Co-designing the future: Integrating social transition and compliance for sustainable mine closures

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Abstract

Mine closures have traditionally prioritised environmental rehabilitation, often overlooking the deep socio-economic disruptions that follow, particularly in mining-dependent communities. This paper argues that mine closure should not mark the end of prosperity but rather the beginning of a sustainable transition. The coproduction model, which integrates community participation, governance, and economic planning, offers a transformative approach to closure planning.

Drawing on case studies from Ghana, Zambia, and Indonesia, this research examines the successes and failures of past closures, highlighting the critical role of stakeholder engagement, skills development, and economic diversification. By incorporating emerging technologies such as AI-driven economic forecasting, blockchain for governance transparency, and decentralised finance (DeFi) models, mining companies can ensure a just and sustainable post-mining future.

This study challenges outdated closure models and presents a forward-looking strategy that sees mine closure not as an endpoint, but as a catalyst for social resilience and economic transformation. It underscores the need for policy reforms, stronger governance, and investment in alternative industries to prevent mining towns from becoming economic wastelands.

By shifting the paradigm from remediation to regeneration, this research calls for a new era of mine closure planning that puts people and prosperity at its core.

Keywords

stakeholder engagement, social transition, mine closure, international standards, social license to operate

Introduction

Mining has long been a cornerstone of global economic development, providing essential raw materials for industrial growth. However, as mines reach the end of their operational lifespan, they often leave behind significant environmental, economic, and social challenges. Traditionally, mine closure planning has focused primarily on environmental rehabilitation, aiming to restore landscapes and mitigate ecological damage. While this is crucial, it fails to address a critical issue – the long-term socio-economic sustainability of mining dependent communities.

In many regions, especially in Africa, mine closures have triggered economic collapse, unemployment, and social instability. Local economies built around mining operations struggle to transition, leaving communities vulnerable. This is evident in past closures such as the Copperbelt mines in Zambia, where the absence of post-mining economic planning led to widespread poverty and illegal mining. Similarly, the Grasberg mine in Indonesia saw social unrest when thousands of workers were left without alternative livelihoods. The Obuasi mine in Ghana, however, provides an example of a partial success, where economic transition efforts, although initially mismanaged, were later improved through stakeholder engagement. These cases highlight a crucial question: How can mine closure be managed as a long-term socio-economic transition rather than an abrupt shutdown?

This paper proposes a co-production model for sustainable mine closure, in which mining companies, governments, and communities work together to design inclusive, forward-thinking closure strategies. This model moves beyond conventional environmental remediation to integrate economic diversification, skills development, and long-term governance frameworks. Additionally, emerging technologies such as AI-driven economic forecasting, blockchain-based governance, and decentralised finance (DeFi) models present new opportunities for ensuring transparent, data-driven, and community-led transition planning.

Using case studies from Ghana, Zambia, and Indonesia, this paper examines both the failures of traditional mine closures and the potential of the co-production model. It also explores the challenges in implementing this approach, particularly in Africa, where weak governance, economic dependence on mining, and limited financial investment create barriers to sustainable transition. Finally, the paper outlines policy recommendations, demonstrating how a combination of regulatory reforms, technology-driven solutions, and inclusive governance structures can transform mine closure into an opportunity for long-term community resilience.

By reframing mine closure as an economic reinvention rather than a regulatory burden, this research contributes to the growing discussion on sustainable mining practices. If properly implemented, the co-production model can prevent economic collapse, empower communities, and create a legacy of resilience in post-mining regions.

Literature review

Understanding social transition

Social transition in the context of mine closure refers to the process of preparing local communities for life after mining. It involves a shift in the economic, social, and environmental dynamics of communities that have relied on mining as their primary economic driver. The goal of social transition is to minimise the socio-economic disruptions caused by the termination of mining activities and to create a pathway for communities to adapt to new forms of livelihood and societal structure (Bainton, Holcombe, 2018).

In many cases, the closure of a mine represents the loss of the primary source of employment in the region, leading to economic stagnation and social dislocation. The co-production model addresses this by investing in skills development and alternative industries, ensuring that communities are not left economically vulnerable when mining operations cease (Monteiro et al., 2019). A key outcome of the co-production model is building community resilience, which refers to a community's ability to adapt to changing circumstances, particularly in the face of economic shocks such as mine closures. By involving communities in the planning process and investing in social infrastructure (e.g., education, healthcare, local governance), the co-production model helps to ensure that communities are better equipped to navigate the transition from a mining-dependent economy to a diversified one (Bainton, Holcombe, 2018).

Key elements of social transition include

i. Economic transition: Shifting the economic base from mining to other sustainable industries, such as agriculture, renewable energy, or tourism.
ii. Skills development: Providing workers with the training and skills necessary to transition into new employment opportunities post-mining.
iii. Community resilience: Strengthening social institutions, such as education and healthcare, to ensure the long-term sustainability of the community.
iv. Infrastructure investment: Ensuring that local infrastructure, such as roads, schools, and utilities, is maintained or repurposed for new economic activities (Morrison-Saunders, 2019).

Social impacts of mine closure

Research has consistently shown that the social impacts of mine closure are extensive. Communities often experience a rapid decline in employment opportunities, leading to increased poverty, migration, and social dislocation. These impacts are compounded by the fact that mining towns are often built around the mining operations, with limited infrastructure or alternative economic opportunities in place once the mine closes (Edwards, Maritz, 2019). In the African context, where economic diversification is often limited, mine closures can have especially devastating consequences. For instance, the closure of large-scale coal mines in South Africa has been linked to rising unemployment rates, increased crime, and the breakdown of social services in affected communities (Kemp, Owen, 2019). Similar patterns have been observed in other regions where mining is a key driver of local economies, such as Zambia and Ghana (Laurencont et al., 2019).

While international standards such as the IFC Performance Standards and the UN Guiding Principles on Business and Human Rights emphasise the importance of stakeholder engagement in mine closure, implementation remains inconsistent, particularly in developing economies (World Bank, 2021). The World Bank further notes that regulatory frameworks often lack enforcement mechanisms, allowing companies to abandon operations without adequately supporting local communities (World Bank, 2021).

International best practices: IFC, UNGP, and SDGs

The shift toward more socially responsible mine closure practices has been driven, in part, by international frameworks such as the IFC Performance Standards, the United Nations Guiding Principles on Business and Human Rights (UNGP), and the United Nations Sustainable Development Goals (SDGs). These frameworks emphasise the importance of integrating social considerations into mine closure plans, particularly in relation to human rights, sustainable livelihoods, and community resilience (Monteiro et al., 2019).

The International Finance Corporation (IFC) Performance Standards serve as a global benchmark for responsible mine closure practices. Standard 5 focuses on land acquisition and involuntary resettlement, highlighting the need to avoid or minimise displacement and to provide affected communities with opportunities for alternative livelihoods (IFC, 2012). By focusing on social impacts, the IFC standards push for more inclusive closure strategies, ensuring that mining companies are held accountable for the socio-economic wellbeing of local populations during and after the closure process.

The United Nations Guiding Principles on Business and Human Rights (UNGP) provide a framework for ensuring that the rights of local communities are protected during mine closure. These principles emphasise the importance of preventing and mitigating human rights abuses associated with corporate activities, including mining (Ruggie, 2011).

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, also offer a blueprint for integrating social sustainability into mine closure planning. Goals such as SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action) are directly relevant to the challenges posed by mine closures (Monteiro et al., 2019). In countries like Zambia and Ghana, where mining is a dominant economic activity, adhering to the SDGs can help ensure that closure plans contribute to long-term social and economic resilience in affected regions.

Emerging research advocates for a more participatory approach to mine closure, often referred to as the co-production model. This model is centered around the principle that mine closures should be designed and implemented in collaboration with local communities. In contrast to the top-down approach of traditional closure plans,

the co-production model emphasises stakeholder engagement and shared decision-making (Brock et al., 2019). This ensures that closure plans are not only technically sound but also socially responsive to the unique needs of the affected communities.

The co-production model: A new framework for sustainable mine closure

The co-production model is intrinsically linked to the concept of social transition because it offers a framework for integrating the needs and aspirations of local communities into the mine closure process. The co-production model recognises that communities are not passive recipients of mine closure plans but are active agents in shaping their post-mining future (Brock et al., 2019).

Key elements of the co-production model include:

1. Early stakeholder engagement: Ensuring that local voices influence closure planning before operations stop (Morrison-Saunders, 2019).
2. Economic diversification strategies: Investing in alternative industries, skills development, and local businesses to prevent economic collapse (Bainton, Holcombe, 2018; Banks, 2018).
3. Decentralised governance: Establishing multi-stakeholder committees to oversee and adjust closure plans over time (Kemp, Owen, 2019).

Case studies

Grasberg mine, Indonesia: A failure of social transition

In many instances, failures in mine closure planning can be attributed to a lack of meaningful consultation with affected communities, government bodies, and other stakeholders. As a result, closure plans often fail to address the specific social and economic needs of those most impacted by the cessation of mining activities (Morrison-Saunders, 2019).

One high-profile example of the consequences of inadequate stakeholder engagement is the closure of the Grasberg mine in Indonesia. Operated by Freeport-McMoRan, the mine was one of the largest gold and copper mines in the world, providing jobs and economic opportunities to the local population in the remote region of Papua. However, when operations began winding down, there was little effort to engage with the local indigenous communities regarding their future livelihoods or the social impact of the mine's closure. The result was social unrest, economic instability, and long-term disputes between the local community and the mining company (Söderholm, Svahn, 2015).

Challenges and mistakes

i. Lack of alternative livelihoods: Over 13,000 workers lost their jobs upon closure, no formal transition programmes to support re-employment (Gunawan et al., 2023).
ii. Minimal stakeholder engagement: Indigenous communities were not involved in closure planning, leading to protests (ICMM, 2020).
iii. Poor economic transition strategy: Despite years of mining profits, little investment was made in alternative industries, making the transition economically unsustainable.

Lessons learned

i. Grasberg demonstrates the risks of abrupt closure without stakeholder planning; stakeholder engagement must start early to prevent social backlash.
ii. The co-production model could have mitigated social unrest by incorporating local governance and transition strategies.
iii. AI-driven economic forecasting could have predicted the economic risks and helped identify sustainable industries for transition.

Obuasi mine, Ghana: A shift toward co-production

In 2014, operations were suspended due to high operating costs and safety concerns, leading to mass layoffs and economic stagnation (Adu-Gyamfi et al., 2021). Initially, local communities were excluded from closure discussions, resulting in protests. However, the co-production model was later implemented, leading to a more sustainable transition.

Key takeaways

i. The local community viewed the closure as a corporate decision, excluding local voices (Mususa, 2022). The closure announcement led to protests due to job losses (Hilson, Yakovleva, 2007).
ii. Initial plans failed to address alternative livelihoods, forcing reliance on artisanal mining but participatory planning improved outcomes.
iii. Investment in alternative industries (agribusiness, SMEs) helped stabilise the economy.
iv. Agricultural training programmes were introduced, helping ex-miners transition into agribusiness (Hilson et al., 2022).
v. A community-led oversight board ensured transparency in post-mining projects.
vi. The government and AngloGold Ashanti partnered to fund small and medium-sized enterprises (SMEs) (World Bank, 2021).

Lessons for future mine closure strategies

i. Governments must enforce stronger regulations to ensure that companies provide clear post-closure economic transition plans.
ii. Blockchain-based governance could ensure mine closure funds are managed transparently, preventing companies from abandoning their financial obligations.
iii. Decentralised finance (DeFi) models could enable mining communities to self-fund local businesses and post-mining development projects, reducing reliance on government assistance.

Copperbelt, Zambia: The dangers of economic over-reliance on mining

The socio-economic and political realities of African countries, such as weak governance and regulatory oversight, can make it difficult to enforce social closure commitments (Kemp, Owen, 2019). Limited economic diversification, and high levels of poverty, create a complex environment for mine closure planning (Banks, 2018), especially in regions where there are deep cultural or political divides between mining companies and local communities (Bainton, Holcombe, 2018). However, these challenges also make the co-production model particularly relevant in the African context. The Zambian Copperbelt has historically been one of the world's most productive copper mining regions, contributing significantly to the country's economy. However, the closure of several large mines in the late 1990s and early 2000s, combined with the privatisation of state-owned mining companies, led to severe economic and social consequences (Mususa, 2022). As several mines in the region approach closure, local stakeholders have been involved in developing a closure plan that focuses on skills development, agricultural investment, and the promotion of small- and medium-sized enterprises (SMEs) (Hilson, Yakovleva, 2007).

Challenges and mistakes

i. Mass unemployment and informal mining: Thousands of former mine workers turned to unsafe artisanal mining, leading to dangerous working conditions, environmental damage, and health risks (Hilson, Maconachie, 2020).
ii. Policy failures and lack of enforcement: Weak regulatory oversight allowed private mining companies to exit without fully implementing closure plans, leaving communities without economic alternatives (World Bank, 2021).
iii. Economic collapse and social decline: With no structured transition programmes, former mining towns experienced high poverty rates, rising crime, and deteriorating infrastructure (Mususa, 2022).

Lessons for future mine closure strategies

i. AI-driven economic forecasting could have helped predict which alternative industries (e.g., agribusiness, tourism, renewable energy) would be most viable for the Copperbelt.
ii. Blockchain-based governance could ensure mine closure funds are managed transparently, preventing companies from abandoning their financial obligations.
iii. Decentralised finance (DeFi) models could enable mining communities to self-fund local businesses and post-mining development projects, reducing reliance on government assistance.

Challenges in implementing the co-production model in Africa

The co-production model offers a promising and innovative approach to mine closure, particularly in terms of its emphasis on stakeholder engagement, socio-economic resilience, and long-term sustainability. However, while the model has shown great potential, its implementation, particularly in developing regions such as Africa, presents several challenges. These challenges stem from a range of political, economic, social, and environmental factors, each of which must be addressed to ensure the successful execution of the model. This chapter explores the primary challenges to implementing the co-production model and offers suggestions for overcoming them.

Weak governance and regulatory gaps

One of the primary obstacles to effective mine closure in Africa is the lack of strong regulatory enforcement. Many governments have mine closure policies on paper, but poor enforcement mechanisms allow mining companies to abandon sites without fulfilling their obligations (World Bank, 2021). In Zambia's Copperbelt, for instance, weak regulatory oversight meant that mining companies privatised and exited without implementing structured transition programmes, leaving communities in economic distress (Mususa, 2022). Without strong governance, the co-production model struggles to gain traction, as it depends on the active participation of both the government and communities to hold mining companies accountable. In addition to weak governance, corruption is a pervasive issue in many mining-dependent economies. Mining companies may form corrupt relationships with government officials, prioritising short-term profits over the long-term well-being of the communities affected by mine closure. In such cases, the co-production model, which depends on transparent and accountable decision-making, can be difficult to implement (Banks, 2018).

Key issues

i. Limited monitoring and accountability. Governments often lack resources and technical capacity to ensure compliance with mine closure plans (Vivoda et al., 2019).
ii. Political interference and corruption. Some mining firms exploit loopholes or negotiate lenient closure requirements through political channels (Hilson, Maconachie, 2020).
iii. Short-term policy focus. Many governments prioritise immediate revenue from mining rather than long-term sustainability planning (ICMM, 2020).

Economic barriers and over-reliance on mining

Many African economies are heavily dependent on mining revenues to fund public services, infrastructure, and economic development. This dependency can create a conflict of interest, as governments may prioritise the continued extraction of resources over long-term social planning, making it difficult to prioritise post-mining economic planning. Countries such as Zambia, the DRC, and South Africa rely on mining for a significant share of the GDP and foreign exchange earnings, meaning governments have little incentive to focus on closure strategies (Vivoda et al., 2019). Mining companies may be reluctant to adopt the co-production model due to the perceived high costs associated with socio-economic transition planning, skills development, and community engagement.

Key issues

i. Lack of economic diversification. Alternative industries (e.g., manufacturing, agribusiness, or renewable energy) are not well-developed in mining regions (Adu-Gyamfi et al., 2021).
ii. Limited access to capital. Small and medium-sized enterprises (SMEs) struggle to secure funding for post-mining business ventures (Monteiro et al., 2023).
iii. Job market mismatch. Many former mine workers lack the skills needed for non-mining industries, leading to high post-closure unemployment rates (Hilson et al., 2022).

Infrastructure and investment gaps

Even when governments and companies are willing to invest in alternative industries, the lack of infrastructure in many mining-dependent regions makes economic transition difficult. Many former mining towns lack adequate transport, energy, and digital infrastructure, which discourages new investment. Many African governments face significant capacity constraints, particularly in rural regions, where government officials may lack the resources and expertise to oversee complex closure plans or hold mining companies accountable for failing to meet social and environmental commitments (Hilson, Yakovleva, 2007). Many communities lack the technical expertise needed to engage fully in the planning and implementation of mine closure strategies. This skills gap makes it difficult for communities to actively participate in decision-making, particularly in areas such as economic planning and environmental management (Edwards, Maritz, 2019; Kemp, Owen, 2019). In the absence of effective monitoring, the co-production model, which relies on continuous evaluation and stakeholder feedback, becomes difficult to sustain (Vivoda et al., 2019).

Key issues

i. Poor transport and logistics networks. Many former mining towns are geographically isolated, making new businesses unviable (World Bank, 2021).

ii. Unreliable energy supply. Industries such as manufacturing or agribusiness require stable power, which is often lacking in post-mining regions (ICMM, 2020).
iii. Limited digital infrastructure. The absence of broadband connectivity hinders the growth of technology-driven sectors that could replace mining (Monteiro et al., 2023).

Overcoming the challenges

While the challenges to implementing the co-production model are significant, they are not impossible. The following strategies could help overcome these barriers and ensure the successful execution of the co-production model:

i. Strengthening governance and anti-corruption measures: African governments must focus on strengthening governance structures and implementing anti-corruption measures to ensure that mining companies are held accountable for their social and environmental obligations. This may involve international collaboration with organisations such as the World Bank or United Nations, which can provide technical assistance and monitoring support (Monteiro et al., 2019).
ii. Promoting economic diversification: African governments and mining companies should invest in economic diversification strategies that reduce dependence on mining revenues. This could include promoting industries such as agriculture, tourism, and renewable energy, which can provide sustainable livelihoods for communities post mine closure (Banks, 2018).
iii. Cultural sensitivity and community empowerment: Mining companies must prioritise cultural sensitivity when engaging with African communities. This involves respecting local governance structures and involving traditional leaders in the planning process. By building trust and fostering genuine partnerships, companies can overcome the social barriers that often hinder the co-production model (Bainton, Holcombe, 2018).
iv. Long-term investment from mining companies: Mining companies should view investments in the co-production model not as costs, but as investments in their social license to operate. By building strong relationships with local communities and investing in sustainable livelihoods, companies can avoid costly social conflicts and enhance their reputations (Brock et al., 2019).
v. Transparency and trust-building: Mining companies must prioritise transparency and open communication with local communities to rebuild trust. This involves engaging communities early in the closure process and ensuring that they have a say in key decisions about their future (Vivoda et al., 2019).

Recommendations for future mine closure strategies

To ensure that mine closures do not lead to economic and social collapse, a multi-pronged approach is needed—one that integrates technology, governance, and inclusive economic planning. As mining evolves in complexity and scale, so too must the strategies for mine closure. The future of mine closure cannot simply rely on past models or incremental improvements. It must embrace innovative, disruptive strategies that break away from traditional thinking and offer more comprehensive, resilient, and socially responsible outcomes for communities. This section presents futuristic and barrier-breaking recommendations, leveraging emerging technologies, new governance models, and bold approaches to economic diversification.

Leveraging emerging technologies for sustainable mine closure

Recent advancements in technology-driven governance and economic planning offer new solutions for sustainable mine closure.

i. Artificial intelligence (AI) can be used to predict viable alternative industries in post-mining regions by analysing:
   - Local workforce skills and retraining needs.
   - Market demand for new industries (e.g., agribusiness, renewable energy, tourism).
   - Investment potential and resource allocation (Monteiro et al., 2023).
ii. Blockchain technology can help track and enforce mine closure commitments, ensuring that:
   - Funds for post-mining projects are not misused.
   - Mining companies remain accountable for rehabilitation efforts.
   - Community oversight is strengthened through transparent smart contracts (Laurencont et al., 2019).
iii. DeFi models allow communities to self-fund local businesses and post-mining initiatives, reducing reliance on government aid. Through smart contracts and decentralised funding pools, former mining towns can:
   - Finance small businesses in sectors like agriculture and manufacturing.
   - Provide microloans to ex-mine workers for entrepreneurship.
   - Develop universal basic income (UBI) programmes funded by mine rehabilitation dividends (Vivoda et al., 2019).

Policy recommendations for governments and mining companies

For governments

i. Stronger regulatory frameworks. Enforce stricter mine closure policies, ensuring companies invest in long-term economic transition programmes (World Bank, 2021).
ii. Incentives for economic diversification. Provide tax breaks and funding for companies investing in post-mining industries like renewable energy, agriculture, and tourism (Adu-Gyamfi et al., 2021).
iii. Public-private partnerships (PPPs). Encourage collaborations between governments, mining companies, and private investors to fund infrastructure and skills training programmes (ICMM, 2020).

For mining companies

i. Early stakeholder engagement. Include communities from the start of closure planning to prevent social unrest (Hilson et al., 2022).
ii. Long-term rehabilitation funds. Establish secure, blockchain-tracked financial reserves for community-led post-mining projects (Laurencont et al., 2019).
iii. Investment in alternative livelihoods – Support skills training, agribusiness, and digital economy jobs to reduce dependency on mining jobs (Vivoda et al., 2019).

A structured co-production framework for mine closure implementation

The co-production model ensures inclusive, transparent, and sustainable mine closure planning. The following framework outlines the key stages for implementation:

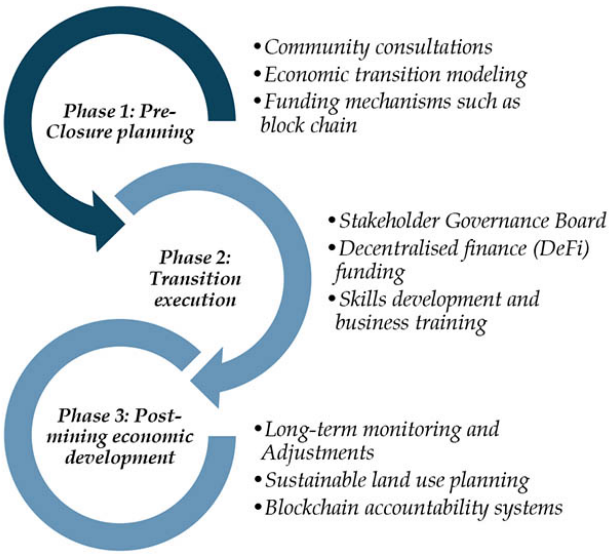

Figure 1—Three-phase futuristic co-production model by O. Koatlhai, 2025

Conclusion

The future of mine closure is not just about managing the end of an era; it is about ushering in a new beginning. Traditional approaches to mine closure, focused heavily on environmental restoration, have often left socio-economic devastation in their wake, particularly in regions like Africa, where communities are deeply intertwined with mining operations. The co-production model offers a breakthrough, rethinking mine closure as a collaborative process that places communities at the heart of decision-making, ensuring that they not only survive but thrive post-closure. This paper has highlighted the critical need to embed stakeholder engagement, economic diversification, and long-term resilience into every closure plan. The co-production model, bolstered by AI-driven economic forecasting, blockchain for transparency, and decentralised finance models, marks a bold shift from simply closing mines to transforming entire communities. It is a model that brings sustainable livelihoods, empowerment, and self-determination to the forefront of the mining lifecycle. In the African context, where challenges like weak governance, economic dependence on mining, and social tensions present unique barriers, this model offers a path forward. By embracing innovative technologies, investing in skills development, and building systems of trust and ownership, mining companies and governments can ensure that mine closure becomes a springboard for regenerative economies rather than a source of economic collapse. The success of these strategies lies in the collective effort of governments, corporations, and communities, who must recognise that mine closure is an opportunity to redesign the future, creating lasting legacies of prosperity, equality, and sustainability. The end of mining need not be the end of growth. Instead, it can be the beginning of something far greater: A future where communities stand stronger, economies diversify, and the environment regenerates. The journey to this future begins with innovative mine closure strategies that look beyond the immediate horizon and embrace the possibilities of what's next.

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