

Leadership-Driven Operations Management for Sustainable Mining: A Review

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Abstract

The mining industry in South Africa remains the cornerstone of the national economy, yet it operates within highly turbulent and complex environments that continually threaten long-term sustainability. Rapid technological advancement, the emergence of the Fourth Industrial Revolution (4IR), and increasing operational complexity have intensified the need for adaptive and resilient operational approaches. Technologies such as artificial intelligence, the Internet of Things (IoT), and retrofitted digital systems are reshaping operational landscapes, requiring more than traditional efficiency-focused management models. This paper presents a comprehensive review of literature on operations management models applied in the mining sector, with particular attention to their contributions to sustainable mining practices. The review highlights the growing importance of leadership-driven operations management, arguing that sustainability outcomes are increasingly dependent on agile, ambidextrous leaders who can integrate technological, human, and system-level changes. Findings reveal a notable gap in existing research concerning leadership-centred operations management models in the mining context, particularly in South Africa. To address this gap, a conceptual framework grounded in the Input–Process–Output systems thinking model is proposed. This framework provides a foundational structure for developing a leadership-driven sustainable operations management model, aimed at enhancing system integration, adaptability, and long-term operational sustainability within the mining industry.

Keywords

Leadership-driven, Operations Management Models, Sustainability, Fourth Industrial Revolution (4IR), South African Mining Operations

1. Introduction

The mining industry remains a key player in South Africa's economic structure, significantly contributing to employment, export income, and industrial development, among other things (Oloba & Ramhurry 2025). The sector remains vulnerable to persistent volatility and changes driven by legacy issues, regulatory pressures, labour dynamics, environmental constraints, declining ore grades, and heightened stakeholder engagement. These conditions have intensified the difficulty of sustaining mining operations over the long term, particularly where operational performance, environmental responsibility, and social legitimacy intersect (Hamann, 2003).

The Fourth Industrial Revolution (4IR) technologies have significantly impacted the operational context of mining and have expanded rapidly, alongside other technologies such as artificial intelligence (AI), automation, real-time monitoring systems, and the Internet of Things (IoT). These technologies, among other key factors, offer opportunities to improve safety, productivity, and environmental performance. However, these could also disrupt established operational routines and decision-making structures, as noted by Uys & Webber-Youngman (2019). From a global

mining perspective, 4IR technologies include autonomous haulage systems, real-time sensor networks, predictive maintenance algorithms, drone-based surveying and digitised platforms that replicate underground environments for planning and risk assessment (Alqaraleh et al. 2024). These tools limit human exposure to hazardous conditions while improving throughput and reducing unit cost. In the South African mining context, technology adoption is frequently uneven, shaped not only by capital availability and technical readiness, but also by leadership orientation and organisational culture (Mokganya et al. 2024). From a global perspective, the patterns of adoption and acceptance show a blurred picture, with observations of technology adoption models needing recalibrations for 4IR (Kruger and Steyn 2025). Further, McKinsey (2023) notes that early adopters of AI and robotics can expect a positive cash flow impact, while lagging organisations may see a decline.

It is therefore important to understand the impact of these technologies on the sustainability of the South African mining sector. To note, sustainability challenges cannot therefore be addressed solely through technical optimisation or compliance-driven operational controls; they require a focus on leadership-driven operational models. In recent years, literature has started to recognise leadership as a critical element that can be used and possibly seen as a tool for shaping how organisations interpret sustainability objectives, integrate technology, and respond to complex operational demands (Ramphisa et al. 2025). This, therefore, means that leaders in mining need to look beyond the production output they can maximise today and juggle and balance short-term production pressures to ensure profitability, while ensuring that environmental and social obligations are not trampled upon.

Even though a growing body of research acknowledges the importance of leadership in sustainability and innovation, leadership behaviour is seldom positioned as a core component of operational sustainability models in mining. Most of the existing frameworks tend to focus on systems, indicators, or governance mechanisms while treating leadership as an enabling background condition rather than an active operational driver. This study addresses this gap by advancing a leadership-driven conceptualisation of sustainable mining operations, with a focus on a ‘systems-thinking’ model.

1.1 Objectives

The main problem that propelled this study was the lack of an operational sustainability model for the South African mining industry that carefully integrates leadership behaviour as a primary mechanism shaping sustainable outcomes. McLaggan et al. (2013) noted that “the need for inspired leadership is nowhere more evident than in this dynamic context of stakeholders, including employees, shareholders, politicians and academics”. This was seen with the recent closure of mines and their operations, to which Mosiane (2008) noted that “Highveld Steel and Vanadium Corporation” was one of the world's former primary steel producers, which has since closed down and shut its doors, and further noting in media releases the closure of many more mines and their operations in period 2024-2026.

In essence, this can be attributed to the lack of an operational model that is/was agile and suitable for the present time, and further confirmed by Uys and Webber-Youngman (2020) when they noted that the mining industry needs “a new kind of leaders as certain leadership styles currently employed in South Africa are not sustainable”. While sustainability assessment frameworks and operational models are widely applied, they often fail to capture how leadership behaviour influences systems integration, technology uptake, and adaptive capacity under conditions of uncertainty (Farahdel et al. 2024).

This study's aim and objective are to understand how leadership, with a focus on leadership behaviour, leadership theories and styles, and leadership agility, can enable a sustainable operational model within the South African mining industry and its operations. The study further seeks to develop a conceptual framework that positions leadership as a key input within a systems-based operational sustainability model, following the Input-Process-Output (IPO) model.

2. Literature Review

The purpose of this literature review is to critically examine, in detail, existing operational management models, sustainability, and leadership within the mining industry in a South African context. Indeed, mining operations are increasingly affected by economic, environmental, technological, and social pressures, as well as the need to be sustainable. To contextualise and detail further, South Africa's mining industry contributed roughly 6% of nominal gross domestic product (GDP) in the first three quarters of 2024, yet the sector shed 12 877 formal jobs during that year, amid sustained low commodity prices (Minerals Council South Africa 2025). This, in turn, presents a challenge that forces mining operations to review their traditional operations management models and frameworks. The

literature also examines the growing hypothesis that sustainability in mining is not achieved solely through isolated technical or managerial interventions, but through the interconnectedness of systems, behaviours, and evolving institutional constraints (Hamann 2003; Department of Minerals and Energy 2009).

This literature review acknowledges that one cannot treat sustainability, operations, and leadership as silos, or rather treat them separately, but takes an integrative perspective that views leadership, behaviours, traits, skills, etc., as a linking mechanism between operational structures and models and sustainability outcomes. Most of the existing studies on sustainability assessment, business model innovation, and technology adoption in mining highlight persistent gaps between strategic intent and operational practice, often attributed to limited adaptive capacity and weak behavioural alignment within organisations (Farahdel et al. 2024; Mokganya et al. 2024; Duh et al. 2026). By synthesising these strands of literature, the review establishes the theoretical basis for a leadership-driven operational sustainability model grounded in systems thinking.

2.1 Sustainability in the South African Mining Industry

Sustainability in mining has evolved from a narrow emphasis on environmental compliance towards a broader integration of economic viability, social responsibility, and environmental stewardship. In South Africa, this evolution is closely linked to historical inequalities, community development expectations based on history, and regulatory frameworks governing mineral extraction (Department of Minerals and Energy 2009). Mining operations are increasingly evaluated not only on production outcomes, but also on their contribution to local development and environmental protection. Thus, the “quest for sustainability is already beginning to transform the competitive landscape, which will force companies to change how they think about products, technologies, processes, and business models (Longoni and Cagliano 2009).

The literature highlights that sustainability challenges in mining are interconnected rather than discrete. Environmental degradation, community opposition, and operational inefficiencies often emerge from the same underlying systemic conditions (Hamann 2003). As a result, sustainable mining requires coordinated decision-making across organisational levels rather than isolated technical interventions. Essentially, organisations will need to develop operational strategies to efficiently optimise their resources and build a model for sustainable operational decision-making to ensure they operate effectively and competitively now and in the future (Chikwanda 2020).

2.2 Operational Models and Sustainability

The available operational models within the mining industry have traditionally been structured around efficiency, productivity, and cost optimisation, to which Wilder (2023) noted that “effective leadership is necessary as it manages cost, improves efficiencies, addresses environmental concerns, achieves company goals, and navigates the industry challenges. These models are grounded in engineering logic, in which throughput, unit costs, and equipment utilisation are used to measure performance, and, in addition, McLaggan et al. (2013) note organisations as social systems in which human resources are important contributors to effectiveness and efficiency. While such models have supported large-scale extraction under relatively stable conditions, the literature indicates that they offer limited capacity to respond to sustainability pressures that extend beyond production efficiency. This means that, in a dynamic mining world and in the face of factors beyond one's control, such as pricing, changes in the global economic order, and political stability, as we see currently with the USA government's tariff imposition, these models would not work and would be very unsustainable. In the South African mining context, this limitation is evident in the decoupling of operational success from social legitimacy and environmental resilience, leading to persistent conflict with communities and regulators (Hamann 2003).

In response to these shortcomings, sustainability-oriented operational models have emerged that seek to integrate environmental and social considerations into operational decision-making. These models often draw on sustainability assessment frameworks and triple-bottom-line principles, incorporating indicators of environmental impact, safety, and community outcomes alongside financial performance (Farahdel et al. 2024). This sentiment was shared by Uys and Webber-Youngman (2020), who noted that Many mining operations were driven primarily by the goal of maximising profit, often with little consideration for human life, worker safety, environmental impact, the company's social responsibility, or the interests of other stakeholders. While such frameworks improve visibility into sustainability performance, the literature suggests they often remain compliance-driven and indicator-focused. As a result, they provide limited guidance on how organisations adapt operationally when sustainability objectives conflict with short-term production demands or when operational conditions change rapidly.

Recent research in the mining sector highlights that operational sustainability is increasingly influenced by organisational capabilities rather than formal models alone. It can be noted that in the past, mining operations were mainly managed using a top-down leadership approach, often referred to as the “management knows best” style (Uys and Webber-Youngman, 2020). Recently, there has also been a growing emphasis on transforming managerial practices that need to align with more inclusive and responsible leadership, with a heightened focus on employee health and safety, environmental stewardship, the well-being of host communities, and the active engagement of all relevant stakeholders.

Studies on sustainable business model innovation demonstrate that the effectiveness of sustainability-oriented operations depends on organisations' ability to reconfigure processes, competencies, and decision-making structures over time (Duh et al. 2026). This perspective shifts attention from static operational designs toward adaptive operational capacity. It underscores the important distinction between traditional "managers," who focused primarily on control and output, and modern "leaders," who are expected to inspire, engage, and adapt. In this regard, operational models are not self-executing; they require ongoing iterations, interpretation, prioritisation, and reinforcement within the organisational context, meaning that there needs to be a consideration of a holistic approach to the value chain and an undertaking of how maximised benefits can be achieved for the workers, the community, the business (all stakeholders), and the country's economy to a large extent.

The introduction of digital technologies, working hand in hand with the Fourth Industrial Revolution, has further exposed limitations in conventional operational models. Technologies such as automation, real-time monitoring, and data analytics introduce new dependencies and collaborations between technical systems and human decision-making. Research in the South African mining industry indicates that technology-driven operational models often fail when leadership attention is directed solely to technical deployment rather than to organisational integration (Mokganya et al., 2024). From this, it may be inferred that sustainability-focused operational models must account for behavioural and cultural dimensions, particularly when technological change alters work practices, risk profiles, and accountability structures.

From a sustainability perspective, the literature is increasingly recognising mining operations as complex socio-technical systems rather than straight-lined production chains. It has been seen that policy frameworks governing the South African minerals sector reflect this shift by emphasising integrated decision-making across economic, environmental, and social domains (Department of Minerals and Energy, 2009). Essentially, operational models that are not aligned with this interdependence tend not to emphasise and recognise the correct responsibilities across functions, weakening accountability and limiting learning. In contrast, models that recognise systemic interactions create space for adaptive responses to sustainability challenges when leadership can coordinate and align interactions.

The literature indicates that operational sustainability in mining cannot be achieved solely through the operation of prescriptive operational models or performance metrics. However, rather than operational models providing structural guidance, their effectiveness depends on how they are introduced, operated, adapted, and sustained within organisational systems. Critically, this shows that there is a critical gap in existing operational sustainability frameworks, noting that leadership and its associated interactions are properly positioned in theory and literature as a means of translating operational models into sustained practice. To address this gap, operational sustainability needs to be reconsidered and framed as an outcome of a system-level interaction, supported and aligned by leadership-driven interpretation and integration.

2.3 Leadership and Ambidexterity in Mining

The mining sector indeed works within highly complex environments characterised by environmental sensitivity, market volatility, regulatory obligations, and technological evolution. Effective leadership is essential for daily operations, navigating strategic shifts, and advancing long-term sustainability imperatives (Schlosser et al., 2023; Singh, 2024). Thus, leadership research in mining increasingly points to the inadequacy of traditional hierarchical leadership approaches in complex operational environments. It can be argued that traditional management techniques often fail to address these multifaceted challenges, necessitating a leadership model that integrates sustainability, digital adaptation, and people-centred innovation.

Leaders and managers are different to an extent. Leadership by its nature is future-oriented, people-centred, and strategic, whereas management is present-focused and task-oriented (Rosing & Zacher, 2022). Managers within

mining operations are primarily expected to maintain compliance with safety regulations, monitor outputs, and control production schedules. Conversely, leaders envision long-term improvements in productivity, community impact, and environmental performance (Singh, 2024). Further, leaders would be expected to leverage data-driven decision-making, artificial intelligence (AI), and process automation to enhance efficiency, promote inclusive growth, and ensure environmental accountability (He & Wong, 2004). However, it is important to understand that every organisation needs both managers and leaders, and that their roles should be viewed as complementary (Moh, 2017). Li (2016) also agreed, noting that “leadership and management are the two sides of one thing that are dynamic and complementary”. As such, mining companies need to integrate robust managerial processes and visionary leadership to thrive in digital complexity and stakeholder-driven governance.

Khan et al. (2016) noted that “leadership theories have been refined and modified with the passing of time, and none of the theories is completely irrelevant. Uys and Webber-Youngman (2020) noted that “although these theories have contributed immensely to the understanding and development of leadership, they have also led to conventional thinking about leadership in a conventional world mindset. Udin (2024) noted that “several theories of leadership have been developed over the years, each offering a different perspective on what makes an effective leader”. “Transformational leaders inspire and motivate employees to go beyond their formal role as a manager who is reciprocating the leader’s positive influence. Udin (2024) noted that situational leadership theory emphasises that effective leaders adjust and adapt their leadership styles based on how their followers (Udin 2024). Interestingly, Bezuidenhout and Schultz (2013) concluded that “an increased need for transformational leadership at times of uncertainty” was best suited. South African mining industry, which is very volatile with continuous labour unrest, industrial actions and further increasing pressure to remain globally competitive as noted by Bezuidenhout and Schultz (2013), transformational leadership theory is key in this respect as there would be an expectation of the leaders to influence employees in a way that will get them to own and share the common goals to achieve the organisation's vision and mission.

In summary, the literature indicates that transformational leadership has worked hand in hand with innovation and workforce engagement, while transactional leadership supports consistency and control. And not any of the approaches alone is sufficient to address sustainability challenges that require both stability and change (Uys and Webber-Youngman 2019). Uys and Webber-Youngman (2020) noted that the current leadership theories are mostly two-dimensional and, as such, a “new leadership postulation is therefore needed.”

As such, the Ambidextrous leadership theory can serve as a helpful lens for understanding the demands of leadership in mining. Ambidextrous leadership is the capacity to look at innovations while simultaneously exploiting existing competencies. Leaders who demonstrate ambidexterity are particularly effective in transitioning outdated systems to newer, more efficient technologies without disrupting continuity (Rosing and Zacher 2022). As also confirmed by Mokganya et al. (2024), ambidextrous leaders can balance the exploitation of existing capabilities with the exploration of new opportunities, enabling organisations to maintain operational reliability while adapting to technological and environmental change. Studies within the South African mining sector show that ambidexterious leaders who demonstrate adaptability, ethical judgement, and stakeholder awareness are better positioned to manage sustainability pressures (Ramphisa et al. 2025).

Ambidextrous leaders balance centralisation (for control and compliance) with decentralisation (for innovation and speed), allowing lower-level employees to experiment and propose technology-based solutions to everyday challenges. This leadership style closely aligns with the Leadership-Based Sustainable Operations Management Model (LBSOMM), which seeks sustainable outcomes through continuous innovation and operational resiliency. Operating mine leadership teams must balance piloting new technologies, such as mining, with maintaining strict safety protocols, permit compliance, and cost discipline, while making no compromise on maintenance. The IPO model provides a structured lens for studying how that balance unfolds at the mine shaft, operational site and corporate levels. Table 1 below shows the different leadership behaviours in terms of technology management and sustainability orientation.

Table 1. Leadership styles versus the technology and sustainability factors

Leadership Style	Technology Management Focus	Sustainability Orientation
Traditional Command & Control	Manual oversight, low-tech processes	Limited integration of ESG
Transactional Leadership	Basic automation, KPI-driven tech upgrades	Reactive sustainability
Transformational Leadership	Vision-led digital transformation, IoT/AI integration	Proactive ESG implementation
Ambidextrous Leadership	Balances old and new systems for agility and control	Strategic, future-focused sustainability

2.4 Leadership and Technology Adoption

The sentiment that companies and organisations to be successful and sustainable, would need to assess their technology management (TM) strategy and practice (Cetindamar et al. 2009), aligns well with the fact that “firms must learn how to deal with the reality that in today’s competitive landscape, only companies capable of meeting, if not exceeding global standards typically earn above-average returns as noted Hitt et al (Pretorius 2020). To this effect, technology is affecting all aspects of how an organisation operates, and thus, any organisation or company cannot ignore technology as it impacts everything from supply chains to customer engagement, and the advent of even more advanced technologies, such as artificial intelligence (AI) and the Internet of Things (IoT). It has been observed that many South African primary vanadium mines lag in digital maturity and require leadership that understands how to evaluate, adopt, and scale technologies that support profit and sustainability imperatives as described by Rosing & Zacher (2022). The absence of technology adoption nor incorporation into business systems may lead to failure in the future, thus rendering them unsustainable.

Technology adoption in mining is shaped by organisational interpretation and behavioural alignment rather than technical feasibility alone. Radically adopting emerging technologies to enable organisations to remain competitive and sustainable in the short and long term (Mulaudzi 2022) is key in the present dynamics and, effectively, from a leadership perspective. Leadership behaviour then becomes a key influencing factor on how new technologies are framed, how risk is managed, and how employees engage with innovative initiatives. Despite its benefits, technology adoption in South African mining is often hindered by several challenges, as listed below, which are not limited to:

- Lack of digital fluency and sustainability (PWC 2022) – rural areas are highly likely, with no connectivity
- Mid-level managers resist change due to fears of redundancy or lack of training.
- Implementing high-end technologies such as AI, blockchain, or remote sensing can be prohibitive for small and medium mining operations (Shabangu & Zungu 2023).
- Lack of funding - Initial capital requirements are high, especially for renewable energy and automation systems.
- Workforce resistance - Unions and employees may resist changes perceived as threats to job security, low employability.
- Lack and shortage of skill (Chikwanda and Mulaudzi 2023): There is a limited supply of tech-aware professionals in the mining sector.

These barriers highlight the critical role and the required calibre of leadership, which is not merely to introduce technology but to manage cultural transformation. Leaders must invest in training, communicate the long-term value of innovation, and design inclusive implementation strategies that align with workforce realities. Effectively, leaders would need to navigate the challenges of digitisation, the innovation process, innovation actors, service sustainability, and a significant paradigm shift. Existing technology adoption models understate this behavioural dimension, focusing mainly on individual acceptance rather than leadership-driven organisational readiness (Mokganya et al. 2024).

Most qualitative studies of mining leadership indicate that supportive leadership behaviours, open communication, and learning-oriented cultures are critical to effective technology integration and adoption. In contrast, misaligned leadership approaches often result in partial adoption and unrealised sustainability benefits (Castle and Bornman 2024). Leadership determines the direction, pace, and ethics of technology adoption in this context, through vision, commitment, and strategic guidance. In simpler terms, the challenge for these leaders will also be to find a balance

between protecting the existing jobs and also investing in technologies that will impact headcount in mining organisations

2.5 Leadership and Digital Transformation

Digital transformation (DT) has emerged as a pervasive force in today's rapidly evolving world, touching almost every sector and industry (Gkrimpizi et al. 2024). In the mining context, digital transformation refers to the integration of data-driven technologies across the value chain, from exploration and extraction through processing, logistics and trading, as noted by (CSIR 2023; Chandrahas et al. 2025). The CSIR (2023) further found that major data-driven decision-making platforms are expected to mature between 2025 and 2027. At that point, they will challenge established assumptions about how mining operations are designed and managed. This was further emphasised by Chandrahas (2025), who noted that digital transformation in mining is essential for operational optimisation, safety enhancement, and productivity improvement.

Cost leadership, efficiency and profitability remain the primary concerns of mining chief executives, with long-term business sustainability ranked second. Leaders who want to utilise the digital transformation agenda need to pair technology investment with reskilling programmes, community transition plans, and transparent engagement with labour unions. Part of their challenge is the contestation of digital transformation, where automation and artificial intelligence reduce exposure to falls of ground, seismic activity predictions and dust, which aligns with the sector's safety mandate, as per the Mine Health and Safety Act (MHSA). On the other hand, each automated function can displace semi-skilled workers in communities already under economic pressure, as noted by Mining Review Africa (2024).

3. Methods

This study uses a qualitative research design grounded in an interpretivist philosophical orientation. The interpretivist stance is appropriate given the study's focus on leadership behaviour, organisational meaning-making, and sustainability within complex operational environments. Sustainability challenges in mining stem from leadership decisions, institutional expectations, and stakeholder interactions, making them unsuitable for reductionist or purely positivist inquiry. Qualitative design enables deeper engagement with these contextual and behavioural dimensions, which are central to understanding how sustainable operational models emerge in practice.

The proposed study takes an exploratory stance and is a theory-building endeavour. Rather than testing predefined hypotheses, it seeks to synthesise existing knowledge to develop a conceptual model that advances understanding of leadership-driven sustainable operations in the South African mining industry. This approach aligns with prior qualitative research in mining leadership and sustainability, which emphasises depth, context, and interpretive insight over statistical generalisation (Ramphisa et al. 2025; Castle and Bornman 2024).

4. Data Collection

The research draws on secondary qualitative data sourced from peer-reviewed journal articles, policy documents, and authoritative industry-focused academic publications. These sources were selected for their rich conceptual and empirical insights into leadership behaviour, operational sustainability, technology adoption, and systems integration in mining contexts. Emphasis was placed on literature addressing the South African mining industry to ensure contextual relevance and analytical coherence.

Policy documents governing sustainable development in the South African minerals sector were included to ground the analysis within the institutional and regulatory environment shaping mining operations (Department of Minerals and Energy, 2009). In addition, empirical qualitative studies on mining leadership and sustainability were incorporated to capture leadership behaviours, challenges, and practices observed within operational settings (Ramphisa et al. 2025; Mokganya et al. 2024). Conceptual and review-based studies were used to frame sustainability assessment and business model innovation from a systems perspective (Farahdel et al. 2024; Duh et al. 2026).

4.1 Data Analysis Technique

A structured thematic analysis was employed to analyse the selected literature. Thematic analysis was chosen for its suitability in identifying recurring patterns, relationships, and conceptual linkages across diverse qualitative sources. The study focused on extracting themes related to leadership behaviour, operational processes, sustainability

outcomes, and system-level interactions within mining operations. The analytical processes involved examining literature themes, focusing on the dominant conceptual positions on operational models and sustainability, and exploring leadership-related constructs such as ambidexterity, adaptability, and systems. Further, the relationship between sustainability and leadership was then examined and detailed. These themes informed the development of the leadership-driven Input–Process–Output conceptual model.

4.2 Conceptual Model Development Procedure

The conceptual model was developed inductively by synthesising the analysed literature and systems thinking, and the Input–Process–Output framework provided the organising structure for the model, positioning leadership as an enabling input that shapes operational processes and sustainability outcomes, which form a feedback loop. This approach reflects established practice in conceptual and theory-building research, where models are developed to clarify relationships, guide future empirical inquiry, and address gaps in existing frameworks.

Leadership, as identified in the literature, was mapped onto operational processes, such as technology adoption, stakeholder engagement, and decision-making, to illustrate how sustainability outcomes emerge through system interactions. The model reflects both stability-oriented and change-oriented leadership demands, drawing on ambidextrous leadership theory as articulated in mining-specific research (Uys & Webber-Youngman 2019; Mokganya et al. 2024).

5. Results and Discussion

5.1 Conceptual Model Development

In resource-intensive industries such as mining, the absence of a present leadership operating model often results in fragmented and delayed decision-making, poor change management, and operational stagnation (Movahedi et al. 2022). It has been seen that global mining and operations leaders in this sector, such as Rio Tinto and BHP, have adopted formalised leadership operations models to drive innovation, streamline governance, and embed sustainability into day-to-day operations. These models often include leadership development pipelines, scenario planning, digital dashboards, and systems-thinking approaches to resilience.

Building on systems thinking, this study proposes a leadership-driven model of sustainable operations management structured around the Input–Process–Output (IPO) framework, which is well established and can be used globally to understand team effectiveness, leadership dynamics, and organisational performance. In their paper, Claassen (2016) noted that “mechanistic vs systemic evaluations can lead to conclusions that a systemic flow-based approach better serves complex, ever-changing mining systems”. The proposed model will include a feedback loop from the output back to the input, indicating a sustainability loop. The conceptual model will be based on the Input-Process-Output-Feedback (IPO-FBL) model.

Inputs refer to the antecedent conditions that shape the behaviour of mining teams and operations. These include leadership capability, digital infrastructure, safety culture, and organisational structure (Rosing & Zacher 2022). Leadership should be seen as the main constituent of the primary input shaping operational dynamics and sustainability performance. Within the proposed model, leadership is conceptualised as a dynamic system input rather than a static managerial role.

Empirical research in the mining sector demonstrates that leadership shapes how sustainability priorities are interpreted, how operational trade-offs are negotiated, and how organisations respond to uncertainty and technological disruption (Ramphisa et al. 2025).

Zooming in on leadership inputs, some of which include ambidextrous capability, ethical orientation, adaptability, and systems awareness. These inputs influence operational processes, which in the IPO model denote the mechanisms by which inputs are converted into outputs. Leadership plays a central role in coordinating these mechanisms, whether through decision-making, feedback loops, empowerment, or alignment of team objectives. Effective leadership processes involve clear goal setting, strategic decision-making, technology adoption, stakeholder engagement, and organisational learning.

The system's outputs are reflected in sustained operational performance, resilience, and long-term value creation. Outputs refer to the measurable consequences of leadership-driven processes within the system. In the mining

environment, important outputs would include safety records, throughput metrics, employee retention, energy consumption rates, and community impact assessments (Ali & Nouban 2024).

By embedding leadership within a systems-based framework, the model addresses limitations working hand in hand with static operational approaches and reflects the adaptive demands placed on South African mining organisations. The adoption of an Input–Process–Output- feedback Loop logic is consistent with systems-based perspectives in the operations and sustainability literature, in which organisational outcomes are understood as the result of interactions among social, technical, and institutional elements rather than isolated managerial actions. In the mining industry, this perspective is particularly appropriate given the interdependence between production systems, environmental constraints, regulatory oversight, and community relations.

Studies on sustainability assessment frameworks indicate that operational failures are common when these elements are treated as discrete or silo components rather than as part of an evolving, integrated system (Farahdel et al. 2024). Within the South African mining context, this fragmentation has been linked to persistent sustainability challenges, including weak alignment between policy intent and operational execution (Department of Minerals and Energy 2009).

This model is particularly relevant in mining operations where leaders must balance production continuity with innovation, safety, and long-term resource stewardship (Uys and Webber-Youngman 2019; Mokganya et al. 2024). By carefully linking leadership inputs to operational processes and sustainability outcomes, the model addresses gaps identified in existing operational and sustainability frameworks, which often understate behavioural agency in favour of structural or indicator-based controls (Hamann 2003; Duh et al. 2026).

5.2 Validation

Methodological rigour was addressed through credibility, dependability, and confirmability. Credibility was supported through reliance on peer-reviewed academic sources and established policy documents relevant to the South African mining sector. Dependability was enhanced by applying a transparent and systematic approach to literature selection and thematic analysis. Confirmability was achieved through theoretical triangulation across leadership, sustainability, operational, and systems-based literature, reducing reliance on any single theoretical lens. The resulting framework provides a very solid foundation for future empirical research, including qualitative case studies or interview-based investigations with mining leaders and operational teams.

6. Conclusion

This study advances a leadership-driven conceptualisation of sustainable operations in the South African mining industry. The analysis demonstrates that sustainability outcomes are shaped not only by technical systems and governance frameworks, but also by leadership attributes and behaviours, such as clear goal setting, conflict resolution, real-time communication, Innovation enablement, and distributed decision-making that facilitate integration across operational, social, and environmental domains.

By positioning leadership as the main operational input within a systems-based framework, the study addresses gaps in the existing sustainability and operations literature. The proposed model highlights the importance of ambidextrous capability, ethical judgement, adaptability, and systems awareness in sustaining mining operations under conditions of uncertainty and technological change.

From a practical perspective, the model provides guidance on leadership development and organisational design for mining firms seeking to strengthen their sustainability performance. Further research is underway to delve deeper into and break down the proposed framework, using qualitative case studies and in-depth interviews with mining leaders and operational personnel.

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Biography

Caleb Wisdom Mulaudzi is a qualified metallurgical engineer with a strong foundation in pyrometallurgical processing operations and production management. He graduated from the University of the Witwatersrand (Wits), where he earned recognition for academic excellence, including being placed on the Dean's List of the Faculty of Engineering and the Built Environment in 2013, ranking him in the top 10% of students in the faculty. He further

completed his master's in engineering management (MEM) at the University of Pretoria (UP) in 2022, where he developed a high research interest in sustainable leadership and management practices, particularly in the mining Industry. Caleb Mulaudzi has gained valuable hands-on experience in the vanadium and chrome processing industry, where he has held key operational roles and was appointed as general manager. He excels at optimising production processes, maintaining quality and stability, and leading cross-functional teams to meet targets safely and efficiently. Proficient in advanced simulation tools, he combines technical expertise with effective collaboration across all levels of the organisation. Committed to continuous improvement and knowledge sharing through co-supervision of honours and master's students, who deal with real industry problems.

Hilda Kundai Chikwanda is a distinguished Professor of Engineering Technology Management with over 35 years of experience in metallurgical engineering and operations management. Complemented by an MBA, her expertise spans both the technical and business aspects of the field. Professor Chikwanda has dedicated her career to advancing production efficiencies and fostering innovative practices in academic and industrial settings. She earned her PhD in Engineering and her MBA from leading institutions, equipping her with a unique blend of technical insight and managerial acumen. This dual expertise enables her to seamlessly bridge cutting-edge research with real-world applications, preparing her students to navigate the complexities of modern engineering challenges.