prevent accurate and timely reporting.	*"Primavera and SAP are powerful tools, but they aren't fully integrated; information flows manually between them."* – Planning Engineer *"Sometimes SAP data doesn't reflect the current progress in Primavera, so cost reports appear inconsistent."* – Cost Engineer	Strengthening digital integration between project management and financial systems is critical for real-time data synchronization, transparency, and accountability.
4. Communication and Departmental Silos	Communication breakdowns and siloed operations were identified as key barriers. Departments like engineering, finance, and procurement often work in isolation, leading to conflicting data, delays, and duplication of effort.	*"Departments still operate in isolation—engineering focuses on technical delivery, finance on budgets, and procurement on compliance."* – Senior Project Manager *"Sometimes cost control officers only find out about scope changes after the work is already done."* – Project Engineer	Encouraging cross-functional meetings, shared reporting platforms, and joint planning sessions would enhance alignment and reduce duplication or reactive cost management.
5. Organizational Culture and Human Factors	Cultural resistance to change, limited user training, and hierarchical communication structures hinder integration. Staff rely heavily on manual methods despite available digital systems. Leadership efforts to promote collaboration are ongoing but gradual.	*"Not everyone has the skills or access to use project tools effectively, so much of the work still happens in spreadsheets."* – Junior Engineer *"Our systems are modern, but our organizational culture hasn't caught up with them."* – General Manager	Building a culture of collaboration, digital literacy, and shared ownership across departments is essential for sustained integration of cost and project management.

The Senior Project Manager explained that *"departments still operate in isolation—engineering focuses on technical delivery, finance on budgets, and procurement on compliance. They rarely sit together to plan jointly."* The Contracts Manager added that *"this silo mentality results in repetitive meetings and conflicting data because everyone tracks progress using different formats."*

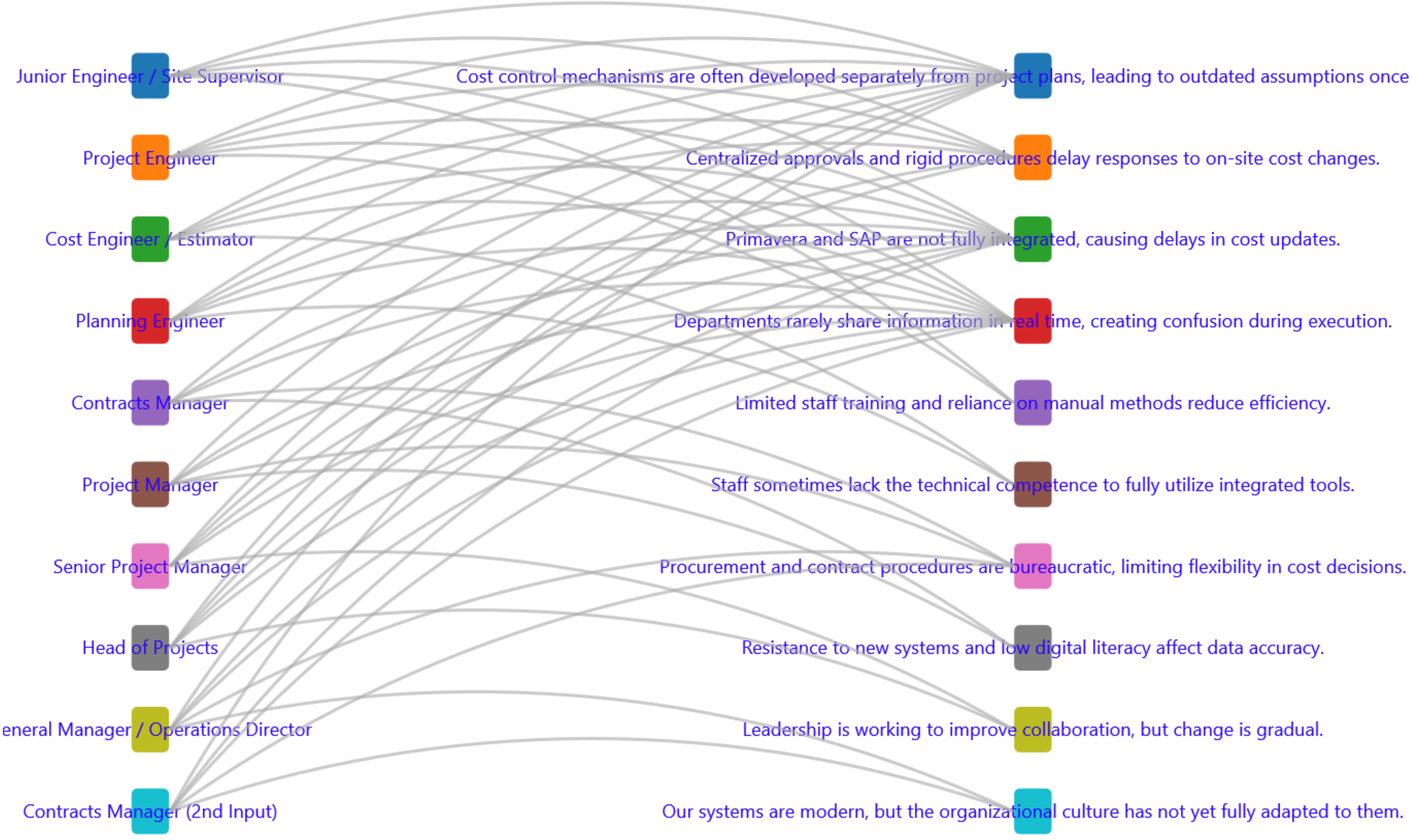

Figure 10: Standardized Qualitative Responses of Participants on Barriers to Cost and Project Management Integration at Lubambe Copper Mine

The Project Engineer described how these gaps affect implementation: *"Sometimes, cost control officers only find out about changes to project scope after the work is already done. That makes cost reconciliation reactive rather than preventive."* Similarly, the Planning Engineer remarked that *"information flow is too hierarchical—decisions and reports move slowly up and down the chain, so by the time cost teams get updates, the situation has already changed on the ground."* The Head of Projects noted that *"siloed operations stem from historical structures—departments evolved separately and still see their mandates as distinct rather than complementary."* The General Manager added that *"we are gradually breaking down these silos by encouraging integrated planning sessions, but it takes time to change old habits."* The Junior Engineer shared that *"sometimes I see site issues that could have been solved cheaply if discussed early, but by the time cost control gets involved, it's already an expense item."*

These accounts highlighted that communication challenges are both logistical and cultural. Participants emphasized that achieving integration requires not just systems and tools but collaboration, mutual accountability, and leadership that reinforces cost-conscious behavior. External variables such as regulatory changes, supply chain disruptions, and community engagement further affect project costs and timelines. As the General Manager concluded, *"Integration isn't just about technology—it's about people, communication, and trust across departments."*.

Participants emphasized that early community engagement played a critical role in mitigating social resistance and preventing costly project stoppages, thereby enhancing both cost and time efficiency. This perspective highlighted the importance of proactive risk management and sustained stakeholder collaboration in managing infrastructure projects within a complex and uncertain operating environment. Collectively, the insights revealed that Lubambe Copper Mine functioned within dynamic internal and external conditions that demanded continuous adaptation and integrated management approaches. Overall, the findings reflected a mature understanding of project cost management as a comprehensive and integrative process rather than a standalone technical function. Participants consistently agreed that success depended on three core pillars, namely effective planning systems, skilled human resources, and adaptive leadership. The interaction of these elements shaped the effectiveness of cost strategies and determined whether project objectives could be achieved amid evolving operational, regulatory, and environmental challenges. Consequently, cost optimization was perceived not only as a technical exercise but also as a strategic, human-centered, and environmentally responsive practice essential for sustainable project performance.

When participants were asked about conflicts between budget priorities and technical project needs, they provided detailed reflections based on everyday operational experiences. The Project Engineer acknowledged that *"budget limitations often clash with technical requirements, especially when unexpected design modifications arise mid-project,"* illustrating the persistent tension between financial control and engineering demands. The Cost Engineer reinforced this view by stating that *"finance departments tend to emphasize budget adherence, while engineers prioritize quality and safety,"* creating inevitable disagreements over resource allocation. From a managerial standpoint, the Head of Projects explained that *"these conflicts usually surface when cost forecasts fail to capture unforeseen site realities,"* necessitating budget reallocations to maintain progress. Participants emphasized that such conflicts were typically resolved through structured dialogue, cross-functional meetings, and leadership intervention. The General Manager observed that *"engineers justify the technical necessity of additional funds, and finance assesses affordability,"* while the Project Manager noted that leadership approval was often required to preserve both cost discipline and technical integrity. This approach ensured that operational quality and safety were not compromised while maintaining financial control.

In response to limitations in monitoring and evaluation systems, participants identified significant challenges related to data integration, reporting frequency, and staff capacity. The Planning Engineer remarked that *"Primavera and SAP are not fully synchronized, which causes time lags in cost updates,"* while the Cost Engineer added that *"by the time cost overruns appear, the project has already advanced beyond correction."* The Senior Project Manager pointed out that reporting cycles were often too infrequent, and the Junior Engineer highlighted delays in field data entry due to limited digital skills. Despite these constraints, participants acknowledged ongoing improvements, with the General Manager concluding that *"real-time dashboards and more frequent communication"* were essential to strengthening early risk detection and enhancing decision-making.

Flow of integrated strategies for the development of the framework for cost and project management optimization

The third question focused on sustainability of learning, asking, *"What strategies could be implemented to ensure continuous feedback and learning between project planning, cost estimation, and project execution teams?"* The responses to this question revealed a strong appetite for a culture of reflection and communication. The **Senior Project Manager** remarked that *"post-project reviews should become standard practice, not a formality. Every team should know what worked and what didn't."* (see figure 11). The **Cost Engineer** proposed that *"lessons learned from completed projects be stored in a central database accessible to everyone."* This idea was echoed by the **Planning Engineer**, who added that *"we can't optimize what we don't measure; tracking patterns of cost deviation helps improve future planning."* The **Contracts Manager** suggested introducing *"monthly review meetings where cost and progress data are discussed side by side, allowing issues to be corrected in real time."* (see figure 11).

The **Head of Projects** emphasized the need for accountability, stating that *"each department should have a learning KPI — a measurable goal for how well they apply insights from past projects."* The **Project Engineer** expressed that *"feedback loops work best when supported by management, because people are more willing to share challenges when they know lessons will lead to improvement, not blame."*

Several participants also proposed digital strategies. The **General Manager** noted that *"a centralized digital platform could integrate cost data, schedules, and lessons learned so that all teams access the same information base."* The **Junior Engineer** gave a simple but powerful observation, saying that *"knowledge gets lost when projects end; we need systems that capture it before everyone moves on."*

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

These perspectives converged on the idea that **continuous learning** is not a spontaneous outcome but a structured process that requires deliberate mechanisms for knowledge sharing. Participants envisioned a feedback-driven environment supported by documentation, open communication, and technology-enabled learning.

Across all three questions, a coherent story unfolded about how Lubambe Copper Mine could develop a sustainable framework for **cost and project management optimization**. Participants viewed integration as a journey that begins with **collaborative planning**, matures through **process and system improvement**, and sustains itself through **continuous learning and feedback loops**. (see figure 11).

From the engineers' emphasis on data-driven synchronization to management's focus on leadership and culture, the responses portrayed a company that understands both its challenges and its opportunities. The consensus was clear: to optimize cost and project management, Lubambe must harmonize **people, processes, and technology**.

As the **Head of Projects** aptly summarized, *"integration is not a one-time initiative — it's a continuous cycle of planning, execution, reflection, and improvement."* The **General Manager** closed the discussion with a forward-looking vision: *"If we can connect our systems, align our teams, and capture our lessons, we won't just manage costs — we'll transform how we deliver projects."*

These concluding remarks encapsulated the collective voice of the participants — a voice both pragmatic and aspirational, united by the belief that true optimization lies in an integrated, learning-oriented project culture where cost efficiency, technical excellence, and organizational growth reinforce one another. (see figure 11).

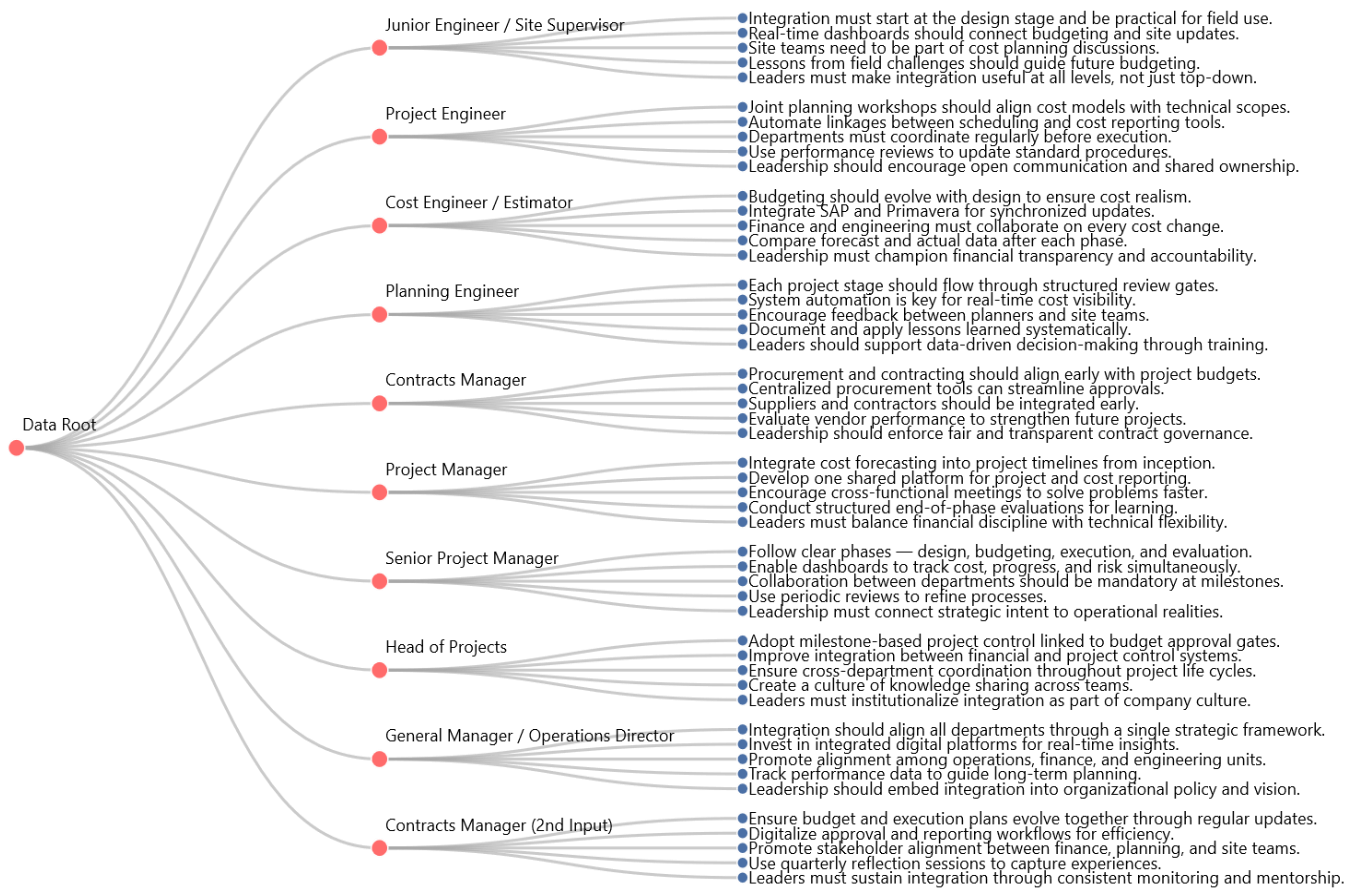

Figure 11. Qualitative Responses of Participants on the Ideal

Participants articulated a forward-looking vision for the future of project delivery at Lubambe Copper Mine, emphasizing that an ideal framework for integrating cost and project management should be grounded in collaboration, system integration, and continuous learning. They highlighted that effective integration must begin with joint planning sessions involving engineering, finance, and procurement teams to ensure early

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue II February 2026

alignment of technical design, cost modeling, and scheduling. Participants stressed that cost estimation should evolve dynamically with project progress, allowing design changes to be immediately reflected in budgets. The integration of digital dashboards combining cost, progress, and resource data in real time was also viewed as critical for enhancing transparency, minimizing duplication, and enabling timely decision-making. In addition, early involvement of contractors and suppliers was considered essential to synchronize procurement timelines, payment structures, and technical deliverables, thereby reducing delays and disputes (see figure 11).

Framework and Leadership Role in Cost–Project Management Integration at Lubambe Copper Mine

Clear review gates and milestone-based evaluations were identified as central components of the ideal framework. Participants advocated for joint reviews of cost and progress data at each project phase to promote accountability and informed adjustments. The framework was conceptualized as a circular and adaptive process, in which each project stage feeds insights and lessons into subsequent cycles, embedding continuous improvement into routine practice. Practicality and responsiveness were also emphasized, with participants underscoring the need for systems that simplify field operations rather than adding administrative burden.

Leadership emerged as a decisive factor in championing and sustaining integration. Participants agreed that leaders must actively promote collaboration, dismantle departmental silos, and align strategic goals with operational realities. Leadership was viewed as responsible for fostering a culture of teamwork, supporting capacity building through training and digital literacy, and safeguarding institutional memory by ensuring systematic documentation of lessons learned. Ultimately, participants envisioned leadership as the bridge between strategy and execution, embedding integration as a cultural norm rather than a standalone initiative. Collectively, the findings underscored that sustainable integration depends on the alignment of people, processes, and technology under committed and visionary leadership, transforming cost and project management into a unified and purpose-driven system.

DISCUSSION

The study found that cost and project management optimization at Lubambe Copper Mine was shaped by procurement efficiency, technological integration, leadership commitment, workforce competence, and market stability. These findings are consistent with Gubanov (2023), who emphasized the importance of strong internal management systems for cost efficiency, and Bag (2016), who linked procurement inefficiencies to cost overruns and delays. Similar to Buthelezi and Naidoo (2024) and Mazzaro et al. (2024), the study established that although digital tools such as SAP and Primavera are widely adopted, poor system integration and resistance to change limit their effectiveness. Leadership and human competence were also found to be central, aligning with Daka (2024), Raman (2023), and Qwathekana and Masilela (2023), who highlighted leadership and skills as key drivers of project performance.

Regarding barriers, the study identified institutional rigidity, communication silos, technological fragmentation, and cultural resistance, which mirror findings by Osei (2015), Musonda (2023), and Hyder et al. (2019). Finally, the proposed four-stage integration framework of collaborative planning, synchronized execution, real-time monitoring, and continuous feedback aligns with Botin and Vergara (2015), Callaca et al. (2024), and Maregedze et al. (2022). Overall, the findings reinforce the need for an integrated, technology-enabled, and leadership-driven approach to cost and project management optimization.

CONCLUSION

The study examined the factors influencing the optimization and integration of cost and project management in Zambia’s mining infrastructure projects, with a focus on Lubambe Copper Mine. The findings demonstrated that effective project performance and cost efficiency were shaped by a complex interaction of operational, environmental, human, technological, and institutional variables. Key determinants included procurement and supply chain efficiency, market stability, scope management, workforce competence, digital system integration, reporting practices, and leadership discipline. Procurement delays, import clearance challenges, fluctuating material prices, and exchange rate instability were identified as major drivers of time and cost overruns. Inadequate scope definition often resulted in design changes, rework, and inefficiencies, while limited skilled labor and subcontractor inconsistencies reduced productivity and increased supervision costs. Although digital tools such as Primavera P6, SAP, and Microsoft Project supported scheduling and budgeting, their effectiveness was constrained by weak system integration and inconsistent application across departments. Additionally, leadership coordination and institutional discipline emerged as critical enablers of cost optimization. However, the integration of cost and project management was hindered by misaligned planning systems, rigid institutional policies, technological fragmentation, communication silos, and cultural resistance. Participants emphasized that organizational culture, limited digital competence, and hierarchical communication structures restricted collaboration and slowed decision-making, thereby undermining the achievement of integrated, real-time project control.

Building on these findings, the study developed a practical framework for optimizing cost and project management through a continuous and cyclical process grounded in collaboration, process standardization, digital alignment, and leadership-driven learning. The proposed framework emphasized early integration at the feasibility and design stages, joint planning by finance, engineering, and procurement teams, synchronized execution, real-time monitoring, and continuous feedback mechanisms. Strategic actions included value engineering, early contractor involvement, automation of reporting systems, and structured post-project reviews to promote organizational learning. The practical implications highlighted the need for mining firms to adopt integrated digital systems, reform procurement and approval policies, enhance cross-functional collaboration, and prioritize continuous capacity building in digital and project management competencies. The study also contributed to the academic literature by offering an integrated conceptual framework that linked cost optimization, digital transformation, human capacity, and leadership dynamics within a developing economy context. Despite its contributions, the research was limited by its focus on a single mining firm and reliance on qualitative data from a small sample. Overall, the findings underscored that sustainable cost and project management optimization in Zambia’s mining sector depended on aligning people, processes, and technology within a unified, learning-oriented organizational culture supported by proactive leadership.

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