Digital Value Chain Reconfiguration, Supplier Ecosystem Transformation, and Strategic Renewal in Southern African Mining

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ABSTRACT

The Southern African mining industry stands at a decisive juncture as digital technologies, including artificial intelligence (AI), the Internet of Things (IoT), autonomous systems, and blockchain, converge with established value chain architectures. This paper examines how digital value chain reconfiguration reshapes supplier ecosystem dynamics and compels strategic renewal among mining firms in South Africa, Botswana, Zimbabwe, and Zambia, drawing on evidence that is deliberately balanced across all four jurisdictions rather than concentrated in any single market. Building on an integrated theoretical framework that combines the Resource-Based View, Dynamic Capabilities Theory, and Global Value Chain theory, and following a structured literature review and purposive case-selection methodology, the paper develops a causal, feedback-sensitive model linking digital adoption to supplier ecosystem transformation and strategic repositioning. The analysis identifies four reconfiguration trajectories: automation-led disintermediation, data-driven supplier integration, platform-mediated ecosystem orchestration, and sustainability-linked value chain redesign, and evaluates their differential and at times contradictory implications for incumbent mining firms and supplier communities, weighing documented successes against documented failures, including cybersecurity breaches, workforce displacement, and inconsistently enforced beneficiation commitments. Particular attention is given to cybersecurity exposure, AI ethics and algorithmic accountability, data governance, and platform dependency as intensifying risks of digital reconfiguration, and to the strategies by which small and medium-sized suppliers can be included in, rather than excluded from, the digital transition. The paper's original theoretical contribution is an integrated, feedback-sensitive model of the evolution of digital governance in resource-dependent supplier ecosystems, from which strategic renewal frameworks and policy recommendations are derived for mining firms, governments, and development finance institutions across the region.

Keywords: digital transformation; value chain reconfiguration; supplier ecosystem; strategic renewal; mining industry; Southern Africa; dynamic capabilities; global value chains; cybersecurity; AI ethics; data governance; platform dependency; SME digital inclusion

INTRODUCTION

The Southern African mining industry occupies a paradoxical position in the global economy. As one of the world's most resource-endowed regions, accounting for a substantial share of global platinum group metal reserves, alongside significant shares of gold, diamonds, chrome, and copper, and some of the deepest underground mining operations on earth, Southern Africa's mining sector generates substantial foreign exchange earnings, tax revenues, and employment across South Africa, Botswana, Zimbabwe, Zambia, and neighbouring states. However, this same industry faces intensifying structural pressures: declining ore grades, rising energy and labour costs, increasing regulatory demands for environmental sustainability, and the growing digital disruption that is fundamentally reconfiguring how value is created, captured, and distributed across mining value chains (Lèbre et al., 2020; Musingwini, 2022).

The fourth industrial revolution, defined by the convergence of artificial intelligence, the Internet of Things, autonomous vehicles and drilling systems, advanced data analytics, robotics, and distributed ledger technologies, has entered the mining sector not as an incremental technological upgrade but as a systemic transformation that reshapes the fundamental architecture of mining value chains (World Economic Forum, 2020). Autonomous haul trucks operate in surface mines in South Africa's Northern Cape and in Botswana's diamond mines. Predictive maintenance systems powered by machine learning reduce unplanned downtime in Zambian copper operations. Integrated operations centres in Johannesburg manage geographically dispersed assets in real time. Blockchain platforms are being piloted to verify mineral provenance and track ESG compliance from ore body to end consumer (Deloitte, 2022).

These digital transformations do not occur in isolation. They cascade through the supplier ecosystems that serve mining firms, altering the capabilities required of equipment manufacturers, maintenance service providers, logistics operators, engineering firms, and community-based enterprises, and compelling strategic renewal at every level of the value chain. Suppliers that fail to develop digital interface capabilities risk disintermediation. Mining firms that fail to build dynamic digital capabilities risk competitive obsolescence as digitally agile competitors extract greater value from the same resource endowments. Governments that fail to embed digital-transition considerations in mining-sector policy risk presiding over value-chain upgrades that intensify technological dependency rather than build local industrial capacity (Fessehaie & Morris, 2018).

Despite the scale and pace of these changes, the scholarly literature systematically examining digital value chain reconfiguration in the Southern African mining context remains limited. The bulk of existing research either focuses on digital transformation in global mining without regional differentiation (Azapagic, 2004; Levine, 2019) or examines Southern African mining value chains without adequately incorporating the digital-transformation dimension (Fessehaie, 2012; Tregenna & Andreoni, 2020). This paper seeks to address that gap by developing an integrated analytical framework and synthesising available evidence, balanced across South Africa, Botswana, Zambia, and Zimbabwe, on the four principal trajectories of digital reconfiguration observed in the region.

The paper pursues four interconnected objectives: first, to conceptualise digital value chain reconfiguration and its relationship to supplier ecosystem transformation in the Southern African mining context; second, to identify and critically analyse, with attention to both successes and failures, the principal trajectories through which digital transformation is reconfiguring mining value chains in the region; third, to examine the cybersecurity, AI ethics, data governance, and platform dependency risks that accompany these trajectories; and fourth, to develop strategic renewal frameworks, with explicit attention to SME inclusion, that enable mining firms and their supplier ecosystems to navigate digital transformation in ways that sustain competitive advantage and support inclusive regional development. Section 2 sets out the methodology underpinning this literature-based conceptual synthesis; Section 3 develops the theoretical framework and states the paper's original contribution; Sections 4 through 7 present the trajectory analysis, the digital-risk analysis, the supplier ecosystem analysis, and a dedicated critical balancing of successes and failures; and Sections 8 and 9 develop the strategic renewal framework and conclusion.

METHODOLOGY

This paper is a literature-based conceptual synthesis rather than a primary empirical study. Because digital value chain reconfiguration in Southern African mining is a fast-moving and unevenly documented phenomenon, a conceptual synthesis approach is appropriate: it allows integration of peer-reviewed theory, industry and regulatory reporting, and recent documented incidents into a single coherent analytical framework, at the cost of the statistical generalisability that a primary survey or interview-based study would offer. This section sets out the literature review process, the case-selection rationale, and the limitations of the approach.

Literature Review Process

The review drew on Scopus, Web of Science, and Google Scholar, supplemented by the websites of industry bodies (the International Council on Mining and Metals, the Minerals Council South Africa), consultancy publishers (Deloitte, McKinsey & Company, PwC, EY), and government and regulatory sources (the South African Department of Mineral Resources, the Zambian Ministry of Mines and Minerals Development). Search strings combined "digital transformation", "Industry 4.0", "automation", "platform", or "cybersecurity" with "mining" and with "Southern Africa" or the name of one of the four focal jurisdictions. The review covered material published between 2018 and 2026, with deliberate emphasis on sources from 2024 to 2026 to ensure the analysis reflects the current state of adoption, incidents, and policy rather than an earlier phase of the digital transition.

Screening prioritised peer-reviewed journal articles and, where peer-reviewed coverage of a recent event was not yet available, independently verifiable industry and news reporting on documented firm-level incidents, such as cyberattacks, environmental failures, and workforce actions. Purely promotional vendor material lacking independent corroboration was excluded unless it was the only available source describing a specific, otherwise well-attested deployment, in which case it was used narrowly for descriptive detail rather than for evaluative claims.

Case and Trajectory Selection

South Africa, Botswana, Zambia, and Zimbabwe were selected as the four focal jurisdictions because they are the SADC member states with the largest mining sectors by GDP contribution and export share, and because they collectively span the region's principal commodity classes: platinum group metals and gold in South Africa, diamonds in Botswana, copper and cobalt in Zambia, and lithium and platinum group metals in Zimbabwe. This spread was a deliberate selection criterion, intended to avoid the concentration on South African evidence that characterises much existing commentary and to ensure that Botswana, Zambia, and Zimbabwe are represented with comparable depth rather than as brief comparators.

The four reconfiguration trajectories discussed in Section 4, automation-led disintermediation, data-driven supplier integration, platform-mediated ecosystem orchestration, and sustainability-linked value chain redesign, were identified inductively as the recurring patterns across the reviewed literature, rather than derived deductively from a single prior typology. Illustrative firm-level cases, including Anglo American, Debswana, Sibanye-Stillwater, De Beers, Bikita Minerals, and Sino-Metals, were selected because they are the most extensively and independently documented cases of digital adoption, incident, or policy interaction in the reviewed sources. This is a purposive rather than a representative sample: these firms are, almost by definition, larger and more digitally advanced than the median regional supplier, and the case selection should be read with that skew in mind.

Analytical Approach and Limitations

The paper uses narrative and thematic synthesis to integrate the reviewed material into the causal, feedback-sensitive model presented, rather than a systematic review protocol or meta-analysis, since the underlying literature is too heterogeneous in method and scope for formal aggregation. Three limitations follow from this design and are addressed directly in the future research agenda. First, reliance on secondary and documented sources privileges large, well-covered multinational operators and systematically underrepresents informal and micro suppliers, whose digital exclusion is correspondingly harder to document with the same specificity. Second, the field is evolving quickly, so figures on adoption rates and platform penetration (Table 1) should be read as directional estimates rather than precise measurements. Third, the analysis does not draw on primary interview or survey data with mining firms or suppliers, and its critical claims about successes and failures are accordingly bounded by what has been independently reported rather than independently verified by the authors.

THEORETICAL FRAMEWORK AND CONCEPTUAL REVIEW

Global Value Chain Theory and Mining Sector Governance

Global Value Chain (GVC) theory, initially developed by Gereffi et al. (2005) and later extended to the resource sector by Ponte and Sturgeon (2014), provides a key analytical framework for examining how value is generated and shared across the interconnected activities within the mining value chain. Within this framework, lead firms govern the value chain by setting participation conditions for suppliers, establishing quality and performance standards, and controlling access to end markets. The governance structure of a value chain, ranging from market-based, arm's-length transactions to captive relationships characterised by strict specifications and power imbalances, critically shapes suppliers' potential to upgrade and the distribution of value among chain participants.

In the Southern African mining context, GVC analysis reveals a characteristic pattern: large multinational mining houses (Anglo American, Glencore, Gold Fields, Sibanye-Stillwater) function as lead firms that define supply-chain standards, select and qualify suppliers, and increasingly use digital platforms to govern supplier relationships. The governance implications of digital transformation for this structure are profound. Digital platforms enable lead firms to extend their governance reach deeper into supplier ecosystems, monitoring supplier performance in real time and enforcing compliance with specifications to a degree previously impossible. This intensification of governance simultaneously creates efficiency gains and raises barriers to supplier participation, with important implications for local content and SME inclusion (Ponte et al., 2019).

Dynamic Capabilities Theory and Digital Transformation

Dynamic capabilities are defined as a firm's ability to sense emerging opportunities and threats, seize them by investing in new competencies, and reconfigure existing assets and routines to sustain competitive advantage as the environment changes (Teece et al., 1997). Dynamic capabilities theory has been widely applied to the study of digital transformation, where the ability to sense technological change, integrate new digital tools into operational processes, and reconfigure organisational structures and supplier relationships in response to digital disruption is now widely recognised as a fundamental determinant of competitive survival (Teece, 2018).

Applied to Southern African mining, dynamic capabilities theory directs analytical attention to the organisational and managerial foundations, leadership vision, data governance structures, digital talent pipelines, and change-management capabilities that determine whether digital investments translate into operational improvements and sustainable competitive advantage. It also explains why digital transformation outcomes diverge so sharply among mining firms and supplier communities that have access to broadly similar technologies: differences in dynamic capability, not merely differences in capital, account for much of the variation in who captures value from digital reconfiguration (Helfat & Peteraf, 2009).

Resource-Based View and Supplier Ecosystem Analysis

The Resource-Based View (RBV) of the firm, dating to Penrose (1959) and formalised by Barney (1991), argues that competitive advantage is sustained through the possession and utilisation of valuable, rare, inimitable, and non-substitutable (VRIN) resources. In the context of supplier ecosystem transformation, the RBV directs attention to the extent to which digital transformation creates new VRIN resources, including proprietary data assets, algorithmic capabilities, and platform infrastructure, while eroding the value of previously VRIN resources such as specialised manual maintenance knowledge, established vendor relationships, and proximity-based logistical advantages that characterised pre-digital supplier value propositions (Eisenhardt & Martin, 2000).

The integration of GVC theory, dynamic capabilities, and the RBV into a unified analytical framework demonstrates how digital transformation reshapes the governance structure of mining value chains (the GVC lens), necessitates dynamic capabilities to sense and respond to technological change (the dynamic capabilities lens), and reconfigures the resource bases that underpin competitive advantage for both mining firms and their suppliers (the RBV lens). Figure 1 presents this integrated framework.

Figure 1. Integrated Analytical Framework — Digital Value Chain Reconfiguration in Southern African Mining

Global Value Chain Theory	Dynamic Capabilities Theory	Resource-Based View
Focus: Governance structure, lead-firm power, supplier upgrading opportunities	Focus: Sensing, seizing, and reconfiguring capabilities for digital adaptation	Focus: VRIN resource creation, erosion, and reconfiguration
Digital impact: Platform governance deepens lead-firm control; alters supplier participation barriers	Digital impact: Exposes capability gaps; rewards firms with digital sensing and integration routines	Digital impact: Data assets become VRIN; manual knowledge erodes; new substitution risks emerge
Analytical output: Reconfiguration trajectories and governance evolution	Analytical output: Strategic renewal pathways and capability-investment priorities	Analytical output: Supplier resource repositioning and competitive-survival conditions

Source: Author's conceptual development.

Integrated Framework: Causal Pathways and Feedback Mechanisms

The interaction between the three frameworks is mediated by dynamic capabilities, which bridge the internal focus of the RBV with the external focus of GVC theory. Internal RBV resource configurations constrain the scope of a firm's dynamic capabilities; conversely, the successful execution of these capabilities alters the firm's positioning within the GVC governance structure. GVC governance shifts and RBV resource reconfigurations, therefore, do not merely run in parallel but exist in a continuous feedback loop, in which external value-chain pressures dictate resource needs and internal resource constraints limit GVC mobility.

Making this loop explicit is important because it is the mechanism through which the trajectories analysed in Section 4 generate the polarisation documented in Section 6 and, ultimately, the institutional responses analysed in Section 8.3. Figure 2 sets out the causal pathway as a six-stage sequence, from the emergence of a digital technology through governance intensification, capability activation, resource reconfiguration, and ecosystem polarisation, to the institutional response that resets the conditions for the next cycle. The model is explicitly cyclical rather than linear: institutional renewal at Stage 6 alters the governance terms at Stage 2, so the same trajectory can produce different outcomes in a jurisdiction with strong local-content enforcement than in one without it, a distinction that motivated the four-country comparative scope of this paper.

Figure 2. Causal Pathways and Feedback Mechanisms in Digital Value Chain Reconfiguration

Stage	Mechanism	Feedback Effect
1. Digital emergence	AI, IoT, autonomous systems, and blockchain have become commercially available to lead mining firms and their preferred suppliers.	Availability alone confers no advantage; adoption decisions are shaped by firm-level dynamic capabilities (Stage 3).
2. Governance intensification (GVC)	Lead firms embed digital platforms into procurement and performance monitoring, extending the reach of governance into supplier operations.	Deeper governance raises supplier switching costs, which feed forward into resource dependence (Stage 4) and back into lead-firm bargaining power.
3. Dynamic capability activation	Firms that can sense, seize, and reconfigure around digital opportunities capture disproportionate value; firms that cannot fall behind do so.	Capability gaps widen over successive investment cycles, reinforcing the polarisation identified in Stage 5.
4. Resource reconfiguration (RBV)	Data assets, algorithmic capability, and platform infrastructure become new VRIN resources; manual knowledge and proximity-based advantages erode.	New VRIN resources alter what counts as a barrier to entry, feeding back into GVC governance terms (Stage 2).
5. Supplier ecosystem polarisation	Digitally capable suppliers consolidate contracts and margins; digitally excluded suppliers, including many SMEs and BEE-designated firms, lose share.	Polarisation generates social-licence and local-content pressure that feeds forward into institutional renewal (Stage 6).
6. Institutional response	Governments and industry bodies revise local-content frameworks, data governance rules, and cybersecurity standards in response to observed polarisation and incidents.	Revised institutions reset the digital participation conditions suppliers face, closing the loop back to Stage 2.

Source: Author's conceptual development, derived from integrating GVC, dynamic capabilities, and RBV theory in Section 3.3.

Original Theoretical Contribution

This paper's original theoretical contribution is threefold. First, it integrates GVC theory, dynamic capabilities theory, and the RBV into a single causal model of digital value chain reconfiguration, rather than applying the three frameworks separately, as most existing treatments do. Second, it renders explicit the feedback loop between value-chain governance and firm-level resource reconfiguration (Figure 2), showing digital transformation to be an iterative, path-dependent process rather than a one-off shock to which firms adapt; this addresses a gap identified by Jacobides et al. (2018) in the ecosystem literature, where governance and resource dynamics are more often described than causally linked. Third, it locates this integrated model in the specific institutional context of Southern African mining, where local-content policy, BEE and citizen-empowerment requirements, and resource-nationalist pressures interact with digital governance in ways that the existing global mining-digitalisation literature (Musingwini, 2022; World Economic Forum, 2020) does not capture.

Four Trajectories of Digital Value Chain Reconfiguration

Automation-Led Disintermediation

The first and most immediately visible reconfiguration trajectory is automation-led disintermediation: the replacement of human labour and human-intermediated supplier services with autonomous systems and machine intelligence. In Southern Africa, autonomous haulage systems (AHS) have progressed from pilot programmes toward operational deployment across several large-scale operations, though at markedly different speeds across the four focal jurisdictions.

South Africa leads regional adoption, particularly through Anglo American. Operations including Mogalakwena and Sishen use Epiroc's Pit Viper autonomous drills to improve accuracy, safety, and efficiency; these rigs integrate autonomous drilling, wireless communication, GPS, fleet management, and remote operating stations, enabling minimal human intervention (Epiroc, 2019, 2021). Mogalakwena is among the most digitally advanced automation projects in the region: as part of Anglo American's FutureSmart Mining™ programme, the operation uses autonomous Komatsu haul trucks, advanced fleet management, collision-avoidance technology, high-precision GPS, and remote operation centres to improve productivity and safety (Mining Weekly, 2018; International Mining, 2018).

Botswana provides a comparably advanced but distinct case. Debswana, the De Beers–Government of Botswana joint venture, partnered with Huawei to deploy the world's first 5G-oriented smart diamond mine at Jwaneng, connecting more than 260 pieces of equipment, including drilling rigs, excavators, and haul trucks, through a private network that underpins collision-avoidance, fleet-management, and remote-operation capability (Huawei, 2023; Mining Review, 2024). Debswana's Future Smart Connected Mine strategy has since extended similar connectivity toward Orapa, Damtshaa, and Letlhakane, and toward the deeper, more technically demanding Jwaneng Underground Project, which is evaluating autonomous machinery, digital twinning, and augmented reality (Debswana, 2025a; Mining Weekly, 2024b). Notably, this automation agenda is explicitly tied to Botswana's Citizen Economic Empowerment Programme, illustrating a deliberate, if still evolving, attempt to link automation-led disintermediation to local supplier and workforce development rather than allow the two to run in tension (Debswana, 2025b).

Zambian copper mines, including Mopani, Kansanshi, and Konkola, use automated long-hole drilling systems that allow remote supervision, reducing worker exposure to hazards while improving consistency and productivity (Epiroc, 2018a, 2018b). Zimbabwe's trajectory is more recent and more narrowly focused on ore-processing automation than on haulage: at the century-old Bikita lithium mine, a 2024 partnership with HPY Technology introduced sensor-based optical and X-ray ore-sorting systems that raised waste rejection to as much as 36 per cent and lifted concentrate grade, improving both the economics and the sustainability profile of the operation (Mining.com, 2025). This illustrates that automation-led disintermediation in the region is not confined to haulage and drilling; it is also reshaping the mineral-processing segment of the value chain, with corresponding implications for the suppliers who previously provided manual sorting and beneficiation services.

Southern Africa's adoption of autonomous haulage nonetheless remains at an earlier stage than in Australia, where several thousand autonomous trucks are already in operation (McKinsey & Company, 2023). Constraints include high capital costs, uneven digital infrastructure, cybersecurity exposure, skills shortages, and workforce resistance (PwC, 2024). Many operators consequently pursue phased strategies, beginning with collision avoidance, fleet management, and remote operating centres before progressing toward fuller autonomy (Deloitte, 2022).

The consequences for the supplier ecosystem are heterogeneous and context-specific. For large international equipment manufacturers such as Caterpillar, Komatsu, Epiroc, and Huawei, automation and connectivity present a significant revenue opportunity, as digitally enabled equipment and networks command price premiums and generate recurring revenue from software licensing, remote monitoring subscriptions, and data analytics services. For local and regional suppliers that previously provided staffing for manual equipment operation, basic maintenance services, and conventional spare-parts supply, however, automation-led disintermediation poses an existential threat. In the Southern African context, where mining employment carries community-livelihood and political-economy dimensions largely absent in Australia, these impacts are considerably amplified, and Debswana's own panel discussions on next-generation mining technologies have explicitly acknowledged workforce anxiety about job displacement as a live management concern rather than a hypothetical risk (Debswana, 2025b).

Data-Driven Supplier Integration

The second trajectory, data-driven supplier integration, represents a less visible but strategically significant reconfiguration in which digital data flows are used to integrate supplier capabilities more deeply into mining operations, rather than to replace them. This trajectory is most evident in predictive maintenance ecosystems, where mining firms share real-time sensor data from equipment with original equipment manufacturer (OEM) suppliers, enabling remote condition monitoring, predictive failure alerts, and just-in-time maintenance interventions that reduce unplanned downtime and extend asset life.

Anglo American's FutureSmart Mining programme illustrates this trajectory. Through its Operations Centre in Johannesburg, the company integrates data streams from sensors embedded across multiple mining sites and shares relevant data subsets with OEM suppliers who are contractually obliged to respond to predictive alerts within defined service-level windows (Anglo American, 2022). This arrangement transforms the supplier relationship from a transactional parts-and-labour model into a continuous performance partnership, in which supplier revenue is increasingly tied to asset availability outcomes rather than to the frequency of maintenance events.

The strategic implications for supplier ecosystems are double-edged. Suppliers that develop remote monitoring and predictive analytics capabilities can secure more stable, relationship-intensive, and higher-margin service contracts than conventional transactional arrangements allow. At the same time, deep data integration creates switching costs and lock-in dynamics that can disadvantage mining firms in supplier negotiations over time. It raises data-sovereignty questions about who owns the operational data generated by mining equipment and who controls access to the predictive insights derived from it (World Economic Forum, 2020), and, increasingly, questions about the fairness of the algorithmic scoring models built on that data.

For Southern African supplier ecosystems, data integration also poses a local-content challenge. The analytical platforms, machine learning models, and remote-monitoring infrastructure underpinning data-driven integration are predominantly developed and hosted by multinational technology companies and OEM suppliers headquartered outside the region. Local suppliers that lack the technical capability to interface with these platforms or are excluded from data-sharing arrangements dominated by international OEM relationships face progressive marginalisation from the most valuable segments of the evolving supplier ecosystem.

Platform-Mediated Ecosystem Orchestration

The third trajectory involves the emergence of digital platforms as governance mechanisms that orchestrate supplier ecosystem interactions at a scale beyond bilateral firm-to-firm relationships. In mining, this trajectory is most advanced in procurement and supply chain management, where platforms such as Coupa, SAP Ariba, and mining-specific procurement systems manage the full supplier lifecycle from qualification and onboarding through performance monitoring and payment within a single integrated digital environment.

South Africa's mining sector shows the most advanced development of platform-mediated ecosystems in the region. Anglo American's competitive positioning stems less from any single technology than from its ability to orchestrate an ecosystem of interoperable digital platforms: by integrating cloud computing (Microsoft Azure), enterprise systems (SAP), operational technologies, digital twins, AI, IoT, and proprietary analytics through its VOXEL™ platform, the company has established a platform-mediated ecosystem supporting autonomous operations, sustainability reporting, and data-driven decision-making across its global mining portfolio (Anglo American, 2024; Jacobides et al., 2018). Sibanye-Stillwater has similarly invested in supplier development platforms that integrate compliance training, BEE certification, and performance scoring within a single supplier relationship management system. Botswana's Debswana, through its 5G-enabled infrastructure, is building toward comparable orchestration capability. However, Zambia and Zimbabwe remain at an earlier stage, with platform adoption concentrated in a small number of large operators rather than diffused across the supplier base (see Table 1).

The governance consequences of platform-mediated orchestration closely mirror the captive governance structure identified in GVC theory: suppliers face high switching costs as their operational processes become deeply integrated with the mining firm's platform, operate under tightly specified performance requirements enforced through real-time monitoring, and have limited ability to leverage their position to secure better commercial terms. For large, technically capable suppliers with the resources to invest in platform integration, this governance structure provides access to stable, high-volume contracts. For smaller, less technically sophisticated suppliers, including many community-based enterprises and black economic empowerment (BEE) companies, platform requirements that are nominally designed to support them can instead create barriers that effectively exclude them from the most lucrative procurement categories.

Sustainability-Linked Value Chain Redesign

The fourth trajectory, sustainability-linked value chain redesign, is the most recent to emerge but is gaining rapid traction as ESG pressures from institutional investors, international customers, and regulatory frameworks converge, making mineral provenance, carbon footprint, and human rights compliance core dimensions of value chain governance. Blockchain-based mineral traceability platforms, including the Responsible Minerals Initiative's blockchain pilot and De Beers' Tracr platform for diamond provenance in Botswana, are enabling end-to-end digital tracking of minerals from ore body to consumer product, generating verifiable ESG compliance data and creating new value-chain segments centred on sustainability certification.

Zambia and Zimbabwe illustrate the trajectory's extension into base and battery metals. Zambia's National Critical Minerals Strategy 2024–2028 explicitly links the country's ambitions for copper, cobalt, and manganese to traceability and environmental governance commitments aimed at attracting green finance and meeting international supply chain due diligence requirements (Republic of Zambia, Ministry of Mines and Minerals Development, 2024). Zimbabwe's push to move lithium production from raw ore export toward local sulphate refining, most visibly through Sinomine's investment at Bikita and Zhejiang Huayou Cobalt's refinery at Arcadia, is similarly framed as a sustainability and value-capture measure, since domestic processing reduces the transport-related emissions and revenue leakage associated with exporting unrefined concentrate (Business Tech Africa, 2026; Mining Technology, 2025).

This trajectory's limits, however, are as instructive as its successes. In February 2025, a tailings dam operated by Sino-Metals Leach in Zambia's Copperbelt collapsed, releasing toxic sludge into the Kafue River system and contaminating water supplies and agricultural land relied upon by surrounding communities (International Growth Centre, 2025). The incident is a governance rather than a digital failure in the narrowest sense. However, it is directly relevant to this trajectory: no amount of blockchain-based provenance tracking or digital ESG reporting substitutes for the physical integrity of tailings infrastructure, and a firm can score well on digital traceability metrics while remaining exposed to catastrophic environmental risk. This distinction between digitally verifiable compliance and substantively safe operation is returned to in the critical analysis in Section 7.

For Southern African mining firms and their suppliers more broadly, sustainability-linked redesign creates new compliance requirements alongside significant market-access opportunities. Firms able to demonstrate verified low-carbon, conflict-free, and community-benefit mineral supply chains can command price premiums in ESG-sensitive markets, particularly in Europe and North America, where supply-chain due diligence legislation is becoming mandatory, and gain preferential access to green finance and development finance institution (DFI) investment. Suppliers able to integrate sustainability data capture and reporting into their service offerings gain a competitive advantage in procurement processes increasingly shaped by ESG scoring criteria (Lèbre et al., 2020).

DIGITAL ETHICS, CYBERSECURITY, DATA GOVERNANCE, AND PLATFORM DEPENDENCY

The four trajectories analysed share a common underside: each increases the mining value chain's exposure to a cluster of interrelated digital risks, cybersecurity, algorithmic unfairness, contested data ownership, and dependency on a small number of external platform and technology providers, which existing GVC, dynamic capabilities, and RBV analysis addresses only implicitly. This section treats these risks as a distinct analytical object, consistent with their growing weight in both the academic and practitioner literature.

Cybersecurity Exposure in Digitally Reconfigured Value Chains

Automation, IoT sensor networks, and cloud-integrated platforms expand the attack surface available to malicious actors at precisely the moment mining firms are becoming more operationally dependent on those systems. The regional evidence is no longer hypothetical. In August 2024, Sibanye-Stillwater issued a formal notice under South Africa's Protection of Personal Information Act reporting a cyberattack that compromised global ICT systems and exposed stakeholders' identity, health, financial, and contractual information (Mail & Guardian, 2025). In December 2023, Anglo American's email distribution systems were compromised, disrupting communications with subscribers and suppliers (Mine Magazine, 2024). These incidents are consistent with a broader continental pattern: Kaspersky ICS CERT recorded that 47 per cent of industrial control system computers in Africa were targeted by malware in 2022, a rate above the global average (Kaspersky, 2023), and South Africa's Council for Scientific and Industrial Research, in its October 2024 National Cybersecurity Survey, recommended that the mining sector integrate cybersecurity as a core component of risk and safety management rather than treat it as a peripheral IT concern (Mail & Guardian, 2025).

The strategic implication is that cybersecurity is not a cost of digital transformation to be minimized alongside other implementation costs; it is a determinant of whether the value created by automation, data integration, and platform orchestration is retained or destroyed. A cyberattack on a predictive-maintenance data pipeline or a procurement platform can, in principle, cascade through the same supplier relationships that digital integration was intended to strengthen, converting an efficiency mechanism into a point of systemic fragility. Mining firms that pursue digital operations excellence and ecosystem orchestration pathways accordingly incur a parallel obligation to invest in incident response planning and supplier-facing cybersecurity standards, not merely in their own perimeter defences.

AI Ethics and Algorithmic Accountability in Mining Operations

As mining firms deploy AI-powered analytics for predictive maintenance, geological modelling, and, increasingly, supplier and workforce scoring, the general risks of algorithmic bias identified in the wider AI ethics literature become directly relevant to the sector. Bahangulu and Owusu-Berko (2025) show that algorithmic bias in business analytics applications typically originates from biased training data, flawed model assumptions, and insufficient diversity in the underlying datasets, and that, without deliberate bias mitigation and audit practices, automated scoring systems reproduce and can amplify existing inequalities rather than correct them.

This finding has a direct, if under-examined, application to the platform-mediated supplier scorecards described in Section 4.3. A supplier performance-management system trained predominantly on the historical delivery and compliance records of large, technically sophisticated, internationally connected suppliers risks systematically undervaluing smaller, community-based, and BEE-designated suppliers whose historical data is thinner or whose operating context differs from that of the training population, even where their underlying service quality is comparable. Because such scores increasingly feed directly into contract-renewal decisions, an unaudited algorithmic bias of this kind would not merely reflect existing supplier-ecosystem polarisation; it would actively accelerate it. Explainability, independent bias audits, and a documented right of appeal for suppliers scored by automated systems are accordingly proposed as a necessary complement to the institutional renewal agenda, rather than as an optional governance refinement.

Data Governance and Data Sovereignty

Data governance and data sovereignty questions, introduced in relation to predictive maintenance, extend across all four trajectories. Operational data generated by mining equipment increasingly resides on infrastructure owned or hosted by international OEMs and cloud providers, and the analytical models built on that data, whether for predictive maintenance, ore-body modelling, or supplier scoring, are correspondingly difficult for host-country regulators or local suppliers to inspect. Zambia's National Critical Minerals Strategy 2024–2028 represents an early instance of national mining policy attempting to address this gap, situating data and technology governance alongside the more familiar concerns of ownership and beneficiation (Republic of Zambia, Ministry of Mines and Minerals Development, 2024). However, comparable frameworks remain nascent in Botswana and Zimbabwe and are only partially developed in South Africa.

The absence of clear data governance rules has two compounding effects. First, it allows the progressive concentration of the analytical and commercial value generated by mining data in the hands of international platforms and technology companies, reinforcing the winner-take-most dynamics documented. Second, it leaves open the question of accountability when the algorithmic systems built on that data produce the biased or erroneous outcomes: without clear data governance rules establishing who controls, and who is answerable for, a given dataset and the models trained on it, neither host governments nor affected suppliers have a clear point of recourse.

Platform Dependency and Lock-in Risk

Platform-mediated ecosystem orchestration concentrates governance power in the hands of the mining firms that operate procurement and performance platforms. However, it also creates a second, less visible dependency: the mining firms themselves become dependent on the external technology providers, Microsoft Azure, SAP, Huawei, and comparable vendors, whose infrastructure underpins those platforms. Debswana's 5G smart-mine partnership with Huawei and Anglo American's cloud-hosted VOXEL™ ecosystem are, in this respect, not only competitive assets but also long-term dependencies that raise switching costs for the mining firm, much as captive governance raises switching costs for suppliers.

In the Southern African context, this dependency has an added geopolitical dimension. Chinese technology and mining-finance providers, including Huawei in Botswana's smart-mine programme and Sinomine and Zhejiang Huayou Cobalt in Zimbabwe's lithium sector, have become central infrastructure and capital partners in several of the digital and beneficiation initiatives, alongside Western OEM and cloud providers elsewhere in the region. This is not, in itself, a risk unique to any one provider's national origin; the underlying concern, consistent with the platform-dependency literature more broadly, is concentration itself, the possibility that a small number of external providers, regardless of origin, come to hold disproportionate influence over the operational continuity, data governance, and strategic options of Southern African mining firms and their supplier ecosystems. Diversification of technology partnerships, adoption of open and interoperable platform standards where feasible, and explicit data-portability and exit provisions in platform contracts are accordingly identified as a component of the digital operations excellence pathway rather than a separate risk-management afterthought.

SUPPLIER ECOSYSTEM TRANSFORMATION: DYNAMICS AND IMPLICATIONS

Winner-Take-Most Dynamics and Supplier Ecosystem Polarisation

Across all four reconfiguration trajectories, a common structural dynamic is evident: digital transformation produces winner-take-most outcomes within supplier ecosystems, concentrating value and access to contracts among a relatively small number of digitally capable, well-capitalised suppliers, while progressively marginalising those unable to meet evolving digital participation requirements. This pattern has been documented in supplier ecosystem research across multiple industries (Jacobides et al., 2018) and is now clearly visible in Southern African mining supply chains.

Evidence from South Africa's mining sector is particularly instructive. Industry surveys conducted by the Minerals Council South Africa (2023) indicate that the top tier of mining suppliers by digital capability, those with established predictive analytics offerings, platform-compatible ERP systems, and digital service delivery models, are capturing a disproportionate and growing share of total mining procurement spend, while a substantial share of smaller, more labour-intensive suppliers with limited digital infrastructure are experiencing declining contract values and increasing competition from both digitally advanced regional suppliers and international competitors entering the market through platform-mediated procurement.

This polarisation is not merely a commercial phenomenon. In Southern Africa's political economy, mining supplier ecosystems serve as mechanisms for social and economic transformation, through which mining revenues are distributed to local communities, BEE and citizen-empowerment commitments are implemented, and host communities gain an economic stake in mining operations. Digital transformation that concentrates supplier-ecosystem value among large, internationally connected firms simultaneously undermines the social-licence dimensions of mining-sector legitimacy and intensifies political tensions over local-content requirements and community-benefit agreements.

Local Content Policy and the Digital Transformation Challenge

All four mining jurisdictions examined in this study, South Africa, Botswana, Zambia, and Zimbabwe, have enacted local content or citizen-empowerment frameworks that require mining firms to prioritise locally owned and locally manufactured suppliers in their procurement. In South Africa, Mining Charter III establishes minimum local procurement thresholds and BEE ownership requirements for suppliers (Department of Mineral Resources, 2018). Botswana's Citizen Economic Empowerment Programme performs a comparable function within Debswana's supply chain (Debswana, 2025b). In Zambia, the Citizens Economic Empowerment Act and Zambia Development Agency Act impose broadly comparable requirements, now reinforced by the technology and beneficiation provisions of the National Critical Minerals Strategy 2024–2028 (Republic of Zambia, Ministry of Mines and Minerals Development, 2024). Zimbabwe's local-content push has centred on lithium beneficiation, with export restrictions on raw ore and concentrate intended to compel local processing investment (Business Tech Africa, 2026). These frameworks were designed for a largely pre-digital supplier ecosystem in which geographic proximity, relationship-based business development, and manual service delivery were the primary bases of competitive differentiation.

Digital transformation disrupts the logic of these frameworks in several ways. First, platform-mediated procurement enables international suppliers to participate in mining procurement without a local presence, undermining the advantages of geographic proximity. Second, digital capability requirements effectively create new informal barriers to supplier participation that existing local-content compliance metrics do not capture: a supplier can be locally owned and BEE-compliant yet be technically excluded from digitally governed procurement processes because it cannot integrate with the required platforms. Third, the data and intellectual property generated by digital supplier relationships increasingly accrue to international OEMs and technology companies rather than to local supplier communities, creating new forms of value extraction, that existing local-content frameworks are not designed to address. Zimbabwe's experience since 2024 also illustrates a fourth, more basic tension: even well-intentioned local-processing mandates can be undermined by external shocks, such as the roughly 80 per cent collapse in global lithium prices during 2023 and 2024, which forced Bikita Minerals and other Zimbabwean lithium producers to cut production and lay off workers and led the government to soften its localisation deadlines on a case-by-case basis (Mining Weekly, 2024a). Local-content policy, in other words, cannot rely on digital capability alone to secure durable local participation when commodity-price volatility and policy inconsistency undermine investment confidence.

Table 1. Digital Transformation Readiness of Southern African Mining Supplier Ecosystems

Dimension	South Africa	Botswana	Zambia	Zimbabwe
Digital infrastructure maturity	Advanced	Moderate–Advancing	Developing	Developing
Platform adoption rate (est.)	65–70%	45–55%	25–35%	20–30%

Dimension	South Africa	Botswana	Zambia	Zimbabwe
Local supplier digital capability	Moderate–High	Low–Moderate	Low	Low
Regulatory digital framework	Partially adapted	Early stage, actively coordinated (5G/digitalisation roadmap)	Early stage (Critical Minerals Strategy 2024–2028)	Nascent (1961 Mines and Minerals Act still governs)
ESG traceability adoption	High (PGMs, gold)	High (diamonds, Tracr-linked)	Moderate–Advancing (copper, cobalt)	Low–Moderate (lithium beneficiation focus)

Source: Author's synthesis from Minerals Council South Africa (2023), World Economic Forum (2020), Deloitte (2022), Debswana (2025a, 2025b), Republic of Zambia, Ministry of Mines and Minerals Development (2024), and industry reports.

SME Digital Capability Development and Inclusion Strategies

The polarisation documented falls most heavily on small and medium-sized enterprises (SMEs), which constitute the majority of firms in Southern African mining supply chains but are systematically underrepresented in the digital-adoption evidence base precisely because they are less extensively documented than the large operators. The wider African SME digitalisation literature is nonetheless directly instructive. Ebrahim and Van den Berg (2024), studying South Africa's informal economy, find that affordability, lack of training, and low digital awareness, rather than a simple absence of platforms, are the binding constraints on technology adoption among marginalised entrepreneurs; Achieng and Malatji (2022), in a scoping review of SME digital transformation across sub-Saharan Africa, reach a similar conclusion, that context-specific enterprise characteristics and sectoral dynamics, not platform availability alone, determine adoption outcomes. Noutchie's (2025) comparative analysis of digital platform adoption among SMEs in Kenya, Nigeria, and South Africa reinforces the point at a national-policy scale: South Africa combines advanced digital infrastructure with persistent exclusion of informal and township-based enterprises, while Kenya's more inclusive outcomes are attributed to grassroots digital-literacy programmes and simplified onboarding rather than to superior infrastructure alone.

Applied to mining-linked SMEs specifically, these findings point toward inclusion strategies that address capability and access together, rather than treating platform provision as sufficient on its own. Financing initiatives are beginning to emerge in the region: South Africa's Department of Mineral Resources and Energy introduced the Junior Mining Exploration Fund in September 2025 to support emerging and historically disadvantaged firms with early-stage exploration grants, while comparable public-private financing gateways connecting small mining-linked enterprises with lenders and business-development services have been piloted elsewhere on the continent (Business Tech Africa, 2025). Raji et al. (2024), comparing SME digital transformation in the United States and Africa, argue that financing access, digital-skills training, and regulatory simplification function as complements rather than substitutes, a finding consistent with the multi-pronged approach recommended here.

Drawing on this evidence, four concrete SME inclusion strategies are proposed for mining firms and policymakers in the region. First, tiered platform participation, in which digitally limited local suppliers can transact through simplified interfaces or intermediated onboarding for defined procurement categories, with a structured pathway toward fuller platform integration, allows firms to pursue digital efficiency and local-content objectives simultaneously rather than in tension, extending the ecosystem-orchestration pathway. Second, supplier development funds, co-financed by mining firms, governments, and development finance institutions, should target not only equipment finance but also the digital-literacy and change-management training that Ebrahim and Van den Berg (2024) identify as the more binding constraint. Third, subsidised connectivity and cloud-hosting arrangements can reduce the fixed costs of platform participation that disproportionately deter micro and small suppliers. Fourth, mentorship and subcontracting pairing schemes, in which large, digitally capable suppliers are contractually encouraged or required to subcontract defined work packages to SME and BEE-designated partners with structured technology-transfer components, can convert the winner-take-most dynamic documented into a more deliberately managed capability-diffusion process.

CRITICAL ANALYSIS: SUCCESSES AND FAILURES OF DIGITAL VALUE CHAIN TRANSFORMATION

The preceding sections have, of necessity, discussed successes and failures as they arise within each trajectory. This section draws that evidence together deliberately, weighing documented gains against documented setbacks, in order to avoid the one-sided emphasis on efficiency and productivity benefits that characterises much industry-oriented commentary on mining digitalisation.

Documented Successes

The evidence reviewed in Sections 4 and 6 supports several genuine, independently verifiable successes. Autonomous haulage and drilling systems in South Africa and Botswana are associated with productivity gains, reduced fuel use, lower human risk exposure, and more data-driven decision-making (ICMM, 2023; International Mining, 2021). Predictive maintenance ecosystems, exemplified by Anglo American's Operations Centre, have measurably reduced unplanned downtime and extended asset life. Debswana's 5G-enabled smart-mine infrastructure at Jwaneng has delivered a step change in operational connectivity while remaining explicitly linked to Botswana's citizen-empowerment objectives (Debswana, 2025a, 2025b). Blockchain-based provenance platforms such as De Beers' Tracr have created verifiable, market-facing sustainability credentials that would be difficult to achieve through manual documentation alone. Bikita Minerals' sensor-based ore-sorting partnership demonstrates that digital transformation in the region is not confined to haulage automation but is also improving resource efficiency in mineral processing (Mining.com, 2025).

Documented Failures and Setbacks

Against these successes, the evidence reviewed above documents equally concrete failures. The Sibanye-Stillwater and Anglo American cybersecurity incidents show that the same digital infrastructure that enables efficiency gains also creates exploitable points of failure, with direct consequences for the personal data of employees and stakeholders and for operational continuity. The February 2025 Sino-Metals Leach tailings dam collapse on the Kafue River demonstrates that digital ESG traceability and reporting can coexist with, rather than prevent, catastrophic physical and environmental failure, a distinction between digital compliance and substantive safety that industry reporting on digital sustainability initiatives rarely acknowledges. Zimbabwe's 2023–2024 lithium price collapse, and the production cuts, layoffs, and softened localisation deadlines that followed, show that digital and processing investment does not insulate suppliers or workers from commodity-cycle volatility. The beneficiation policy commitments made during a boom can prove difficult to enforce during a downturn. The algorithmic-bias risk identified has not, to the authors' knowledge, been documented as a confirmed incident within Southern African mining supplier scoring specifically. However, the general finding that unaudited business analytics systems reproduce training data bias (Bahangulu & Owusu-Berko, 2025) is a directly applicable warning rather than a remote concern, given how rapidly supplier scorecards of the kind are being adopted. Finally, workforce anxiety about automation-driven job losses, acknowledged directly in Debswana's own industry panel discussions (Debswana, 2025b), indicates that the disintermediation trajectory carries a social cost that firms are aware of but have not yet systematically measured or mitigated.

Balancing the Record

Read together, the successes and failures documented above do not support either an uncritically celebratory or an uncritically dismissive account of digital transformation in Southern African mining. The clearest pattern is one of asymmetry: the productivity, safety, and provenance benefits of digital transformation accrue disproportionately to large, well-capitalised, technically sophisticated mining firms and their most capable suppliers, while the associated risks, cyberattack exposure, algorithmic unfairness, environmental failure that digital monitoring did not prevent, and commodity-cycle vulnerability, fall more broadly, and often most heavily, on suppliers, workers, and communities with the least capacity to absorb them. This asymmetry is precisely what the causal model predicts: without deliberate institutional renewal at Stage 6 of the model, the same feedback loop that concentrates digital capability also concentrates digital risk exposure at the periphery of the value chain. The strategic renewal framework developed, and in particular the institutional renewal priorities, is framed accordingly, as a response to a documented and asymmetric balance sheet rather than as a generic call for more digital investment.

STRATEGIC RENEWAL FRAMEWORK FOR DIGITAL VALUE CHAIN NAVIGATION

Strategic Renewal Pathways for Mining Firms

Strategic renewal, the process by which firms fundamentally revise their strategic logic, resource configurations, and operating models in response to transformative environmental change, is a central requirement for mining firms navigating the reconfiguration of the digital value chain (Agarwal & Helfat, 2009). Drawing on the reconfiguration trajectories identified in Section 4, the digital-risk analysis in Section 5, and dynamic capabilities theory, three strategic renewal pathways are identified for mining firms in Southern Africa.

Pathway 1: Digital Operations Excellence

The digital operations excellence pathway involves the systematic deployment of digital technologies across core mining operations to achieve step-change improvements in productivity, safety, and cost efficiency. This pathway is most clearly represented by Anglo American's FutureSmart Mining programme, which has set explicit 2030 targets of a 30 per cent improvement in energy efficiency, a 50 per cent reduction in fresh water abstraction, and a 30 per cent reduction in net greenhouse gas emissions through digitally enabled operational transformation (Anglo American, 2022), and by Debswana's Future Smart Connected Mine strategy in Botswana (Debswana, 2025a). The pathway requires investment in IoT sensor networks, operational data platforms, advanced analytics capability, and digital talent development, together with the reorganisation of operational structures needed to realise the value of real-time data insights.

For Southern African mining firms, the digital operations excellence pathway is necessary but not sufficient for sustainable competitive advantage. Because core digital technologies, autonomous systems, predictive analytics platforms, and integrated operations centres are available on commercial terms to all major mining firms globally, early movers gain only temporary advantages from adoption alone. Sustainable advantage requires building organisational dynamic capabilities, data science expertise, change-management routines, and supplier integration practices that competitors find difficult to replicate, together with the cybersecurity resilience and technology-partner diversification, without which the pathway's efficiency gains remain exposed to disruption.

Pathway 2: Ecosystem Orchestration and Platform Leadership

The ecosystem orchestration pathway involves positioning the mining firm not merely as a participant in digital supplier platforms but as an architect and orchestrator of the broader supplier ecosystem. Rather than adopting off-the-shelf procurement platforms from external vendors alone, firms pursuing this pathway invest in proprietary or co-developed supplier ecosystem platforms that integrate qualification, performance management, capability development, and local-content compliance into a single governance infrastructure. This approach enables mining firms to shape the digital participation standards suppliers must meet, to design local-content and SME-inclusion provisions into platform architecture from the outset, and to capture the data and relationship value generated by platform-mediated supplier interactions.

In the Southern African context, the ecosystem orchestration pathway offers particular promise for addressing the identified local-content policy challenge and the developed SME inclusion imperative. Mining firms that design supplier ecosystem platforms with explicit provisions for tiered participation, enabling digitally limited local suppliers to participate in defined procurement categories through simplified interfaces, with development pathways toward more sophisticated participation over time, and that build in the algorithmic-audit safeguards can pursue digital transformation and local-content objectives simultaneously rather than in tension.

Pathway 3: Sustainability-Anchored Value Creation

The sustainability-anchored value creation pathway positions digital transformation not primarily as a cost-reduction mechanism but as the foundation for generating verified ESG compliance credentials that command premium market access and preferential financing terms. Mining firms pursuing this pathway invest in end-to-end digital traceability infrastructure, integrate carbon accounting systems into operational data flows, and develop verified community-benefit reporting capabilities that translate digital data into bankable evidence of social impact. De Beers' Tracr platform is the most advanced manifestation of this pathway in the Southern African context, creating a blockchain-based provenance record that enables diamond purchasers to verify the origin and compliance credentials of individual stones from mine to retail (De Beers, 2023). The critical analysis nonetheless counsels that this pathway must be paired with, rather than substituted for, investment in the physical integrity of tailings and environmental infrastructure, since digital traceability credentials do not by themselves prevent the kind of catastrophic failure documented at Sino-Metals Leach in 2025.

Strategic Renewal for Supplier Ecosystems

Strategic renewal imperatives for supplier firms in the Southern African mining ecosystem differ significantly by supplier size, capability profile, and the depth of existing relationships with mining lead firms. Drawing on the RBV and dynamic capabilities frameworks, three supplier renewal strategies are identified, with the SME-specific inclusion measures developed and forming the third.

For large, established suppliers with existing technical capability and access to capital, the strategic imperative is to deepen digital capability by investing in predictive analytics, remote monitoring infrastructure, and platform integration, positioning the supplier as an indispensable partner in the data-driven integration trajectory. Suppliers in this category should pursue strategic alliances with technology companies to accelerate capability development while negotiating data-ownership provisions, consistent with the data-sovereignty concerns raised, that protect the long-term commercial value of operational data generated through their service relationships.

For mid-tier suppliers with domain expertise but limited digital capability, the strategic renewal imperative is specialised digitisation: applying digital tools selectively to the service domains where they can deliver the greatest improvements in quality, efficiency, or transparency, rather than attempting a broad digital transformation across the full service portfolio. A maintenance engineering firm, for example, might invest in drone-based inspection technology and digital condition-reporting tools without developing AI-powered predictive analytics in-house, instead partnering with analytics providers to deliver integrated maintenance intelligence services.

For small, community-based, and BEE-designated suppliers facing the most severe barriers to digital participation, strategic renewal must be supported by the broader ecosystem rather than pursued in isolation, along the lines set out: supplier development funds, tiered platform participation, subsidised connectivity, and mentorship-based technology transfer. Without such systemic support, the digitally driven polarisation of supplier ecosystems documented and will progressively undermine the local-content policy objectives central to the social contract between mining firms and host communities across the region.

Institutional and Policy Renewal

Strategic renewal in Southern African mining cannot be achieved by firms alone. Consistent with the causal model developed, in which institutional renewal is the stage that resets the governance conditions for the next cycle of digital reconfiguration, the institutional environment, policy frameworks, regulatory structures, financing instruments, and industry coordination mechanisms governing the sector must also be renewed to support digitally enabled value chain transformation that serves regional development objectives. Five institutional renewal priorities are identified.

First, local content and citizen-empowerment frameworks across all four jurisdictions should be updated to incorporate digital capability provisions that establish not only minimum local ownership and employment requirements but also digital participation pathways that enable the phased integration of local suppliers into digitally governed supply chains, with explicit government and industry funding commitments to support the transition, and with built-in tolerance for commodity-price volatility of the kind that disrupted Zimbabwe's lithium localisation timeline in 2024.

Second, regional digital infrastructure investment, particularly in broadband connectivity, cloud computing accessibility, and cybersecurity capacity, must be accelerated through coordinated public-private financing, so that the digital transformation of mining supply chains is not constrained by infrastructure deficits that are themselves addressable through policy action, and so that the cybersecurity exposure is treated as a shared infrastructure risk rather than an individual firm's cost centre.

Third, data governance frameworks for mining-sector operational data should be developed at national and regional levels, building on early examples such as Zambia's National Critical Minerals Strategy, establishing clear principles for data ownership, access, and benefit-sharing to prevent the progressive concentration of value from mining data assets in the hands of international platforms and technology companies to the detriment of host-country economic interests.

Fourth, cybersecurity and algorithmic-governance standards specific to the mining sector, covering incident-response planning, supplier-facing security requirements, and mandatory bias auditing for AI systems used in supplier or workforce scoring, should be developed in coordination with bodies such as South Africa's Council for Scientific and Industrial Research, translating the risks identified into enforceable sector standards rather than voluntary best practice.

Fifth, regional coordination mechanisms through the Southern African Development Community (SADC) and regional mining-sector bodies should be strengthened to enable shared learning, harmonised standards, and coordinated policy responses to digital-transformation challenges, including cybersecurity incidents and data governance gaps, that transcend individual national mining sectors.

CONCLUSION

This paper has examined digital value chain reconfiguration, supplier ecosystem transformation, and strategic renewal in the Southern African mining industry, using a literature-based conceptual synthesis methodology and an integrated analytical framework that combines Global Value Chain theory, Dynamic Capabilities Theory, and the Resource-Based View into a single causal, feedback-sensitive model. The analysis was deliberately structured to draw evidence in balanced measure from South Africa, Botswana, Zambia, and Zimbabwe, rather than concentrating on South African cases as much existing commentary does, and generates several interconnected findings of theoretical and practical significance.

Four distinct reconfiguration trajectories are shaping Southern African mining value chains: automation-led disintermediation, data-driven supplier integration, platform-mediated ecosystem orchestration, and sustainability-linked value chain redesign. Each trajectory creates value for digitally capable actors while simultaneously generating disruption risks for less capable supplier communities, and each carries a distinct cluster of cybersecurity, AI ethics, data governance, and platform dependency risks that Section 5 examined directly. Across all four trajectories, winner-take-most dynamics are evident, concentrating value and access to contracts among large, digitally sophisticated suppliers while progressively marginalising smaller, less technologically advanced firms, including many local, community-based, and BEE-designated suppliers that regional mining policy is designed to support. The critical balancing of successes and failures in Section 7 showed this concentration of benefit to be matched by a concentration of risk at the periphery of the value chain, evidenced concretely by cyberattacks on Sibanye-Stillwater and Anglo American, the Sino-Metals Leach tailings failure, and the layoffs that followed Zimbabwe's 2023–2024 lithium price collapse.

The paper's original theoretical contribution is an integrated model that treats the evolution of digital governance, dynamic capability requirements, and resource reconfiguration as a continuous, cyclical feedback loop rather than as three separate lenses applied to a single case, and that situates this loop within the specific local-content and citizen-empowerment institutions of Southern African mining. The strategic renewal analysis identifies three pathways for mining firms' digital operations excellence, ecosystem orchestration, and sustainability-anchored value creation, three corresponding supplier renewal strategies differentiated by supplier size and capability, with explicit SME inclusion measures, and five institutional renewal priorities. Critically, the paper argues that supplier ecosystem renewal cannot be achieved through firm-level strategy alone: institutional renewal, including updated local-content frameworks, digital infrastructure investment, data governance policy, cybersecurity and algorithmic-governance standards, and regional coordination, is an essential complement to firm-level strategic action, precisely because the causal model identifies institutional renewal as the stage that determines whether the next cycle of digital reconfiguration reduces or reinforces supplier ecosystem polarization.

Future research should pursue four priority directions, extending the three identified in earlier work on this topic to reflect the risk dimensions and the evidentiary limitations acknowledged. First, longitudinal empirical studies, ideally incorporating primary interview or survey data with SME and informal suppliers rather than relying solely on secondary documentation, should track supplier ecosystem outcomes along the four reconfiguration trajectories over time. Second, comparative analysis of digital transformation governance models across Southern African jurisdictions should identify the policy configurations most conducive to inclusive value chain upgrading. Third, quantitative measurement of the local-content impacts of platform-mediated procurement adoption is needed to generate the evidence base for adaptive policy responses. Fourth, empirical auditing of AI-driven supplier and workforce scoring systems already in use in the region is needed to establish whether the algorithmic-bias risk identified is, in practice, being realised. These directions would advance both scholarly understanding of digital value chain dynamics in resource-dependent developing economies and the practical policy toolkit available to governments and industry seeking to govern digital transformation in the public interest.

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