Mine Closure 2026 – AB Fourie, G Boggs, J Heyes & M Tibbett (eds)

doi:10.36487/ACG_repo/2615_160

Sustainable post-mining cities: post-mining urban transformation towards sustainable spatial planning in the context of the global south

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Abstract

Mine closure marks a critical structural transition where exhausting mineral resources necessitates a profound socio-spatial transformation to achieve long-term urban sustainability. However, prevailing post-mining research and policies, particularly within the emerging global south context, remain fundamentally confined to fragmented biophysical reclamation, systematically ignoring long-term socio-economic transitions and failing to synchronise closure plans with statutory regional spatial planning systems. To address this critical analytical gap, this study introduces a novel comparative evaluative domain that cross-examines international and domestic closure models by reinterpreting the 16 life cycle elements of International Council on Mining and Metals (ICMM) through the inclusive spatial principles of the New Urban Agenda (NUA). Using a purposive variation sampling strategy, a qualitative comparative analysis was conducted across multi-contextual mining jurisdictions: Sawahlunto and West Kutai (Indonesia), Broken Hill (Australia) and the Sullivan Mine (Canada). Our findings reveal that while the basis of post-mining transformation in the global north is structurally oriented toward heritage-creative economies and innovation-driven energy transitions, the global south centres primarily on cultural heritage and biophysical ecosystem restoration. Crucially, empirical evidence demonstrates that domestic closure performance is severely constrained by short-term planning horizons and weak cross-sector institutional communication. Ultimately, this paper argues that successful urban regeneration requires transitioning from reactive compliance to proactive spatial integration, establishing collaborative governance councils, and mandatorily embedding post-mining plans into regional spatial plans to structurally enable a resilient, inclusive and diversified post-mining urban future.

Keywords: *global south, integrated mine closure, New Urban Agenda, post-mining urban transformation, regional spatial planning*

1 Introduction

One element of urban planning that is rarely discussed in scholarly discourse is the mining sector, particularly in the context of post-mining planning. Globally, the post-mining transition encompasses not only ecological transformation but also social, cultural and economic aspects, resulting in what is known as urban regeneration (Roberts & Sykes 2000). To measure the success of post-mining planning, global mining companies use a framework developed by the International Council on Mining and Metals (ICMM). This framework is contained in a document titled *Integrated Mine Closure: Good Mining Practice 2nd Edition* (ICMM 2019) which discusses indicators capable of measuring the success of a company's post-mining planning process.

Previous research introduces new terms. Mine closure is now called 'mine transition' and closure planning is better described as 'integrated life of mine planning' (Grant et al. 2018). The post-mining planning process

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begins before a mine first opens to secure required environmental and mining permits (ICMM 2019). However, the ICMM framework only assesses how well a company prepares post-mining plans. It does not measure whether these plans are successfully implemented. This study aims to provide empirical evidence about the transformation process in post-mining areas. It identifies success factors for sustainable post-mining cities. The study also reflects on policy implications, especially for developing post-mining success criteria in Indonesia. These efforts support creating more sustainable post-mining cities. The author examines 4 case studies of post-mining areas, namely Sawahlunto (Indonesia), West Kutai (Indonesia), Broken Hill Mine (Australia) and Sullivan Mine (Canada), to assess their success based on the reinterpretation of ICMM indicators and their relevance to the New Urban Agenda (NUA) principles (United Nations 2017). This paper examines the extent to which a post-mining area has succeeded in transforming into a sustainable post-mining city. These case studies represent a diversity of approaches, institutional contexts and historical trajectories in post-mining practices across several countries.

To ensure the comparative validity of the analysis, the method of selecting the 4 case studies was based on a sampling strategy of prioritising intentional diversity and structural contrast. In terms of approach, the 4 cases demonstrate 2 main models of post-mining area transformation: the ecology-based approach (West Kutai and Sullivan), which focuses on ecosystem restoration and green economic diversification, and the heritage-based approach (Sawahlunto and Broken Hill), which emphasises the preservation of socio-cultural identity and the development of mining heritage. In addition, institutional and geographical variations show a spectrum of contexts ranging from national state-owned enterprises (PT Bukit Asam Tbk in Sawahlunto), subsidiaries of multinational companies (PT Kelian Equatorial Mining/Rio Tinto in West Kutai) to global diversified corporations (BHP in Broken Hill and Teck Resources in Sullivan). The 2 cases in Indonesia provide an adaptive perspective on national post-mining policies, while the cases in Australia and Canada demonstrate best practices for implementation and mature post-mining systems. Australia and Canada are among the world's leading global mining countries, and these 2 countries often hold the highest global standards for sustainable mining practices. Temporally, the 4 locations also illustrate the evolution of the mining industry from the 19th to the 21st century, demonstrating a paradigm shift from extraction to a sustainable transition, while also providing cross-contextual lessons learned between developed and developing countries.

Hence, while this study reflects on the Indonesian policy context, the mandate to structurally align post-mining plans with regional spatial frameworks is framed as a universal urban planning necessity, equally vital for mature jurisdictions like Australia and Canada where corporate behaviours often precede formal regulations regarding social closure. Consequently, the comparative insights generated herein provide a broadly generalised framework for planning resilient and inclusive socio-spatial transition globally.

2 Research problems

In the global context, the post-mining transition has considered ecological, social, cultural and economic aspects. However, in the Indonesian context, several previous studies have shown that the transition of post-mining areas still focuses on ecological aspects and has not addressed other aspects such as social, cultural, economic and governance. For example, previous research showed that the post-mining strategy prioritises the ecological approach (at 65.86%) in the form of soil fertility improvement activities and water quality improvement pits, followed by a socio-economic approach at 26.28% and a cultural approach at 7.86% (Herdiansyah et al. 2018). In addition, previous research also demonstrated that the post-mining strategy is directed at an ecological approach by filling former mine pits (voids) and converting voids into water reservoirs (Aisyah et al. 2025). Furthermore, laws such as Government Regulation No. 78 of 2010 on Reclamation and Post-Mining (Republic of Indonesia 2010) and Law No. 3 of 2020 on Mineral and Coal Mining (Republic of Indonesia 2020), still use a technical approach (for example, regarding land reclamation and financial guarantees) and do not comprehensively discuss post-mining area planning from ecological, social, cultural, economic and governance aspects. Therefore, to comprehensively examine the successful implementation of post-mining areas, this paper examines 4 case studies with distinct characteristics, each of which will be assessed based on reinterpretation of ICMM indicators.

3 Methodology

Based on the background and research focus areas described above, the purpose of this paper is to explore the dynamics of transforming post-mining areas into sustainable post-mining cities through a reinterpretation of indicators from the Integrated Mine Closure Framework (ICMM) and their association with NUA principles. A matrix that synthesises the evaluative domains reinterpreted from the ICMM indicators and NUA principles is shown in Table 1.

Table 1 Reinterpretation of evaluative domains through ICMM elements and NUA principles

No.	Evaluative domain	ICMM elements as indicator (ICMM 2019)	NUA principles justification (United Nations 2017)
1	Governance and Planning	• Element 1: Integration into Life of Mine Planning • Element 5: Engagement for Closure Plan Development • Element 12: Closure Execution Plan • Element 15: Temporary or Sudden Closure • Element 16: Closure Governance	• Local-national multi-stakeholder partnerships (Principle 15c, i) • Strengthening urban governance and institutions (Principle 15c, ii) • Building decentralised urban governance structures (Principles 85–92)
2	Financial and Risk Management	• Element 6: Identifying and Assessing Risks and Opportunities • Element 11: Closure Costs	• Ensuring inclusive and sustainable urban economic growth (Principle 14b) • Innovative financing frameworks supporting local fiscal capacity (Principle 15c, iv) • Mechanisms for mobilising domestic financial resources and investment (Principles 130–143)
3	Environmental Rehabilitation	• Element 2: Knowledge Base • Element 7: Closure Activities • Element 9: Progressive Closure	• Ensuring the sustainability of the urban environment (Principle 14c) • Resilient, climate-adaptive urban development and ecosystem restoration (Principles 63–80) • Provision of urban drainage infrastructure and safe waste management (Principle 119)
4	Social Transition	• Element 10: Social Transition • Tool 11: Social Investment for Closure	• Leave No One Behind commitment and urban poverty eradication (Principle 14a) • Transformative commitment to social inclusion and the fulfilment of the right to the city (Principles 25–42) • Utilisation of urban tangible and intangible cultural heritage (Principles 38, 124–125)
5	Land Use and Spatial Design	• Element 3: Closure, Vision, Principles and Objectives • Element 4: Post-Closure Land Use • Element 8: Success Criteria	• Strengthening long-term integrated regional spatial planning and design (Principle 15c, iii) • Development of spatial design instruments to support resource efficiency (Principles 51–53) • Management of urban land use development and slum upgrading (Principles 93–112)
6	Monitoring and Adaptive Management	• Element 13: Monitoring, Maintenance and Management • Element 14: Relinquishment	• Utilisation of digital technology, disaggregated spatial data, and robust science-policy interface (Principles 157–160) • Global-local tiered periodic evaluation, reporting, and accountability system (Principles 161–175)

Table 1 shows that this research generates 6 evaluative domains: Governance and Planning, Financial and Risk Management, Environmental Rehabilitation, Social Transition, Land Use and Spatial Design, and Monitoring and Adaptive Management. Each of these evaluative domains will be assessed in Section 5 as an empirical instrument to measure the success and form of the holistic transformation of operational areas towards sustainable post-mining cities.

From the reinterpretation that has been carried out, each evaluative domain will be assessed qualitatively using the SMART (specific, measurable, achievable, relevant and timely) principles approach (ICMM, 2019) for each case study in the research. The qualitative evaluation rubric is defined as follows:

- **High (H): The post-mining strategy satisfies all SMART criteria.** It features integration of closure plans within local statutory spatial documents – regional spatial plan (RTRW)/regional medium-term development plan (RPJMD) – and uses measurable quantitative indicators and concrete socio-environmental performance targets. Next, it is institutionalised through a dedicated, active cross-sector agency, making it structurally achievable. It promotes a relevant regional economic identity, including heritage or renewable energy innovation, and operates under a visionary, long-term period of 20–30 years.
- **Medium (M): The strategy meets some SMART criteria while demonstrating clear performance deficits in others.** While the goals may be specific and relevant to the local context, the evaluation remains heavily narrative rather than numerically measurable. Also, the institutional achievability declines or dissolves after the mining operator exits due to weak local public governance. Lastly, the implementation is bound to short-term, reactive timely mandates, possibly 3–5 years.
- **Low (L): The transformation strategy fails to align with the SMART framework.** There are no specific or relevant urban regeneration objectives, as the plan is strictly confined to technical reclamation only. Also, the outcomes are not qualitatively nor quantitatively measurable; they are practically unachievable due to the lack of institutional multi-stakeholder coordination. Lastly, it lacks any proactive or visionary timeframe.

4 Case study

This section will discuss the regional scope for each of the case studies used in the analysis and discussion in this paper.

4.1 PT Bukit Asam Tbk (Sawahlunto), Indonesia

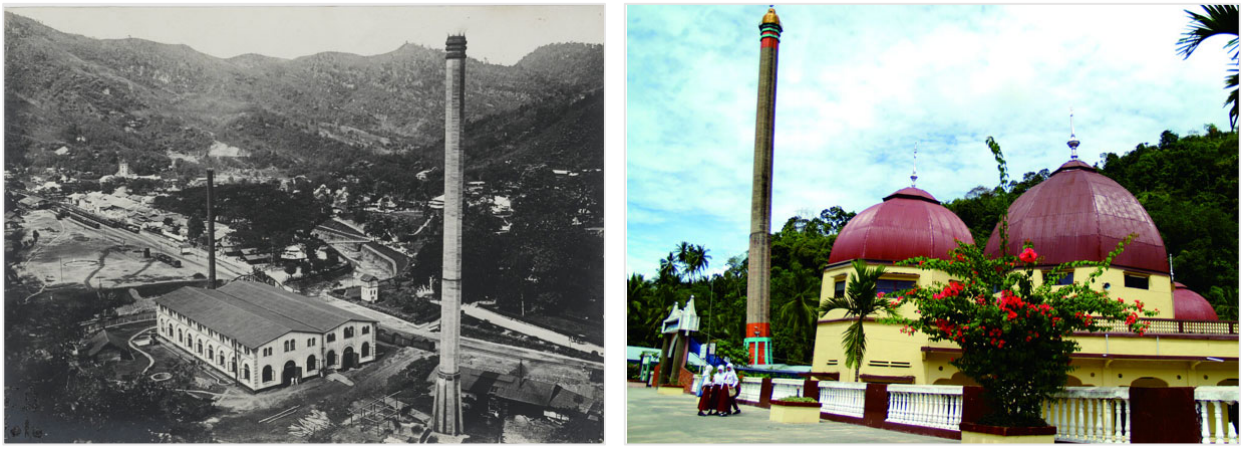
Sawahlunto is the oldest coal mine in Southeast Asia, opened in 1882 by the Dutch East India Company to develop an integrated coal industry during the industrial revolution in Europe at the end of the 19th century. Mining operations at Sawahlunto began to close in 2000, leading to a shift in the economy from mining to tourism (Armis & Kanegae 2021). Previous research also found that tourists visiting the post-mining town of Sawahlunto primarily wanted to experience its cultural diversity and heritage sites, while others sought to enjoy the natural beauty and relaxation through daily activities (Armis & Kanegae 2019).

Furthermore, previous research explains that the period from 1998 to 2001 was a difficult period for the city of Sawahlunto. Following the closure of mining operations in 2000 by PT Bukit Asam Tbk, the city of Sawahlunto experienced an economic and population crisis, in addition to its environmental conditions (lack of rehabilitation). At the time, Sawahlunto was at risk of becoming a dead city (Syafrini et al. 2020). The population of 55,090 in 1995 fell to 51,533 in 2002, a 6.46% decline over a 7-year period (BPS Sawahlunto 2003). Furthermore, the poverty rate increased in just 3 years, from 4.5% in 1996 to 14.9% in 1999 (Bappeda Sawahlunto City 2006).

However, the threat of Sawahlunto becoming a dead city or ghost town began to ease in 2003. The West Sumatra Provincial Government began to prioritise preserving its mining heritage assets. Consequently, the provincial government collaborated with Programma Uitzending Managers (a Dutch non-governmental organisations, NGO) in 2004 to conduct a preliminary study. In 2005, a Sawahlunto revitalisation project

began, funded by local and central governments. Sawahlunto was finally declared a UNESCO World Heritage Site on 6 July 2019 (Armis & Kanegae 2021).

Based on the previous discussion, it is clear that efforts to restore post-mining areas in Sawahlunto (particularly the Ombilin site) were carried out through multi-stakeholder collaboration, including PT Bukit Asam Tbk, which provided the area for revitalisation, the regional government (in this case, the West Sumatra Provincial Government), the central government, and NGOs. In addition, the post-mining strategy is to change the land use to a tourism area that showcases cultural heritage.



(a) (b)

Figure 1 (a) Kubang Sirakuak powerplant during its operational phase in 1904; (b) Kubang Sirakuak powerplant converted to the Nurul Iman Mosque in 1952

Figure 1 shows the results of implementing a post-mining strategy by all stakeholders in restoring cultural heritage in the city of Sawahlunto. It shows how, on a micro scale (individual buildings), the site was transformed from its initial function as a coal-fired powerplant into a permanent place of worship for the local Muslim community. The historical transition of this asset is documented in the official UNESCO evaluation dossier and local heritage archives (Pasbana 2018; UNESCO World Heritage Centre 2019).

4.2 PT Kelian Equatorial Mining (West Kutai), Indonesia

PT Kelian Equatorial Mining (KEM) is a multinational company and a subsidiary of Rio Tinto. In 1992, PT KEM operated a gold mining operation in West Kutai Regency and operations ceased in February 2005. Following the cessation of activities, the post-mining concession area of PT KEM is legally designated to undergo ecological restoration into a protected conservation forest before being officially handed back to the state authority. PT KEM also prepared various data on the conditions of the community around the Kelian mine area from 1999 to 2002 in order to prepare a plan for the termination of mining activities (Fasabeni 2012). Previous research also found that some local communities are still heavily dependent on the Kelian mine area for subsistence livelihoods, specifically driven by informal/artisanal gold panning within the tailings facilities, which led them to continue occupying the mining zone even after the official mine closure (Finucane et al. 2011). Therefore, PT KEM initiated communication strategies and training for local communities to address the difficulties that arise.

This situation has resulted in a decline in the welfare of the local community, leading to poor communication within the community. Therefore, PT KEM created a solution to reduce dependency problems by providing training in economics, agriculture, motor mechanics, simple entrepreneurial management, and implementing food security projects (McGuire 2003). Furthermore, related research highlights that the local community residing adjacent to the concession area developed a strong collective determination to independently manage and mine the Namuk tailings dam (remnant gold) as a way to support their families (Finucane et al. 2011), even though PT KEM has not yet established formal procedures for gold mining safety in the tailings dam area. Based on this, PT KEM engaged artisanal miners (the local mining community) in the

decision-making process and the development of safety and security procedures and standards for mining activities in the Namuk tailings dam area, while simultaneously operationalising a reciprocal co-management framework. This approach incentivised environmental stewardship by conditioning the formalisation of safe artisanal mining access upon the community's active commitment to conduct community-led monitoring and conservation patrols to safeguard the surrounding protected forest (Finucane et al. 2011).

In addition, PT KEM also invited key members of the community and representatives of the government to define the outcome of the Kelian mine closure (Finucane et al. 2011); this led to the formation of the Kelian Mine Closure Steering Committee, which included representatives from PT KEM, Rio Tinto, local communities, government, and NGOs (McGuire 2003). The mine closure approach carried out by PT KEM not only focuses on restoring ecological aspects, but also pays attention to socio-economic aspects. The intention is to help the local community in the post-mining transition by providing training related to potential fields to be worked around the post-mining area.

One of PT KEM's post-mining strategies is to turn former mining pits (voids) into lakes whose water can be used and turn the area into a protected forest (Figure 2a). In terms of community empowerment, PT KEM empowers local communities in managing traditional gold mining activities, including re-mining at the Namuk tailings dam. PT KEM's community involvement also fosters empowerment of women (especially housewives) (Figure 2b). The structural engagement and economic aspirations of these local women's networks during the post-closure phase are formally documented in regional field reports (Swara Kaltim 2025).

(a) (b)

Figure 2 (a) Kelian Lestari protected forest; (b) Community of housewives working in traditional gold mines

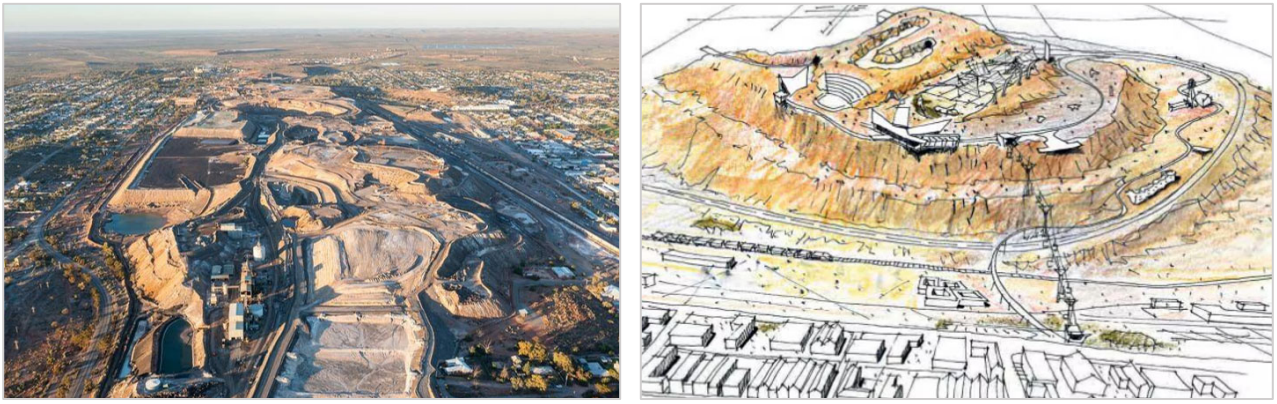
4.3 BHP (Broken Hill Mine), Australia

Broken Hill Mine was first discovered in 1883 by a German immigrant named Charles Rasp, who became the forerunner of the largest silver, lead and zinc mining operation in western New South Wales. One of the largest mineral deposits is known as the Line of Lode. The city of Broken Hill is located 1,160 km from Sydney and 511 km from Adelaide. Broken Hill Mine quickly developed into a major mining hub, and 2 years later, Broken Hill Mine became Broken Hill Proprietary Ltd, which is currently known as BHP (Jones 2016; Eklund et al. 2021). Since the founding of BHP, the city of Broken Hill experienced a population increase of up to 30,000 residents in 1907, with 9,000 residents working in several mining companies. BHP's presence contributed significantly to Australia's development, including through the birth of the Australian Trade Union movement and its role in shaping important national labour and social regulations since the early 1900s. In 2000, Broken Hill successfully extracted 170 million tonnes of mineral resources at the Line of Lode (Jones 2016). This mining activity supported Broken Hill's economy throughout the first half of the 20th century.

However, as mineral reserves depleted, production began to decline, leaving the landscape drastically altered and the future of the mine uncertain. This was reflected in the early 1970s, when the town of Broken Hill began experiencing a decline in the mining workforce, and a difficult transition between the town and its residents occurred. Also, around the 1960s and 1970s, the town of Broken Hill began to initiate the protection and conservation of its cultural heritage (Eklund et al. 2021). Research by Eklund et al. (2021) also showed that there were 650 job cuts in 1972, and between 1971 and 1986, the workforce decreased from 4,473 (including 160 women) to 2,062 (including 80 women). However, this situation reversed in 1986, when female workers outnumbered male workers for the first time (Eklund et al. 2021).

Furthermore, research by Eklund (2012) in Eklund et al. (2021) also found poor workforce regeneration in the mining sector. In 1991, the percentage of the population over 65 years old was 14%, a 7% increase from 1961 (Eklund et al. 2021). Therefore, the City of Broken Hill began to accelerate its transition to a heritage area through several strategies, including the formation of the Broken Hill Council's Heritage Advisory Committee in 1986 and the appointment of Elizabeth Vines as a heritage advisor in 1983 to preserve the city's cultural heritage (Eklund et al. 2021). These include the Main Street Program in 1988 and the Local Heritage Restoration Fund, which covered small main streets, suburbs and commercial area conservation in 1991. Broken Hill is now a living museum where visitors can experience the past and present (Broken Hill City Council n.d.).

Figure 3 represents several implementations of BHP's post-mining strategy. The company faced severe socio-economic challenges, primarily driven by rapid labour downscaling, structural job redundancies, and intense union-led community anxiety over the town's economic collapse in Broken Hill. Therefore, one of the implementations chosen was to transform the post-mining area into a heritage tourism destination. BHP's strategy is to make the Line of Lodes area in Broken Hill City a cultural heritage site that can be preserved and eventually become a tourist destination, similar to the Ombilin site in Sawahlunto. Currently, the 'Line of Lode Miners Memorial' already exists, and more destinations will be developed to revitalise tourism there.



(a) (b)

Figure 3 (a) Line of Lode in Broken Hill during operation; (b) Plans for the restoration of the Line of Lode into a heritage tourism destination

Entering the 2000s, as BHP shifted its operational focus to mining sites in other areas, Broken Hill began transforming into a tourism and renewable energy sector. The deployment of localised solar photovoltaic and wind infrastructure in Broken Hill mirrors the global technical benchmark established by Teck Resources SunMine project at the Sullivan Mine, demonstrating how structurally degraded landforms can be progressively repurposed into sustainable municipal energy grids (Teck 2025). Despite efforts to preserve the historical mining landscape, Broken Hill continues to function as a mining historical area while also developing into a popular tourist destination known for its unique architectural style and rich mining history. Its location is at a distance from the city centre, and the community spirit to preserve Broken Hill remains strong. Broken Hill is a good example of the challenges faced in the Australian outback. The unique landscape and legacy mining infrastructure also make Broken Hill a location for film and television productions (DCCEEW 2021). In

January 2015, Broken Hill became the first city in Australia to be inscribed on the National Heritage list. The City of Broken Hill has been a pioneer in the transformation of mining towns into smart communities that combine industrial heritage with modern innovation (Broken Hill City Council n.d.).

4.4 Teck Resources (Sullivan Mine), Canada

The Sullivan Mine was first discovered in 1892 in Kimberley, British Columbia (B.C.). The very large silver, lead and zinc deposits contribute approximately 50% of the global supply of lead and zinc (Dycke 2019). The Sullivan Mine operated from 1909 to 2001 as one of the main economic pillars of the City of Kimberley, becoming a very important part of the social structure of Kimberley, as well as one of the largest metal mines. In its 100 years of operation, the Sullivan Mine produced approximately 26 million tonnes of lead, zinc and silver concentrates, becoming one of the largest underground mines in Canada with a tunnel network of almost 500 km (Teck 2025). During its operation, the Sullivan Mine employed an average of 1,000 people per year. Until its closure, it was the largest tax contributor to the City of Kimberley and the largest employer in the region. Many former workers and their families still live in the post-mining area. The Sullivan Mine was acquired and managed by a mining company called The Consolidated Mining and Smelting Company, or Teck Cominco, now known as Teck Resources (Teck), until its closure in 2001.

As the mine approached closure in 1990, Teck identified that reserves would be depleted by 2001. Teck worked with various community partners and the city government to develop a transition plan, designing a new development direction to reduce Kimberley's economic dependence on mining, with the hope of sustaining livelihoods after the mine's closure. More than 30 stakeholder and community meetings were held to provide input on the post-mining transition plan, which began in 1992 with the formation of the Sullivan Public Liaison Committee (SPLC). The committee comprised various parties, including local government, provincial and federal ministries, labour unions, tribal councils, Kimberley city council members, the general public, and the East Kootenay Environmental Society. The long-term spatial outcome of this collaborative transition planning, demonstrating a profound structural shift from high-impact industrial operations to successful ecological land restoration, is chronologically illustrated in the temporal comparison in Figure 4.

(a) (b)

Figure 4 (a) Concentrator area at the Sullivan Mine during operations in 1989; (b) After implementation of post-mining strategies in 2020

Reclamation research began in 1972, focusing on converting waste rock piles and tailings ponds into forests and productive land (Teck 2025). Teck reclaimed approximately 1,000 ha and invested over USD100 million, a process that began in 1990 and continued until the mine's closure. Teck collaborated with the SPLC to develop an economic transition plan to eliminate the town's dependence on mining. Today, Sullivan Mine has transformed from a mining town into a tourist destination. Several Teck assets in the town's non-mining areas have been donated or auctioned to support post-mining success.

Prior to mine closure, the company facilitated transition planning for employees, working with the town to accelerate economic development and diversification initiatives. The primary focus of post-mining activities is the development of a golf tourism area by selling land to the city government at below-market prices for the construction of a golf course and the expansion of the ski area, including other tourist attractions such as the Civic Arena and Cominco Gardens, the use of hiking trails and the Kimberley's Underground Mining Railways Area, and the provision of land for residential development on over 3,000 ha of private property within the City of Kimberley. The Kimberley's natural landscape, climate and location are being optimised to create new economic activities in the tourism and recreation sectors.

Continuous monitoring, including water management and treatment, is ongoing indefinitely. Employees, contractors and suppliers at Sullivan Mine remain actively involved in property management, monitoring post-mining conditions and operating the water treatment plant. The Ministry of Environment and Climate Change Strategy and the Ministry of Energy, Mines, and Petroleum Resources provide regulatory oversight to ensure post-mining objectives are met. Teck also expanded post-mining community investment beyond reclamation facilities and real estate by building SunMine (a solar power facility) managed by the community with Teck's support. This area became the first renewable energy project on a former mining site and became the largest power farm in western Canada directly connected to the electricity grid (Teck 2016).

5 Results and discussion

In this section, we will discuss the factors that indicate the success of the transformation of post-mining areas into post-mining cities and use these results to reflect these success factors on the process of forming post-mining cities.

5.1 Factors determining the success of the transformation of each post-mining area into post-mining cities

In examining the success factors for transformation in each case study region, the authors used the SMART principles to measure the Low-Medium-High (L-M-H) performance of the implemented strategies. Table 2 shows the analysis, which shows whether each post-mining region has been assessed as good or lacking in terms of evaluative domains.

Table 2 Analysis of success factors for post-mining area transformation through evaluative domains and SMART principles assessment

Evaluative domain	Sawahlunto (PTBA, Indonesia)	Kutai Barat (PT KEM, Indonesia)	Broken Hill Mine (BHP, Australia)	Sullivan Mine (Teck Resources, Canada)
Governance and Planning	**H:** The Sawahlunto City Government integrated the former mining area into the 2010–2030 RTRW and with multi-stakeholder collaboration has been able to create a heritage city (Armis & Kanegae 2021)	**M:** Although the Kelian Mine Closure Steering Committee existed, it was only active until 2005 and did not continue as a formal institution. Furthermore, there has been no integration into the West Kutai RPJMD (Finucane et al. 2011)	**H:** Broken Hill City Council integrated its industrial identity into municipal planning via a long-term 'living museum' framework, securing its National Heritage Listing in 2015 to structurally fortify post-mining cultural and economic policy integration (Eklund et al. 2021)	**H:** The Sullivan Public Liaison Committee (SPLC) has been in existence since 1996 and has integrated urban planning and post-mining plans through Teck's collaboration with the government (Teck 2025)
Financial and Risk Management	**M:** Post-mining funding relies on the APBD and PTBA CSR, which has not yet created a sustainable legacy fund	**H:** Rio Tinto provided closure costs of ~USD40 million and established the Kelian Community Development Foundation and a government-supervised guarantee fund	**H:** BHP established the Broken Hill Heritage Legacy Fund to support tourism and renewable energy	**H:** Teck invested more than USD100 million for reclamation and establishment of SunMine (1 MW) as a sustainable solar power project (Teck 2025)
Environmental Rehabilitation	**M:** Still focused on the aesthetics of tourist areas and city parks so that the restoration of ecological functions is not yet comprehensive	**H:** Successfully rehabilitating 2,500 ha and carrying out natural revegetation to reach over 85% of the forest cover. Furthermore, an artificial lake area serves to support the ecological balance (Setyawan et al. 2011)	**M:** Restoration is more of a visual aesthetic in supporting the tourism sector (industrial landscape)	**H:** Reclamation of approximately 1,000 ha and construction of a permanent acid mine drainage treatment system, as well as successful long-term revegetation (Marsland et al. 2004)
Social Transition	**H:** Social transition based on cultural heritage and able to absorb labour from tourism activities, thereby reducing the unemployment rate by 30% (BPS Sawahlunto 2022)	**M:** There is socio-economic training but it is not continued, where many residents return to a subsistence economy (choosing to become traditional gold miners)	**H:** Local communities maintain social identity so that local tourism and arts thrive (Eklund et al. 2021)	**H:** Diversifying the economic sector into tourism and solar energy where ex-mining workers are absorbed in the SunMine project (Teck 2025)
Land Use and Spatial Design	**H:** Former mining areas are converted into museums, city parks and heritage tourism areas (Asta 2021)	**M:** Post-mining land becomes conservation forest and community agriculture	**H:** The Line of Lode area has become a living museum and public space as well as a national icon of Australia	**H:** Successfully transformed the tailings area into SunMine and the Kimberley ecotourism zone (Teck 2025)
Monitoring and Adaptive Management	**M:** Monitoring is still limited to the preservation of cultural heritage and there is no integrated ecological monitoring system (BPS Sawahlunto 2022)	**M:** Monitoring was active after the first 5 years post-mining but declined after 2010	**H:** There is still an annual audit held by Broken Hill City Council and the Heritage Advisory Trust	**H:** Teck and the Government of British Columbia implemented an annual environmental monitoring plan (Teck 2025)
Post-Mining Transformation Basis	Heritage	Ecological Restoration	Heritage-Creative Economy	Innovation and Renewable Energy

Table 2 shows that the success of transformation, when viewed from the 'specific' principle, can be seen when there is an integrated closure plan within the regional spatial planning policy, as in Sawahlunto, Broken Hill Mine and Sullivan Mine. Based on the 'measurable' principle, Broken Hill Mine and Sullivan Mine have implemented quantitative indicators, while Sawahlunto and West Kutai Mine are still narrative. The 'achievable' principle can be realised if there is a dedicated post-mining institution, the absence of which makes post-mining implementation in Indonesia relatively weak. The 'relevant' principle can also be realised if there is a regional identity that is continuously promoted and attached to the post-mining area, such as heritage, ecology or renewable energy. Finally, based on the 'timely' principle, post-mining city transformation can be realised with visionary long-term planning, as in the cases of the Broken Hill Mine and Sullivan Mine, with a time span of 20–30 years, whereas in Indonesia, the post-mining plan has a time span of only 3–5 years.

Furthermore, if we look at the evaluative domains, it is clear that Governance and Planning has the most success; this requires cross-sector multi-stakeholder integration to determine the direction of post-mining area transition. Furthermore, to determine the success of post-mining area transformation, it must be able to guarantee sustainable financing through the Financial and Risk Management domain, and strengthening the ecological, social, cultural and economic transition must be strengthened through the Environmental Rehabilitation and Social Transition domains. Likewise, the post-mining plan must be reflected in an integrated spatial plan and have gone through public consultation with the affected community, making the Land Use and Spatial Design domain crucial. Finally, to ensure the creation of future outcomes, the supervisory function must be strengthened to continuously create a climate of long-term learning and innovation, so the Monitoring and Adaptive Management domain is the final domain that must be considered.

5.2 Factors emerging from the successful transformation of each post-mining region into post-mining cities

In the previous section, we learned that although the Governance and Planning evaluative domain is the most dominant, it still needs to be strengthened by the other 5 domains. Therefore, in this analysis, the authors will attempt to reflect on all existing evaluative domains regarding the existing state of governance and regulations related to post-mining plans. The purpose of this section is to determine what lessons can be learned from the synthesis of all regional case studies in realising regional transformation towards sustainable post-mining cities while simultaneously responding to NUA's mandate. Table 3 outlines success factors for each evaluative domain.

Table 3 Success factors of post-mining area transformation across evaluative domains

Evaluative domain	Existing condition	Implications and lessons learned for regulation in Indonesia
Governance and Planning	All successful case studies (Sawahlunto, Sullivan Mine and Broken Hill Mine) demonstrate the existence of a closed governance body capable of coordinating cross-sector communication.	Indonesian regulations do not yet address the establishment of a dedicated agency to manage post-mining transition. In fact, Indonesia Government Regulation No. 78 of 2010 only mandates companies to prepare a post-mining transition plan without specifying a coordination mechanism with the regional government (Republic of Indonesia 2010). Therefore, the absence of a post-mining authority to coordinate post-mining plans will lead to inconsistencies in the RTRW (regional spatial plan) and RPJMD (regional medium-term development plan). Therefore, it is important to form a Post-Mining Transition Council in mining areas as a cross-sector liaison body.
Financial and Risk Management	Sullivan Mine and PT KEM demonstrate the importance of outcome-based financing guarantees, not just nominal ones.	Indonesia Government Regulation No. 78/2010 shows that the guarantee scheme is still input-based or based on fixed deposits without linking it to social/environmental performance outcomes (Republic of Indonesia 2010). Therefore, to ensure efficient financing flows, it is necessary to transition to a performance bond model, where fees are paid if, for example, the evaluative domains measured by the SMART principles have been met.
Environmental Rehabilitation	Sullivan Mine has demonstrated clear success by adopting quantitative indicators such as revegetation area and water quality to assess the success of its environmental rehabilitation.	In the Indonesian context, some post-mining plans still stop at the technical reclamation stage and do not address the ecosystem aspect. Therefore, a post-mining ecological framework is needed that can measure ecosystem carrying capacity and integrate ecological functions into urban spatial planning.
Social Transition	Sawahlunto and Broken Hill Mine demonstrate success in carrying out social transition by strengthening local identity to avoid social collapse.	Ministerial Decree No. 1827/2018 concerning Guidelines for Implementing Good Mining Practice mentions community empowerment, but does not clearly outline the social outcomes used to measure the success of the community empowerment program (Republic of Indonesia 2018). Therefore, there is a need to create a social transition plan (STP) as part of the post-mining plan, including the type of employment sector, employment training, cultural heritage preservation, and the form of the local economy.
Land Use and Spatial Design	Sullivan Mine and Broken Hill Mine have succeeded in transforming the mining area into a new and more productive urban face.	In the Indonesian context, the post-mining plan is not required to be integrated into the RTRW (regional spatial plan) because it is considered to cause overlapping spatial functions. Instead, creators of post-mining plans should be required to synchronise them with the RTRW and RPJMD, in accordance with Government Regulation No. 21/2021 concerning the Implementation of Spatial Planning (Republic of Indonesia 2021).
Monitoring and Adaptive Management	Sullivan Mine has demonstrated success due to the continuous monitoring carried out in collaboration with the community and environmental organisations (NGOs).	In the Indonesian context, monitoring stops when post-mining implementation is completed, and must be handed over to the government. Therefore, a post-closure monitoring framework (PCMF) with a time span of 10–20 years, along with an annual social and environmental audit mechanism, is needed.

Based on the evaluative domains analysis, it can be seen that the success of sustainable post-mining cities must rely on collaborative stakeholder governance, an inclusive social transition, and a fair financing system. However, in Indonesia, post-mining planning remains largely a technical and administrative framework, necessitating a regulatory review to position mine closure planning as part of sustainable urban planning, in line with the mandate of the NUA.

6 Conclusion

Post-mining urban transformation is a complex, multidimensional process that encompasses not only technical ecological reclamation but also social transition, economic restructuring and collaborative governance. This research demonstrates that evaluating post-mining strategies through the lens of a reinterpreted ICMM and NUA framework, resulting in existing evaluative domains, can provide a comprehensive measure of urban transitions toward sustainability. Through case studies from the global north (Broken Hill and Sullivan) and the global south (Sawahlunto and West Kutai), clear differences and similar success factors are found. Although the basis of the transformation varies widely, from cultural heritage and ecological restoration to renewable energy innovation, the most critical determinant of success across all cases is related to the strong Governance and Planning domain. Successful transitions are consistently characterised by a long-term closure vision, cross-stakeholder collaboration and the mandatory integration of post-mining plans into regional spatial planning.

Therefore, lessons learned in Indonesia, as a representative of the global south, regarding the gap in post-mining discourse, which remains highly technical and does not comprehensively encompass the socio-economic spectrum. Here are some policy shifts to consider:

- **Establishment of a regional post-mining transition council:** formed at the provincial or regency level and legally hosted under Bappeda (Regional Development Planning Agency). This council serves as a formal cross-sector liaison body, articulating and reconciling the technical mining mandates of ESDM (Ministry of Energy and Mineral Resources) and KLHK (Ministry of Environment and Forestry) with the statutory local governance and planning instruments.
- **Restructuring the closure funding mechanism:** transitioning the current mine closure guarantee system from passive fixed-deposit escrow accounts managed solely by ESDM into dynamic, Performance-Based Socio-Ecological Bonds. The release of these funds should be conditioned upon verified socio-spatial milestones, with an institutional window to combine these yields with corporate social responsibility (CSR) allocations and regional infrastructure funds to co-finance local public works.
- **Mandatory mainstreaming of a social transition plan (STP):** upgrading the legal status of social management by mandating an STP as a legally binding annex within ESDM's approved post-mining plan. This mechanism ensures that corporate social programs are structurally synchronised with the municipality's RPJMD (Regional Medium-Term Development Plan) to fund targeted economic diversification, labour retraining, and cultural heritage preservation.
- **Implementation of a co-regulated post-closure monitoring framework (PCMF):** enacting a long-term PCMF spanning a 10–20-year post-closure horizon, jointly regulated by ESDM inspectorates and regional environmental agencies. This framework is to be operationally financed through residual performance bond yields and administered via an annual joint social, spatial, and environmental audit mechanism to safeguard the resilience of the transformed urban fabric.

Ultimately, post-mining transition plans must be structurally synchronised with the Regional Spatial Plan (RTRW) and the Regional Medium-Term Development Plan (RPJMD) to prevent overlapping spatial functions and ensure sustainable land use. In addition, the end of the mining operation does not mean the end of a city's life, but rather can offer an opportunity for urban regeneration, so that the paradigm shift from an extractive mindset to a sustainable mindset can increase the potential for the city to be progressively transformed in a more inclusive and resilient manner.

While operationally contextualised within the Indonesian regulatory landscape, these systemic policy shifts carry profound theoretical and practical significance for the wider global south and resource-dependent emerging economies navigating post-mining transitions. In many developing nations, the discourse on mine closures remains trapped in a heavily siloed, technocratic reclamation paradigm that systematically decouples biophysical rehabilitation from long-term spatial and socio-economic planning.

By reinterpreting these localised challenges through the synchronised lens of the ICMM guidelines and the NUA, this research offers a transferable and scalable governance model. The institutionalisation of cross-sector transition councils, performance-based socio-ecological bonds, and long-term co-regulated monitoring frameworks provides a universal blueprint for developing jurisdictions to mitigate institutional fragmentation and structural economic shocks. Ultimately, this framework ensures that the cessation of mining operations globally does not trigger systemic regional decline, but instead catalyses a resilient, equitable, and structured urban regeneration.

Acknowledgement

This research is funded by the ITB Research Program 2026 under the ITB Flagship Research Scheme through the Directorate of Research and Innovation, Institut Teknologi Bandung (Project ID: SAPPK.PN-6-226-2026).

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