A development roadmap for the digitalisation of mining focusing on the impact of smart wearables on occupational health and safety

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This paper presents a roadmap for adopting smart wearable technologies to enhance occupational health and safety (OHS) in South Africa's gold and platinum mining sectors. Conducted under the Real-Time Information Management System programme of the Mandela Mining Precinct, the research explores the role of smart wearables in advancing real-time safety monitoring and hazard detection. Despite the global uptake across industries such as healthcare and construction, adoption in South African mining remains limited due to regulatory, technological, and workforce-related challenges. Using literature review and stakeholder interviews across government, industry, trade unions, and academia, the paper identifies key barriers and enablers. The resulting roadmap is structured around three pillars: technological advancement, digital and OHS maturity, and policy and regulation. Recommendations include the establishment of a digital innovation hub, co-designed pilot programmes, and regulatory updates. This roadmap supports a just, inclusive, and ethical transition toward zero-harm mining through the effective integration of smart wearables.

Keywords: digitalisation, smart wearables, development roadmap, mining

INTRODUCTION

South Africa's mining sector is undergoing a digital evolution aimed at aligning with the Fourth Industrial Revolution. This transformation focuses not only on increasing productivity and operational efficiency, but also on improving occupational health and safety (OHS). Among the technologies driving this change, smart wearables have emerged as a crucial innovation, offering real-time data collection and monitoring that support the zero-harm objective of the mining industry (Mardonova & Choi, 2018; Atif *et al*., 2020).

The mining industry remains one of South Africa's most critical economic sectors, contributing significantly to GDP, employment, and foreign exchange earnings. As of 2023, the sector included over 500 mines producing a wide array of minerals, notably gold, platinum, and coal (Africa Mining IQ, 2024). However, the sector continues to face numerous challenges including fluctuating commodity prices, rising operational costs, environmental sustainability mandates, and—most significantly—persistent health and safety incidents (PwC, 2023).

Occupational injuries and fatalities, especially from fall-of-ground events and transportation incidents, continue to occur despite longstanding regulatory frameworks and collaborative safety initiatives. Mineworkers also face a triple burden of disease, encompassing occupational illnesses, communicable diseases such as tuberculosis and HIV, and non-communicable conditions exacerbated by harsh working environments (Coulson & Christofides, 2020).

These complex health risks necessitate proactive, data-driven safety and health systems that go beyond traditional protective equipment and reactive measures.

Digital technologies have already started transforming mining globally. In South Africa, efforts to digitalise mining operations have led to innovations in autonomous vehicles, real-time environmental monitoring, and smart control centres (Shimaponda-Nawa & Nwaila, 2024). Smart wearables—digital devices integrated into helmets, vests, boots, and face masks—represent a growing frontier of this transformation. These devices can monitor biometrics such as heart rate and fatigue, environmental parameters like gas concentrations, and worker location, enabling predictive and real-time responses to hazardous situations (Hanuska *et al.*, 2016; Slater, 2017).

Despite the demonstrated benefits and successful pilots, the adoption of smart wearables remains slow in South African mines. This is attributed to a variety of interlinked challenges, including inadequate underground connectivity, lack of standardised performance benchmarks, low digital literacy among workers, and concerns over privacy and surveillance (Ndlovu *et al.*, 2022; Jacobs, 2017; Ruotsalainen & Blobel, 2020). Resistance from trade unions and workers also reflects broader apprehension about job security, technological exclusion, and ethical oversight in a rapidly digitising industry (Hlatshwayo, 2017). Table 1 depicts the awareness and utilisation of smart wearable devices. In addition, Table 1 showcases the research findings obtained through the outlined methodology.

Table 1. Application of smart wearables in the South African mining industry

Wearable Type	Use cases/applications	Stakeholder knowledge and awareness	Evidence of pilot testing and/or adoption of SA gold/platinum mining
• **Smart helmet** • **Smart headband**	- Fatigue monitoring - Hazardous gases detection - Humidity measurement - Temperature measurement	Highly aware and knowledgeable of the applications for OHS.	Yes, research and pilot testing for fatigue in a gold mine operation.
• **Smart watches** • **Fitness trackers**	- Activity tracker - Fitness tracker - Heart rate monitor - Navigation - Physiological wellness - Temperature measurement	Highly aware and knowledgeable of the applications for OHS.	Yes, research and pilot testing for fatigue in a gold mine operation.
• **Smart glasses** • **VR glasses** • **VR headsets**	- Barcode scanners - Location mapping - Instant immersion into other environments - Simulation-based training	Highly aware and moderately knowledgeable about some OHS applications.	Yes, research, training and pilot testing in a gold mine operation.

• **Smart face mask and shield**	- Biosensors - Infection mitigator	Highly aware and moderately knowledgeable about some OHS applications.	There is no evidence of a smart face mask and shield with embedded biosensor.
• **Safety vests** • **Smart shoes**	- Body position tracking - Heart rate monitor - Illumination - Mobility Monitoring - Proximity detection - Temperature measurement	Yes, moderately aware and limited familiarity with applications for OHS.	Yes, it is currently in the research phase.
• **Wearable camera**	- Environment monitoring - Real-time photo and video capture	Highly aware and knowledgeable of the applications for OHS.	Yes, it is currently in the research phase
• **Smart jackets** • **Smart rings**	- Temperature measurement - Body movements	Yes, low awareness and limited familiarity with applications for OHS.	No evidence was reported.
• **Industrial exoskeleton**	- Physical support	Yes, moderately aware and limited familiarity of applications for OHS.	Yes, is currently in pilot testing.

In addition, while the global mining industry increasingly integrates wearable technologies into safety systems, South African personal protective equipment guidelines have yet to formally incorporate such innovations, revealing a regulatory lag (Department of Mineral Resources and Energy, 2023). As such, there is a growing urgency to build a robust roadmap for adoption that aligns technical development with regulatory support and inclusive stakeholder engagement.

Parallel to the mining industry, smart wearables have emerged as a transformative tool in industries with high-risk environments analogous to mining—such as construction, oil and gas, and heavy manufacturing—where workers routinely face hazards including extreme temperatures, noise, exposure to gases, repetitive physical strain, and isolated conditions. These devices typically include biometric sensors, GPS trackers, smart helmets, fatigue monitoring headbands, and environmental detectors, all designed to collect real-time physiological and situational data. Their integration into industrial safety protocols allows for continuous monitoring of vital signs (e.g., heart rate, body temperature), worker location, posture, and exposure to hazardous elements like toxic gases or radiation. This real-time feedback enables supervisors and OHS personnel to intervene proactively, preventing accidents before they occur and ensuring a rapid response to emergencies (Sawhney *et al.*, 2020; Shin *et al.*, 2019).

In the construction sector, smart wearables have demonstrated measurable safety benefits. For instance, smart helmets with embedded inertial sensors have been used to detect falls and alert supervisors instantly, while smart vests equipped with vibration sensors warn workers of dangerous machinery proximity. These tools have contributed to significant reductions in workplace injuries and improved worker situational awareness (Sawhney *et al*., 2020). Similarly, in the oil and gas industry, smart wearables are used to detect the presence of hydrogen sulphide and other harmful gases. Devices can be integrated with wireless networks to provide centralised dashboards that track workforce health and safety metrics across large, remote worksites, enabling both on-site and off-site safety oversight (Shin *et al*., 2019).

In manufacturing, smart glasses and wristbands are commonly used to monitor fatigue and stress levels, which are critical in preventing cognitive overload in machine-intensive environments. These devices provide subtle alerts to the worker and management when fatigue thresholds are exceeded, allowing rest breaks to be scheduled more effectively. Moreover, integrating wearable data with enterprise systems enables predictive maintenance and reduces unscheduled downtime by identifying patterns linked to worker strain or unsafe behaviours (Wang *et al.,* 2021).

Beyond individual worker safety, smart wearables contribute to organisational benefits such as reducing insurance claims, improving regulatory compliance, and lowering compensation payouts. Data collected from wearables also feed into data analytics platforms, enabling the identification of trends, high-risk tasks, or times of day when incidents are more likely to occur. This fosters a data-driven safety culture, where interventions can be designed based on evidence rather than assumptions. These technologies are especially valuable in industries undergoing digital transformation aligned with Industry 4.0, where real-time monitoring, automation, and predictive analytics are integrated into operational and safety strategies.

Given these demonstrated benefits in parallel industries, the mining sector stands to gain considerably from the adoption of smart wearable technologies. Mining operations can replicate these safety enhancements by deploying rugged, miner-specific devices capable of operating in deep, humid, and dust-laden environments. Furthermore, by coupling wearables with underground communication networks and centralised control systems, mines can achieve real-time worker visibility, enhance emergency response capabilities, and reduce the frequency and severity of injuries—ultimately contributing to their zero-harm goals and more efficient, resilient operations.

This paper, based on research conducted under the Real-Time Information Management System (RTIMS) programme of the Mandela Mining Precinct, presents such a roadmap. Drawing on stakeholder interviews, literature analysis, and case examples, it outlines a structured path towards digital OHS transformation in South African mining. The roadmap is underpinned by three pillars: technological advancement, digital and OHS maturity, and regulatory alignment.

METHODS

The methodology comprised of a four-step approach was adopted:

1. **Literature Review**: An extensive review was conducted to understand global trends in mining digitalisation and the use of smart wearables in hazardous environments. This informed an assessment of wearable technology adoption in South Africa's gold and platinum mines and shaped the design of stakeholder interview questions.
2. **Stakeholder Engagement**: With ethical clearance from the University of the Witwatersrand (Ref. H24/10/09), eight semi-structured interviews were conducted across key stakeholder groups—government, industry, academia, and civil society (trade unions). Trade union representatives, comprising 38% of interviewees, provided valuable insights into end-user perspectives.
3. **Insights Analysis**: Data from literature, industry reports, media sources, and stakeholder interviews were thematically analysed. This process helped refine the conceptual framework and uncover key barriers to wearable technology adoption.
4. **Roadmap Development**: Insights from the analysis informed the creation of a strategic roadmap. Key enablers were mapped across the transition from traditional to modern mining

environments to support the equitable and practical adoption of smart wearables for OHS enhancement.

Although the research employed a qualitative methodology through semi-structured interviews, which provided rich, in-depth insights into stakeholder experiences and perceptions, the study could have been further strengthened by incorporating a quantitative component. Specifically, a statistical analysis of smart wearable adoption trends across the mining industry—as well as related sectors such as construction, oil and gas, and manufacturing—could have provided broader empirical evidence to support the qualitative findings. This would have enabled the researchers to identify patterns, usage rates, and performance metrics of wearable technologies, enhancing the validity and generalisability of the results.

Additionally, expanding the scope and number of stakeholder engagements could have yielded a more comprehensive representation of industry perspectives. Engaging a broader set of participants, including frontline mineworkers, technology developers, health and safety regulators, and union representatives, would have allowed for greater triangulation of data. Such diversity in viewpoints may have uncovered additional barriers, opportunities, and context-specific considerations that could inform the digitalisation roadmap with more precision. For instance, the inclusion of more female miners or contract workers could have highlighted unique ergonomic or equity challenges that may not be visible in management-level insights alone.

Ultimately, complementing the qualitative findings with quantitative data and expanded stakeholder diversity would have enriched the roadmap's design by offering a more nuanced and data-driven foundation for policy recommendations, strategic planning, and technology deployment in the adoption of smart wearables for occupational health and safety in the mining sector.

OUTPUTS

The consolidation of data from the literature review and from stakeholder engagement resulted in revisions to the underlying conceptual framework for this study (refer to Figure 1). Analysis of the research findings resulted in three overarching themes and barriers contributing to adopting smart wearables in the South African mining industry. These are 1) technological advancements related to smart wearables; 2) digital and OHS maturity; and 3) policy and regulation in the South African mining sector. The nested approach emphasises the linkages and dependencies across the three themes, which are technology advancements and smart wearables driving digital and OHS maturity. Whilst digital and OHS maturity impacts the development of policy and regulation, whereby policy and regulation strive to standardise validated technologies. Furthermore, indicating the difference between sector versus organisational implications is necessary to differentiate how the industry can evolve and what specific organisations/operations can implement. For example, from an industry perspective, the insights concluded that OHS policy and regulation will either hinder or accelerate smart wearable adoption. Similarly, innovations for smart wearables at a mine operational level catalyse industry-wide change and not vice versa. Thus, to optimise and accelerate industry-wide adoption of smart wearables it is essential to ensure that sector-wide processes proactively contribute to the adoption of technology. This study found that the biggest gap in the adoption of smart wearables is in the sector-wide response, in contrast to operational level, where there already is evidence of significant levels of interest, piloting and varying degree of technological adoption.

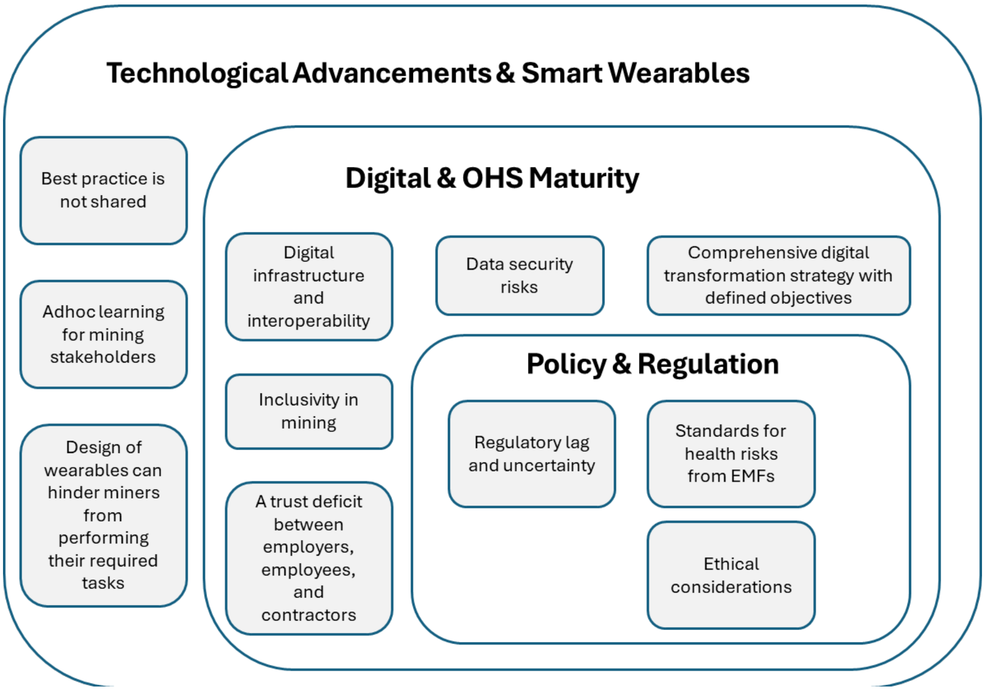

Figure 1. Conceptual framework for digitalisation in South African mining.

Figure 1 illustrates the relationship between the three overarching themes identified in this study. The study concludes that successful digitalisation involves exchanges between technological advancements, digital and OHS maturity, and policy and regulation. With regards to digitalisation in South Africa's mine sector, micro-level changes at an operational level impact the macro-level, political, and regulatory environment. Therefore, digital and OHS maturity impacts policy and regulation development, whereby policy and regulation strive to standardise validated technologies.

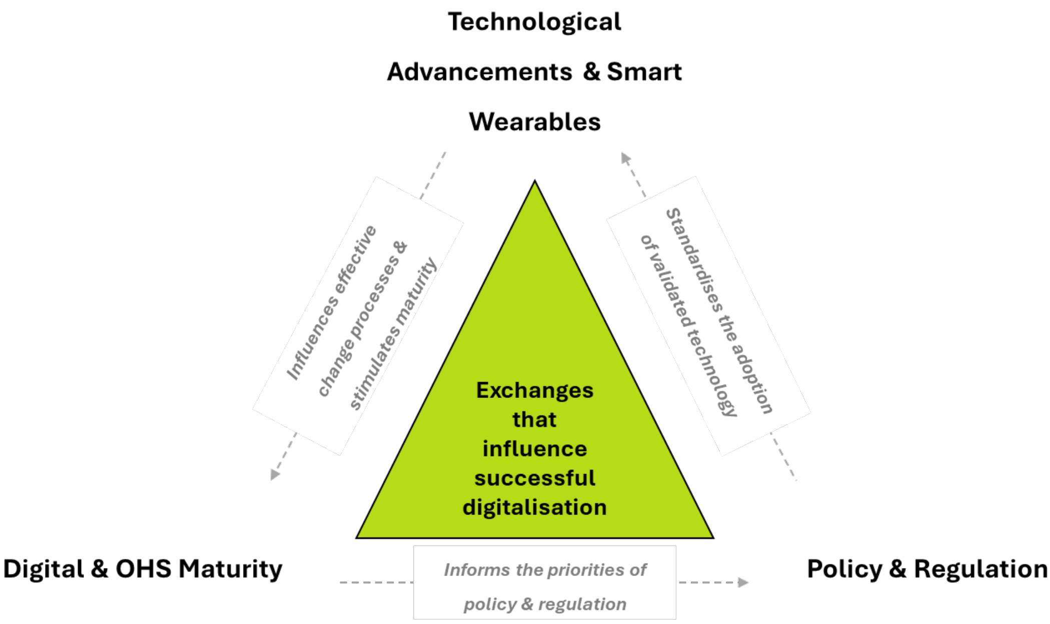

Figure 2. Linkages between digitalisation pillars.

Each pillar contains specific challenges and considerations regarding adopting digital technology, specifically smart wearables, across the South African gold and platinum mining sector. Associated with these barriers are sector-wide and organisation-wide development enablers that catalyse the adoption of technology. Table 2 below represents these various factors, which are then translated into a visual roadmap (Figure 3).

The digital transformation roadmap outlines a structured progression for integrating smart wearables for OHS impacts in South Africa's gold and platinum mining sector. It categorises the transition from traditional mining to hybrid mining and ultimately to modern mining. It focuses on three key pillars: Technological Advancements and Smart Wearables, Digital and OHS Maturity, and Policy and Regulation. The roadmap also differentiates between sector-wide initiatives that drive industry collaboration and organisation-level actions that individual mines could adopt.

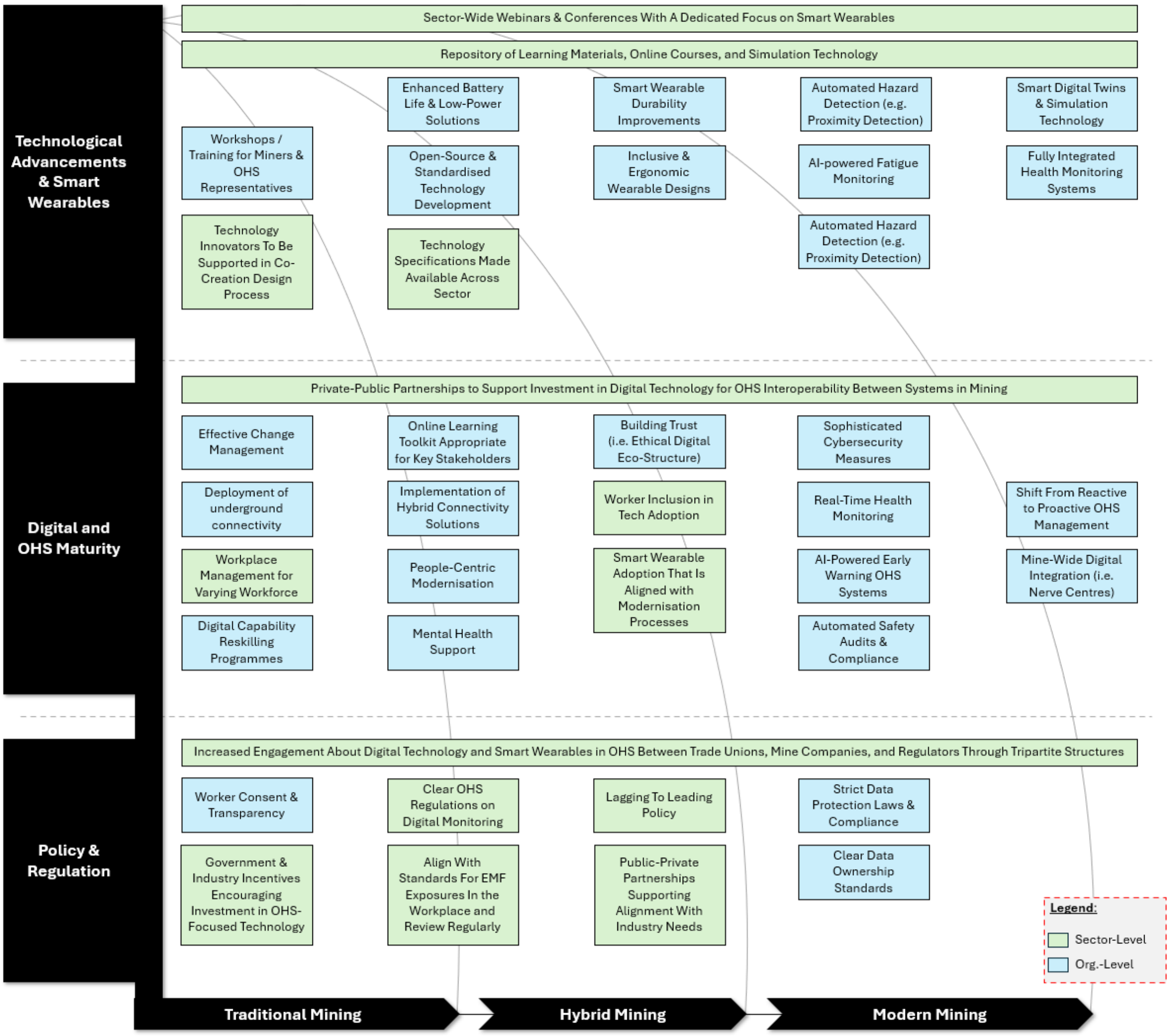

Figure 3. Digitalisation roadmap for the adoption of smart wearables to support OHS in South Africa's mining industry.

Table 1. Digitalisation and smart wearable adoption enablers

Group	Description	Barriers To Adoption	Sector-Level Adoption Enablers	Organisational-Level Adoption Enablers
Technological Advancements and Smart Wearables	The adoption of advanced wearables will facilitate a data-driven digital ecosystem, enhancing productivity and occupational health and safety while reducing human exposure to hazardous conditions. Furthermore, this refers to improvements to the reliability, accuracy, ergonomics, and user-inclusivity of smart wearable technologies.	**Best practice is not shared**	• **Sector-wide webinars and conferences** include a dedicated focus on smart wearables, the use of real-time data and AI in OHS.	• **Fully integrated health monitoring systems:** Wearables (including smart devices and textiles) could provide real-time worker health insights, allowing early intervention for fatigue, stress, and hazardous exposure. • **Automated hazard detection:** AI systems could use real-time data to predict and prevent risks, such as fatigue-related incidents, gas leaks, and seismic activity. • **AI-powered fatigue monitoring:** AI models could learn from worker behaviour, ensuring accurate fatigue detection without false positives.
		Ad hoc learning for mining stakeholders	• **Access to information:** Repository of learning materials, online courses and simulation technology available to all stakeholders. • **Access to information:** An online learning package/toolkit appropriate to all stakeholders: employers, trade unions and the regulator, including at mine operations.	• **Open-source and standardised technology development:** Developing shared platforms for wearables can reduce costs and increase accessibility. • **Smart digital twins and simulation technology:** Digital mine replicas can enable risk scenario testing and training simulations. • **Workshops/training** made available to worker representatives and mine health and safety committee.
		Design of wearables can	• **Co-creation:** Technology innovators may be	• **Smart wearable durability improvements:** Devices must

Group	Description	Barriers To Adoption	Sector-Level Adoption Enablers	Organisational-Level Adoption Enablers
		hinder miners from performing their required tasks	supported by the end users in the co-creation design process. • **Access to information:** Technology specifications can be made available across the sector, including updating guidance on PPE to support best practices.	withstand extreme underground conditions (humidity, dust, heat, vibrations). • **Enhanced battery life and low-power solutions:** Longer battery life will reduce frequent charging requirements. • **Inclusive and ergonomic designs:** Wearables should be lightweight, flexible, and adaptable for various mining environments and genders. Equipment and PPE should fit female miners, ensuring comfort and usability.
Digital and OHS Maturity	The integration of smart wearables depends on the digital readiness of mining operations, including connectivity infrastructure, workforce digital skills, ethical and privacy maturity, and automation adoption. Increasing real-time monitoring, predictive analytics, and AI-driven safety interventions will enhance OHS and operational efficiency as mines transition from traditional to modern.	**Digital infrastructure and interoperability**	• **Increase awareness:** Sector-wide webinars and conferences include dedicated focus on smart wearables, the use of real time data and AI in OHS. • **Partnerships:** Public-private partnerships to support investment in digital technology for OHS and interoperability between systems in the gold and platinum sectors.	• **Deployment of underground connectivity/networks:** This will enable real-time monitoring, data sharing, and AI-driven decision-making. • **Implementation of hybrid connectivity solutions:** RFID, LiDAR, and edge computing can process data locally, reducing dependency on constant network availability. • **Mine-wide digital integration (e.g. Nerve Centres)**: A centralised data-sharing system could allow health, safety, and production departments to collaborate more effectively. • **AI-powered early warning systems:** Wearables could be linked to predictive analytics that can prevent hazards before they occur.

Group	Description	Barriers To Adoption	Sector-Level Adoption Enablers	Organisational-Level Adoption Enablers
				newly adopted digital technologies and possible work intensification.
		Inclusivity in mining	• **Co-creation:** Technology innovators may be supported by the end user in the co-creation design process. • **Access to information:** Technology specifications to be made available across the sector, including updating guidance on PPE to support best practices.	• **Worker inclusion in technology adoption:** Miners should be actively involved in decision-making on wearable implementation including women miners.
		Comprehensive digital transformation strategy with defined objectives	• **Aligned transformation:** The adoption of smart wearables to be aligned and integrated with other modernisation processes.	• **Digital capability reskilling programs:** Training in AI, automation, and digital safety tools can help workers adapt rather than be displaced. • **Understand the user (people-centric modernisation):** Critical to adopting technology is understanding the resistance factors inhibiting technology adoption, coupled with organisational behaviour factors, which could improve the probability of a successful adoption. • **Effective change management:** Clear, comprehensive, and transparent change management strategies are needed to introduce new technology into operations successfully.

Group	Description	Barriers To Adoption	Sector-Level Adoption Enablers	Organisational-Level Adoption Enablers
				• **Shift from reactive to proactive safety management:** Mines may prioritise accident prevention over incident response.
		Data security risks	• **Access to information:** Technology specifications can be made available across the sector, including on data security. • **Cybersecurity guidance:** Policy development and guidance about ethical practice in OHS digitisation.	• **Sophisticated cybersecurity measures:** As mines adopt 4IR technology, specifically IoT, the increased reliance on data exchange raises the risk of cybersecurity threats. More advanced cybersecurity measures are needed to protect data in a significantly more digitally connected environment.
Policy and Regulation	Establishing clear regulatory frameworks and compliance standards is essential to guide the responsible adoption of smart wearables, ensuring data privacy, ethical surveillance, and workforce protection while aligning with OHS regulations and digital transformation policies in the mining sector.	**Regulatory lag**	• **Lagging to leading:** Fast-track policy that considers the implications of future technological advancements rather than reacting to what is occurring. • **Clear OHS regulations on digital monitoring:** The DMRE could provide structured guidelines on the implementation and governance of wearables	• **Data protection laws (POPIA compliance):** Strict policies must be enforced to ensure data security, ownership, and ethical use.
		Ethical considerations	• **Ethical digital-eco structure guidance:** Policy development and guidance about ethical practice in OHS digitisation.	• **Worker consent and transparency:** Employees should understand how their data is collected, used, and stored. • **Data ownership:** Certainty over who controls and accesses health-related

Group	Description	Barriers To Adoption	Sector-Level Adoption Enablers	Organisational-Level Adoption Enablers
			• Access to information: An online learning package/toolkit appropriate to all stakeholders: employers, trade unions and the regulator, including mining operations.	data. As well as how it can be used within the workplace.
		Standards for health risks from EMFs	• **Alignment and review of EMF standards:** Standards and guidance about EMF exposures in the workplace to be regularly reviewed.	
		Structured collaboration across key stakeholders	• **Increased collaboration:** Greater engagement between unions, companies, and regulators through tripartite structures regarding smart wearables and digital technology in OHS will support wearables being used for health and safety, not surveillance and work intensification. • **Government and industry incentives:** Tax breaks and funding programmes could encourage investment in OHS-focused technology. • **Public-private partnerships:**	

Group	Description	Barriers To Adoption	Sector-Level Adoption Enablers	Organisational-Level Adoption Enablers
			Collaboration between government agencies, technology providers, and mining companies can drive cost-effective innovation.	

Technology Advancements and Smart Wearables
The first pillar highlights developing and deploying wearable technologies, AI-driven monitoring, and training to enhance worker safety. In traditional mining, the absence of standardised smart wearables and real-time monitoring systems limits safety capabilities. At this stage, the focus is on training miners and OHS representatives, developing open-source technology standards, and encouraging collaboration between technology innovators and mining operators to design wearables suited for traditional mining environments.

As the industry transitions to hybrid mining, key advancements include improved wearable durability, enhanced battery efficiency, and gender-inclusive ergonomic designs to ensure practical adoption. At this stage, automated hazard detection (e.g., proximity sensors) and AI-powered fatigue monitoring are introduced to mitigate workplace risks.

In modern mining, the implementation of smart digital twins and fully integrated health monitoring systems transforms OHS management. These technologies provide real-time hazard detection, predictive safety analytics, and proactive intervention mechanisms, minimising human exposure to hazardous conditions. The technological evolution in this pillar ensures that wearables and AI-driven solutions become core components of a digitally connected and safety-focused mining ecosystem.

Synonymous across mining is the facilitation and hosting of sector-wide webinars and conferences, with a dedicated focus on smart wearables, to enlighten the industry on technological developments, enhancing OHS practices while establishing a learning platform for increased collaboration across the sector.

Digital and OHS Maturity
This pillar focuses on workforce readiness and operational integration of smart safety systems. Traditional mining faces significant challenges, such as limited underground connectivity, a lack of digital workforce skills, and resistance to technology adoption. To bridge these gaps, the focus is on deploying underground connectivity, implementing workforce management strategies for diverse employment models, and initiating reskilling programmes.

In hybrid mining, people-centric modernisation and worker inclusion in technology adoption become crucial for success. Hybrid connectivity solutions (e.g., RFID, LiDAR) enable seamless real-time data transmission to enhance safety monitoring. Additionally, mental health support systems are introduced to mitigate stress related to continuous monitoring.

By the time mines reach the Modern Mining stage, sophisticated cybersecurity measures, AI-powered early warning systems, and automated safety audits are fully operational. The industry shifts from reactive OHS management to a proactive approach, where real-time monitoring and predictive analytics help prevent workplace accidents before they occur. Mine-wide digital integration (e.g. Nerve Centres) ensures seamless coordination of OHS functions across entire operations, making mining safer and more efficient.

Private-public partnerships to support investment in digital technology for OHS interoperability between mining systems are crucial to enhancing digital and OHS maturing. Enhancing collaboration and learning between the tripartite stakeholders could accelerate the adoption of technology across the South African gold and platinum mining sector.

Policy and Regulation
The third pillar addresses the regulatory evolution necessary to support smart wearable adoption and digital OHS transformation. In traditional mining, greater worker consent and transparency regarding digital monitoring are needed. Government and industry incentives are essential to encourage investment in OHS-focused technology, while standards for EMF exposure from wearables must be defined to ensure worker safety.

During the Hybrid Mining phase, regulatory frameworks evolve through public-private partnerships and structured policy alignment with industry needs. The focus is on developing clear OHS regulations for digital monitoring and transitioning from lagging policies to leading policies that actively support digitalisation.

In modern mining, strong regulatory enforcement ensures compliance with strict data protection laws, standardised data ownership guidelines, and ethical AI governance. These policies safeguard worker rights, prevent biometric data misuse, and establish ethical boundaries for digital surveillance in mining. The alignment of policy, regulation, and technology adoption ensures that digital transformation benefits both workers and employers while upholding global safety and labour standards.

This comprehensive digital roadmap ensures that mining operations evolve into technologically advanced, data-driven environments where productivity, worker safety, and regulatory compliance are seamlessly integrated. By addressing policy alignment, workforce adaptation, and technological enhancements, this transformation improves operational efficiency and prioritises worker health and safety, making the mining industry safer, more sustainable, and more progressive.

CONCLUSION AND RECOMMENDATIONS

The adoption of smart wearable technologies in South Africa’s gold and platinum mining sector presents a transformative opportunity to enhance OHS. While digitalisation has significantly improved safety monitoring and risk management globally, South Africa's adoption remains slow, hindered by connectivity, technological, regulatory, and workforce challenges. Despite a steady decline in mining fatalities, fall of ground incidents and transportation accidents remain the most significant risks. Smart wearables, including fatigue monitoring headbands, hazard detection systems, and missing person locators, could help mitigate these dangers, enhancing real-time safety monitoring and proactive risk management.

However, sector-wide adoption faces key obstacles. Limited knowledge-sharing, fragmented pilot programmes, and connectivity constraints prevent seamless digital integration. The lack of clear OHS regulations, worker trust issues, and ethical concerns surrounding surveillance further delay progress. Addressing these barriers requires a structured digitalisation roadmap, focusing on technological advancements, improved connectivity, workforce training, and regulatory alignment.

Investment in digital infrastructure, hybrid connectivity solutions, and ethical data management is critical for mining operations to achieve zero-harm targets and future-proof safety practices. Stronger collaboration between industry stakeholders, regulators, and workers will ensure a balanced, inclusive, and effective adoption of smart wearables. A worker-centric, well-regulated, and technologically advanced mining environment will improve safety and productivity and position South Africa as a leader in OHS innovation and sustainable mining practices.

The following recommendations are proposed to facilitate the adoption of smart wearables in OHS for gold and platinum mining.

Recommendation 1: An interest group/hub for digital innovation in OHS is established between the Mandela Mining Precinct (MMP), the Mine Health and Safety Council and the Mining Qualifications Authority. This hub will have a dedicated focus on adopting smart wearables and using real-time data for OHS. The hub will ensure the following activities are undertaken:

- Dissemination of best practices across mining stakeholders through dedicated webinars, conference sessions, simulations, and other learning platforms.
- The identification and scoping of a research agenda to support the development of policy related to ethical practice in adopting smart wearables and using real-time information in OHS.

- Fast-track policy development to ensure ethical practice in adopting smart wearables and using real-time information in OHS.
- Align OHS digital policy with the modernisation agenda across the sector.

Recommendation 2: Preparation of an online toolkit/learning package available to all mining stakeholders (employers, trade unions and the regulator) about advances in smart wearables, the potential for OHS and the advantages and ethical concerns about using real-time data. This can be made available at the mine operation to worker OHS representatives and mine health and safety committees.

Recommendation 3: MMP/industry to support co-creation pilots for the design and adoption of smart wearables with a focus on collaboration with end-users (miners) in each stage of the design and adoption process.

Recommendation 4: The Mine Health and Safety Council in collaboration with the Mine Health and Safety Inspectorate to regularly review, update and disseminate standards for EMF exposure in the mine workplace.

Recommendation 5: The industry should explore public-private partnerships and tax concessions with government partners to support the adoption of smart technology in OHS and digital interoperability between systems across the gold and platinum sectors.

ACKNOWLEDGEMENTS

This project was funded by the RTIMS programme of the Mandela Mining Precinct. The Mandela Mining Precinct is a public-private partnership between the Department of Science and Innovation and Minerals Council South Africa. The Precinct is jointly hosted by the Council for Scientific and Industrial Research and the Minerals Council. Furthermore, we would like to acknowledge the mining industry for their valued participation.

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