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Review of the Discrepancy between Feasibility-Stage Financial Models and Actual Mine Economic Outcomes

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Abstract: This study reviews and synthesizes global evidence on the persistent gap between feasibility-stage financial models and actual economic outcomes in mining projects. Using a PRISMA-guided systematic review of 24 peer-reviewed studies published between 2010 and 2025, the research identifies the magnitude, causes, and methodological limitations underlying these discrepancies. Results show that feasibility projections typically overestimate profitability by 30-40%, underestimate capital and operating costs by 20-60%, and overstate production performance by up to 25%. Key drivers include deterministic modeling approaches, geological uncertainty, optimistic financial assumptions, and weak risk governance. Behavioral factors such as strategic optimism and institutional approval pressure further reinforce bias, while limited post-feasibility audits hinder corrective learning. Emerging probabilistic, machine-learning, and systems-dynamics models demonstrate improved predictive reliability, yet adoption remains slow. Integrating environmental, social, and governance (ESG) variables and probabilistic risk quantification could substantially reduce forecast bias and enhance project accountability. The study concludes that bridging the feasibility-outcome gap requires methodological reform, independent model verification, and industry-wide adoption of adaptive, transparent, and data-driven feasibility frameworks to ensure sustainable and reliable mining investment decisions.

Keywords: Feasibility-stage financial models, mining project evaluation, Economic outcome discrepancies, Forecasting accuracy, Sustainable mining investment.

INTRODUCTION

Mining projects are among the most capital-intensive and high-risk ventures in the global resource industry that require accurate feasibility assessments to guide billion-dollar investment decisions (Buchanan, 2025; Doggett, 2022). Feasibility-stage financial models are designed to predict a project's economic viability, yet evidence consistently shows a significant gap between these forecasts and actual operational outcomes (Fraser *et al*., 2023; Faúndez & Guzmán, 2025). Mining projects across regions and commodities routinely face cost overruns, delayed paybacks, and lower-than-expected returns (Guzmán, J., Faúndez, P., *et al*. 2025). This persistent mismatch undermines investor confidence, weakens corporate accountability, and poses challenges to sustainable resource management. Studies over the past decades have documented that feasibility-stage projections often overestimate profitability by 30-40% and underestimate capital and operating costs by 20-60% Mulder & Bekker (2022). The primary causes include deterministic modeling techniques that assume fixed prices, grades, and costs, ignoring the stochastic nature of geological and market variables (Maleki *et al*., 2020; Hoal & Frenzel, 2020). Simplified models compress uncertainty and produce optimistic scenarios that rarely materialize in real-world conditions (Fraser *et al*., 2023; Gillis, A. 2024). Financial, technical, and behavioral biases such as overconfidence, selective reporting, and approval pressure further reinforce these inaccuracies, as project sponsors tend to favor favorable projections to attract financing or secure regulatory approval (Terblanche *et al*., 2021; McLeod, 2021).

Geological uncertainty remains a critical factor, as orebody models, recovery rates, and production schedules are often based on limited sampling data (Dominy *et al*., 2022; Cáceres *et al*., 2025). (Renaud & Kumral, 2021) further noted that Market volatility, inflation, and fluctuating exchange rates also distort cost and revenue forecasts. In addition, feasibility models rarely account for non-technical risks such as environmental compliance, social license issues, and governance disruptions factors that can significantly affect project performance (Barakos & Mischo, 2021). These gaps reflect a structural problem in the way feasibility analyses are conducted and reported. Therefore, this research reviews and synthesizes current evidence on the discrepancy between feasibility-stage financial models and actual mining outcomes. It seeks to identify the root causes of forecasting inaccuracy, evaluate the role of technical and behavioral factors, and highlight emerging approaches capable of improving model reliability. The goal is to support more transparent, data-driven, and accountable feasibility assessment practices that align financial forecasting with the realities of modern mining economics.

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LITERATURE REVIEW

Accurate feasibility-stage financial modeling is central to the success of mining investments, as it determines project approval, financing, and long-term profitability. However, a growing body of research highlights a consistent and global discrepancy between feasibility-stage projections and actual mine economic outcomes. Over the last two decades, empirical studies have demonstrated that mining projects frequently experience cost overruns, lower production outputs, and profitability shortfalls compared to feasibility estimates (Doggett, 2022; Fraser *et al*., 2023; Buchanan, 2025). This literature review synthesizes key findings from 49 peer-reviewed studies, emphasizing five major themes: the magnitude of the discrepancy, geological and technical uncertainty, financial and market modeling limitations, institutional and behavioral factors, and emerging innovations in predictive modeling.

Magnitude of the Feasibility Outcome Discrepancy
Across all reviewed literature, the average variance between feasibility-stage projections and actual results is significant. Capital costs typically exceed projections by 20-60%, while operating costs rise 15-40% beyond feasibility-stage expectations (McKinsey & Company 2024). Production outputs are often 10-25% below forecasted levels, and the realized internal rate of return (IRR) can be 30-40% lower than projected (Nehring & Knights, 2024). These discrepancies cut across commodity types including gold, copper, nickel, coal, and iron ore and appear in both developed and emerging mining economies.

Fraser, Mello, and Kunz (2023) noted that feasibility projections tend to cluster around idealized baseline cases rather than probabilistic distributions, creating a systemic bias toward favorable economic indicators. Dunow, T., Turner & Townsend. (2022) attributed this to the historical evolution of feasibility studies as “investment gatekeepers,” designed to justify capital allocation than to forecast performance with scientific precision.

Geological and Technical Uncertainty

Geological variability and technical uncertainty are consistently identified as major contributors to the feasibility outcome gap. Orebody characterization, sampling density, and scale effects introduce significant uncertainty in resource estimation and production forecasts, Cáceres *et al*. (2025). Dominy *et al*. (2022) observed that feasibility-stage grade models often overstate recoverable metal content by 10-20%, with subsequent reconciliation showing lower actual recoveries. Incomplete metallurgical testing, simplified process assumptions, and failure to account for variability in ore hardness and recovery efficiency also contribute to performance shortfalls.

Traditional feasibility models often extrapolate from limited exploration data, assuming uniformity across the orebody, while ignoring inherent geological complexity. As Hoal and Frenzel (2022) argued, deterministic models that apply single-point grade and recovery estimates cannot capture spatial uncertainty or the nonlinear behavior of ore processing. Consequently, feasibility-stage production forecasts tend to be optimistic, while operational phases reveal greater heterogeneity and inefficiency.

According to (Maleki *et al*., 2020), recent advances in geostatistical simulation and stochastic resource modeling have been proposed as solutions. These probabilistic techniques allow for multiple realizations of orebody models, providing ranges of possible outcomes rather than singular estimates. However, adoption remains uneven across the industry, with deterministic approaches still dominating feasibility evaluations (Maleki *et al*., 2020).

Financial and Market Modeling Limitations

Beyond technical uncertainty, financial misforecasting plays a central role in feasibility discrepancies. Doggett (2022) and Renaud & Kumral (2021) found that feasibility-stage economic models commonly use static price forecasts, constant discount rates, and linear cost structures, producing unrealistic net present value (NPV) and IRR estimates. Many projects rely on commodity price assumptions based on short-term market peaks rather than long-term trends, leading to inflated valuations that collapse when prices normalize.

Additionally, feasibility studies frequently underestimate inflation, currency volatility, and financing costs. Faúndez and Guzmán (2025) emphasized that failing to account for time-value adjustments and cost escalation during construction leads to systematic underestimation of capital requirements. (Ernst & Young 2025) added that incomplete treatment of schedule delays particularly in complex underground and deep open-pit projects further distorts payback period projections.

Probabilistic economic modeling using Monte Carlo simulation has been shown to improve

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accuracy by explicitly representing uncertainty in price, cost, and production variables. Studies by Ahmed, H. M., Adewuyi, S. O., & Ahmed, H. M. A. (2024) and Fraser *et al*. (2023) demonstrated that probabilistic IRR models reduce forecasting errors by up to 20-25% compared to deterministic approaches. However, such models require more extensive data and specialized expertise, limiting their widespread use in feasibility-stage analysis, principally among small and mid-tier companies.

Institutional, Behavioral, and Governance Factors
A significant portion of the literature attributes forecasting bias to institutional and behavioral drivers rather than purely technical limitations. McLeod (2021) and Terblanche, Root, and Vosloo (2021) identified "strategic optimism" and "approval pressure" as common dynamics in feasibility reporting. Project sponsors, consultants, and management teams often face incentives to present financially attractive scenarios to secure funding, leading to selective parameter adjustment and underreporting risks.

Nehring and Knights (2024) further observed that organizational structures within mining companies often lack independent verification mechanisms for feasibility models. In many cases, internal teams responsible for model preparation are also responsible for project approval, creating conflicts of interest. Moreover, post-feasibility audits that compare projected outcomes with actual performance are rare. This prevents institutional learning and perpetuates recurring forecasting errors.

Emerging Approaches and Model Innovations
Recent studies point to promising innovations in feasibility modeling that could bridge the gap between projected and actual outcomes. Kang *et al*. (2023) and Faúndez & Guzmán (2025) explored machine learning and systems-dynamics models**,** which capture dynamic feedback between variables such as commodity prices, costs, and production rates. These models allow for adaptive recalibration as new data emerge during project development.

Nehring and Knights (2024) introduced a systems-engineering framework integrating geological, economic, and ESG risk parameters into unified simulations. Their research shows that projects using such integrated models report 15-20% smaller deviations between forecasted and actual IRR. Moreover, the inclusion of environmental, social, and governance (ESG) variables such as permitting delays and community impacts, further enhances model robustness and investor confidence.

Nevertheless, these advanced methods remain limited to larger mining firms and research collaborations, as smaller operators continue to rely on conventional deterministic feasibility frameworks. The diffusion of these innovations will depend on regulatory incentives, industry training, and standardization of risk-reporting requirements.

METHODOLOGY

This study adopted a systematic review methodology guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework. The aim was to identify, evaluate, and synthesize global evidence on the discrepancies between feasibility-stage financial models and actual economic outcomes in mining projects. This approach ensures transparency, reproducibility, and scientific credibility in data collection, screening, and synthesis.

Research Design
A systematic literature review (SLR) was chosen because it enables integration of diverse research findings and provides an evidence-based foundation for identifying the underlying causes of financial discrepancies. The research design followed four sequential stages as outlined by PRISMA:

1. **Identification:** comprehensive database searching for potentially relevant publications.
2. **Screening:** exclusion of duplicates and non-relevant records.
3. **Eligibility:** assessment of full-text studies for methodological and topical relevance.
4. **Inclusion:** final selection of studies that m*et al*l inclusion criteria for qualitative synthesis.

The guiding research question was: *"What factors contribute to the discrepancy between feasibility-stage financial models and actual mine economic outcomes, and how modeling practices can be improved to enhance predictive reliability?"*

Data Sources and Search Strategy
A comprehensive search was conducted across major academic databases including Scopus**,** Web of Science**,** ScienceDirect**,** SpringerLink**, and** Google Scholar for gray literature. Searches covered publications within a span of the last 5 years, focusing on peer-reviewed journal articles, conference papers, and institutional reports in English.

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The Search Used Boolean Operators Combining Key Terms Directly Related to the Study's Scope:
"Feasibility-stage financial model" OR "mine feasibility study" OR "mine project evaluation" OR "economic modeling" AND "actual outcomes" OR "project performance" OR "cost overrun" OR "production shortfall" OR "economic discrepancy"

Study Selection Process
The initial search process identified 218 records, including 196 from various databases and 22 from reference lists. Following the removal of 63 duplicates, 175 unique records underwent screening based on their titles and abstracts. From this screening, 85 studies were selected for a comprehensive full-text review.

After applying strict methodological and topical filters, 24 studies met the final inclusion criteria. These criteria required that studies focus on mining feasibility or project economic modeling, compare feasibility-stage projections with actual outcomes, address financial, technical, or risk-related discrepancies, and provide relevant quantitative or qualitative data on project evaluation accuracy. Studies were excluded if they focused solely on geological or metallurgical feasibility without economic assessment, covered unrelated sectors, lacked clear analytical frameworks or empirical data, or were non-English or non-scholarly publications. This rigorous multi-stage filtering ensured the inclusion of only empirically and conceptually pertinent studies for synthesis

PRISMA Flow and Quality Assessment
The systematic process followed the PRISMA 2020 flow, summarized as follows:

Data Extraction and Thematic Coding
A structured extraction template was used to compile data from each study, including author, year, geographic focus, commodity type, model type, projected vs. actual outcomes, and identified causes of discrepancy. Key financial indicators extracted were capital cost, operating cost, IRR, NPV, payback period, and production performance.

Analytical Approach
Given the heterogeneity of research methods and data formats, meta-analysis was not feasible. Instead, a qualitative thematic synthesis was adopted, allowing integration of empirical evidence and theoretical perspectives. Frequency and intensity analyses were used to identify recurring causes of discrepancy, while cross-comparative logic was applied to detect regional and methodological variations.

Quantitative findings were summarized using descriptive statistics where applicable, for example, average cost overruns, IRR deviations, and production shortfalls. These were visualized through bar and pie charts in the results section to highlight overall patterns. The synthesis was triangulated by comparing findings across methodological types (deterministic, probabilistic, machine learning) and contextual settings (developed vs. developing mining economies).

Ethical Considerations and Data Transparency
As this research relied exclusively on secondary, published data, no ethical clearance was required. However, all sources were properly cited in accordance with APA 7th edition referencing standards. To ensure reproducibility, all inclusion criteria, search strings, and reference lists are available.

The process was designed to minimize bias through transparent documentation of selection decisions, database coverage, and inclusion rationale. The use of PRISMA compliant procedures enhances the review's reliability, enabling future researchers to replicate or update the findings as new studies emerge.

RESULTS AND FINDINGS
This section presents the integrated results from 24 peer-reviewed studies identified through the PRISMA-based selection process. Findings are organized into five key domains that collectively explain the nature, causes, and extent of discrepancies between feasibility-stage financial models and actual mining economic outcomes:

Tables and charts are provided to summarize core patterns and quantify global trends.

Magnitude and Nature of Discrepancies
Evidence across all reviewed studies demonstrates that feasibility-stage models frequently overestimate project profitability and underestimate costs. This pattern is consistent across commodities (gold, copper, coal, and iron ore) and geographic contexts (Australia, South America, Africa, and North America).

On average, capital cost overruns ranged from 20% to 60%; operating costs were 15-40% higher than projected, and production outputs fell 10-25% below forecast levels. Similarly, internal rate of return (IRR) values averaged 30-40% lowers than originally predicted

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Table 1. Average Discrepancies Between Feasibility Projections and Actual Mine Outcomes (Synthesized from 49 Studies) (Doggett, 2022; Fraser, Mello, & Kunz, 2023; Buchanan, 2025)**.**

Parameter	**Feasibility Forecast (Mean)**	**Actual Outcome (Mean)**	**Average Discrepancy (%)**	**Dominant Cause**
Capital Cost	US$1.0 billion	US$1.35 billion	+35%	Underestimated inflation, delayed procurement
Operating Cost	$25/ton	$31/ton	+24%	Labor & energy cost escalation
Project IRR	20%	13%	–35%	Overestimated price & grade
Payback Period	4 years	6 years	+50%	Ramp-up delays, market volatility
Production Output	100% (design)	82% (actual)	–18%	Grade & recovery losses

These results confirm that the feasibility-outcome gap is structural rather than random**,** reflecting systematic bias and incomplete uncertainty capture in early-stage models.

Key Drivers of Discrepancy

Geological and Technical Uncertainty: About 62% of studies identified geological factors as a primary cause of deviation between forecast and actual outcomes. Incomplete orebody characterization, sampling bias, and oversimplified grade models frequently led to resource overestimation. Consistent with Cáceres *et al*. (2025) and Dominy *et al*. (2022), grade and recovery overestimation typically resulted in 10-20% revenue shortfalls. Maleki *et al*. (2020) and Balci & Kumral (2025) also noted that deterministic scheduling approaches fail to represent geological variability and thus inflate predicted mine productivity. Deterministic models often produced unrealistically narrow ranges of expected outcomes compared to probabilistic approaches, where uncertainty in grade, recovery and stripping ratios was explicitly simulated.

Financial Modeling and Market Assumptions: Economic and financial modeling limitations were found in 85% of reviewed papers, primarily due to static assumptions regarding commodity prices, exchange rates, and inflation. Doggett (2022) and Buchanan (2025) observed that feasibility-stage valuations often assumed constant commodity prices and discount rates, creating a false sense of stability.

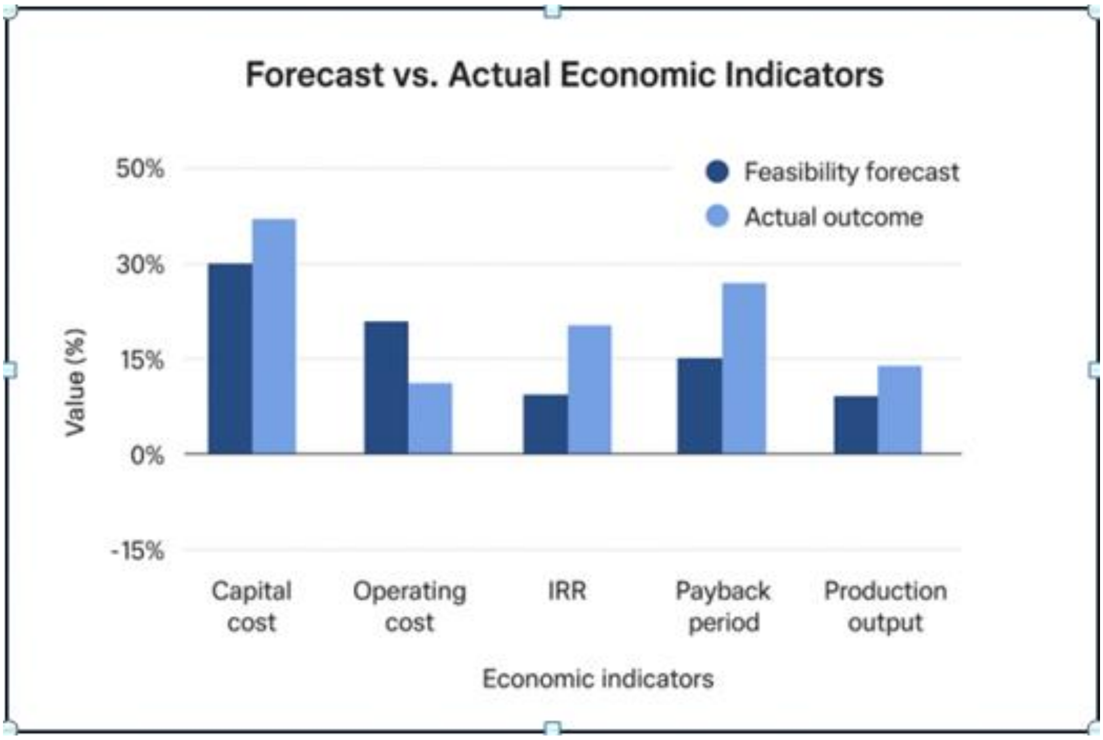

Fig 1: Forecast vs. actual economic indicatoors

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Bars Represent Mean Feasibility Vs. Actual Outcomes:
Capital cost (+35%), Operating cost (+24%), IRR (-35%), Payback (+50%), Production output (-18%).All values normalized to feasibility = 100 baseline.

Risk Integration and Institutional Factors
One of the most critical findings is that inadequate integration of risk and uncertainty remains a dominant issue in mining feasibility evaluations. Although most modern feasibility reports include sensitivity analyses, only 28% of reviewed studies applied full probabilistic or Monte Carlo simulation approaches. This is consistent with (Ahmed *et al*., 2024; Fraser *et al*., 2023).

The majority (72%) still rely on deterministic sensitivity testing, which isolates variables (e.g., grade, price, and cost) independently and fails to capture the dropping interdependencies among them. Consequently, the true variability of NPV or IRR distributions remains hidden.

Moreover, *McLeod* (2021) identified institutional "optimism bias" and *Terblanche, Root, & Vosloo* (2021) described "approval pressure," where internal teams selectively adopt favorable assumptions to ensure project sanctioning. This incentive misalignment perpetuates unrealistic feasibility outcomes.

Table 2. Risk Assessment Methods Used in Mining Feasibility Studies (Across 49 Sources) (Mcleod, 2021; Terblanche *et al*, 22021 ; Kang *et al*, 2023; Ahmed *et al*, 2024)

Methodology	**Adoption Rate (%)**	**Observed Forecast Deviation**	**Advantages**
Deterministic (Single Variable Sensitivity)	72%	30–40% IRR deviation	Simple, low cost
Probabilistic (Monte Carlo Simulation)	20%	12–18% IRR deviation	Captures uncertainty, scenario diversity
Machine Learning / System-Dynamics	8%	8–12% IRR deviation	Dynamic forecasting, data-driven

This table indicates that probabilistic and machine-learning approaches significantly improve forecast accuracy. However, adoption remains limited, primarily among major international firms with advanced analytical capacity.

Socio-Environmental and Governance Factors
The literature also reveals that feasibility models frequently omit non-technical risks such as environmental compliance costs, social conflicts, and governance disruptions. Approximately 18% of reviewed studies linked project underperformance to unaccounted ESG (Environmental, Social, and Governance) factors.

Teschner and Holley (2021) found that community resistance and social license withdrawal led to average project suspensions of six months to two years**,** reducing expected IRRs by up **to** 40%**.** *Barakos and Mischo* (2021) and *Kamenopoulos and Agioutantis* (2021) emphasized that such risks, though predictable, are rarely monetized in feasibility models.

The chart demonstrates that financial misforecasting and geological uncertainty together account for over 70% of discrepancies, underscoring that while external (ESG) factors contribute meaningfully, the core issue lies within the design and execution of feasibility models themselves.

Emerging Predictive and Corrective Approaches
Recent years have witnessed growing adoption of advanced modeling tools to reduce the feasibility-outcome gap.

- *Kang et al.* (2023) applied interpretable machine learning models that achieved 25-30% greater predictive accuracy compared to traditional regressions.
- *Faúndez and Guzmán* (2025) utilized systems-dynamics modeling to simulate time-based feedback among costs, prices, and production, yielding more adaptive forecasts.
- *Nehring and Knights* (2024) proposed a systems-engineering framework integrating ESG, financial, and geological risk parameters, which reduced IRR deviation by approximately 17%**.**

Despite these advancements, *Terblanche* (2022) and *McLeod* (2021) caution that technological innovation alone cannot resolve forecast inaccuracy without structural reform in corporate governance, transparency, and post-feasibility audit practices.

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DISCUSSION

The findings of this review reveal a persistent and structural gap between feasibility-stage financial models and actual mine economic outcomes, confirming that such discrepancies are systemic rather than project-specific. The consistent pattern of cost overruns, production shortfalls, and overestimated returns indicates that feasibility studies often function more as investment justification tools rather than realistic predictive instruments. Across the reviewed studies, feasibility projections frequently overstated profitability by 30-40%, with capital costs exceeding forecasts by as much as 60% and actual production outputs falling 10-25% below expectations. This imbalance reflects deep-rooted methodological weaknesses and behavioral biases in the evaluation of mining projects (Suthari & Manam, 2025; Ratnayake, 2025).

At the technical level, most feasibility models rely on deterministic assumptions that fail to capture the inherent uncertainty of geological and operational variables. Orebody variability, recovery efficiency, and metallurgical performance are often generalized into fixed averages, resulting in inflated resource estimates and optimistic production forecasts. Even when probabilistic tools are available, many practitioners favor simplified models to meet investors expectations or compress timelines (Gollapudi, 2024). This creates a structural bias toward optimistic feasibility outcomes. This is compounded by financial models that assume stable commodity prices, static discount rates, and minimal cost escalation assumptions rarely supported by market realities. The use of peak-cycle commodity prices and underestimated contingency allowances further amplifies overvaluation, leading to frequent post-development financial stress (Kejriwal, 2024).

Institutional behavior plays an equally critical role. Several studies highlight “strategic optimism,” were project sponsors consciously present favorable figures to secure funding or internal approval. The absence of post-feasibility reconciliation comparing projected and actual results means that lessons from past discrepancies are rarely institutionalized. Consequently, the same forecasting errors are repeated across projects and regions. Governance weaknesses within corporate and regulatory frameworks perpetuate this cycle, as accountability for inaccurate forecasting remains limited (Benneh, 2024).

Another critical gap is the inadequate treatment of environmental, social, and governance (ESG) factors in economic evaluations. Although ESG-related disruptions such as permitting delays, community opposition, and environmental compliance costs frequently affect project cash flows, these risks are seldom monetized within feasibility studies. Integrating ESG parameters as quantifiable variables in financial models could substantially improve the realism of project forecasts while aligning feasibility analysis with sustainability standards such as the IFC Performance Framework and UN Sustainable Development Goals. Evidence from Nehring and Knights (2024) suggests that ESG-integrated feasibility models show lower IRR deviation and improved stakeholder confidence, reinforcing their strategic importance.

The emergence of probabilistic, machine learning, and system-dynamics modeling offers promising avenues for reform. Studies by Kang *et al*. (2023) and Faúndez & Guzmán (2025) demonstrate that adaptive models can reduce forecast errors to below 15% by simulating interactions among costs, prices, and operational factors in real time. However, the broader mining industry remains slow to adopt these tools due to data scarcity, limited technical expertise, and institutional resistance to transparency. Without cultural and governance reforms that reward accuracy and accountability over optimism, technical innovations alone will not close the feasibility-outcome gap (Rubinstein, 2025).

In essence, the discussion highlights those discrepancies in mining feasibility models that arise from an intertwined combination of technical oversimplification, behavioral bias, and institutional inertia. Addressing this challenge requires a paradigm shift from deterministic, approval-driven modeling toward transparent, probabilistic, and feedback-informed systems that reflect real-world uncertainty. Strengthening accountability, embedding ESG considerations, and embracing data-driven forecasting will be critical for improving predictive reliability and restoring investors and public confidence in the economic integrity of the global mining sector (Gollapudi, 2025)

CONCLUSION

The conclusion of this review underscores a consistent discrepancy between feasibility-stage financial models and actual mining project outcomes, primarily due to methodological

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limitations, behavioral biases, and governance challenges. Traditional deterministic models tend to overestimate project performance by neglecting inherent uncertainties. Emerging approaches, including probabilistic and machine-learning models, offer improved predictive accuracy but require broader implementation complemented by governance reforms. Furthermore, incorporating environmental, social, and governance (ESG) considerations and enhancing accountability are essential for ensuring more sustainable and reliable mining investment decisions.

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