MOSH DAY OF LEARNING SCRAPER WINCHES & RAILBOUND EQUIPMENT

The current use of scraper winches and an assessment of alternatives - Research outcomes of MHSC Project CoE 210501

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science, technology & innovation

Department:
Science, Technology and Innovation
REPUBLIC OF SOUTH AFRICA

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WHY THIS PROJECT

The system is a century old, yet the risk profile remains unchanged

±5%

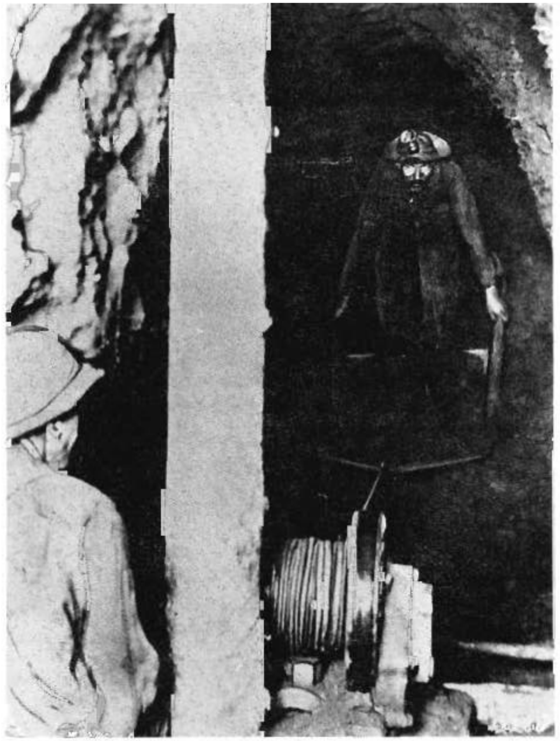
of all SAMI accidents are scraper winch-related — the same share reported by Moseme et al. in 2003 and observed again in 2023

±21%

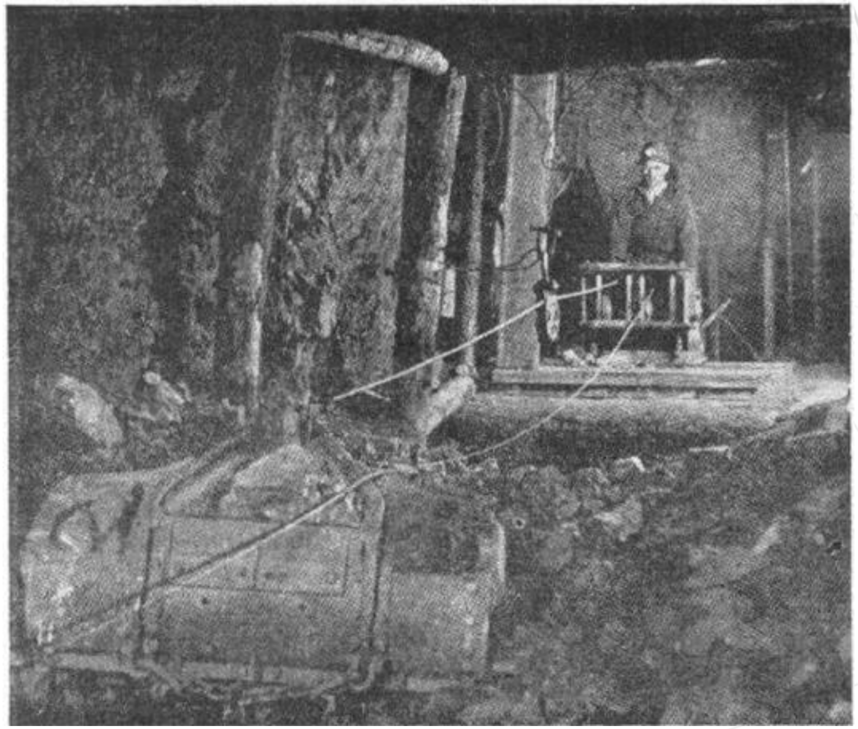
of fatalities in the Transportation & Mining category (TMM, RBE and winches), on average, between 2014 and 2023

2003 = today

the primary and secondary causes identified in 2003 remain the causes of winch accidents today



(An Iron ore mine, USA, 1916 from Rhoades, 1982)



(Montana Gold Mine, USA, 1920s from O'Brien 1951)

AIM & APPROACH

Project CoE 210501 research approach

Aim: to recommend solutions that reduce winch-related injuries and fatalities in mining operations.

WHAT WE INVESTIGATED

- Current trends in the use of winches and accessories in narrow reef hard rock mines
- Current and potential design-related modifications to winches and accessories
- The use of technology (hardware and software) in the winch system
- Alternative cleaning solutions, including ropeless systems
- Alternative mining layouts and methods

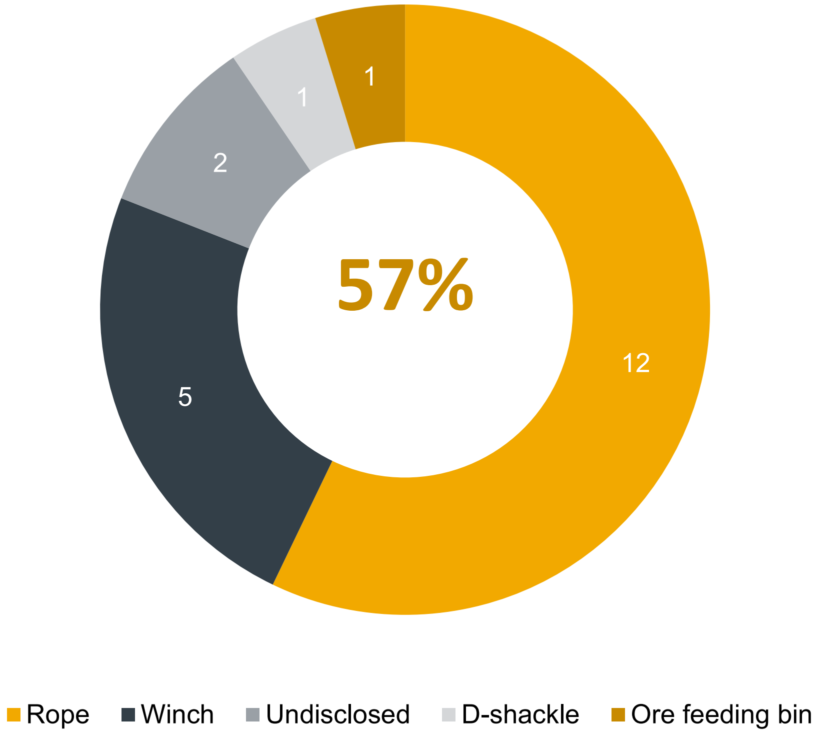
HOW

1. Literature review — history, best practice, legislation, technologies (COMRO, Deepmine, Futuremine archives)
2. Investigations — mine visits, engagements with OEMs, technology and alternative-equipment companies
3. SAMRASS accident data analysis, 2015–2023 (gold & platinum)
4. Industry workshop — solutions discussion and survey
5. Evaluation of solutions and recommendations

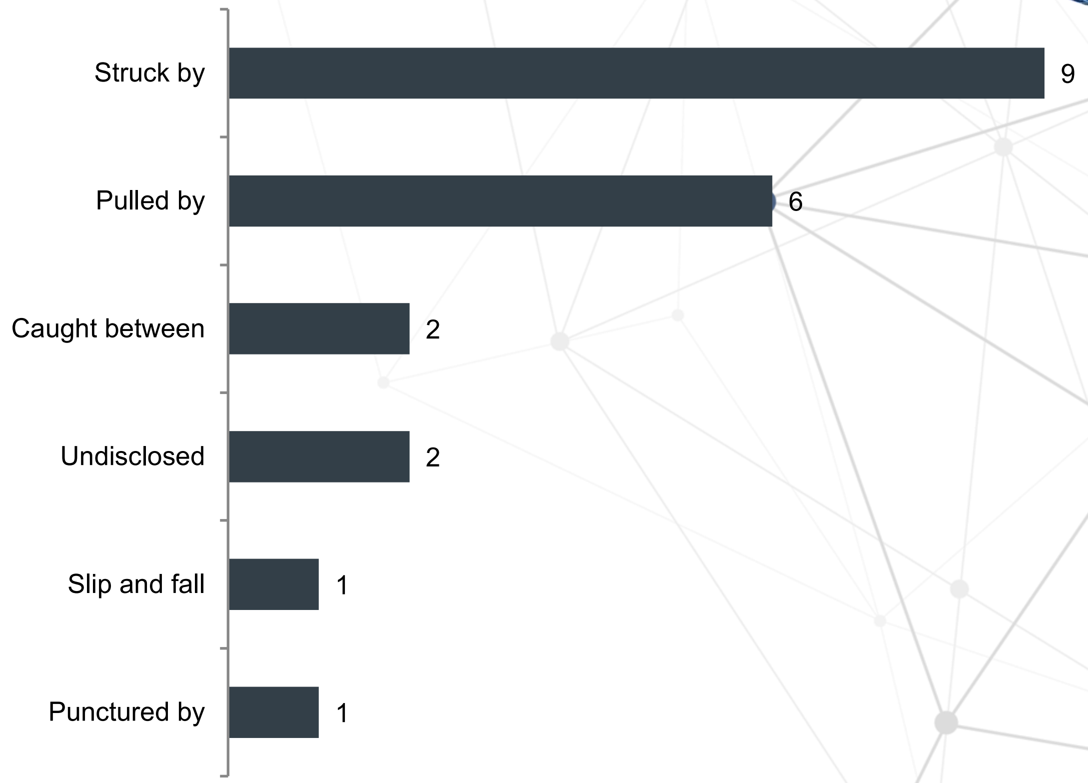
WHY ACCIDENTS HAPPEN

The rope is the primary hazard

HAZARD LEADING TO FATALITY (n = 21)



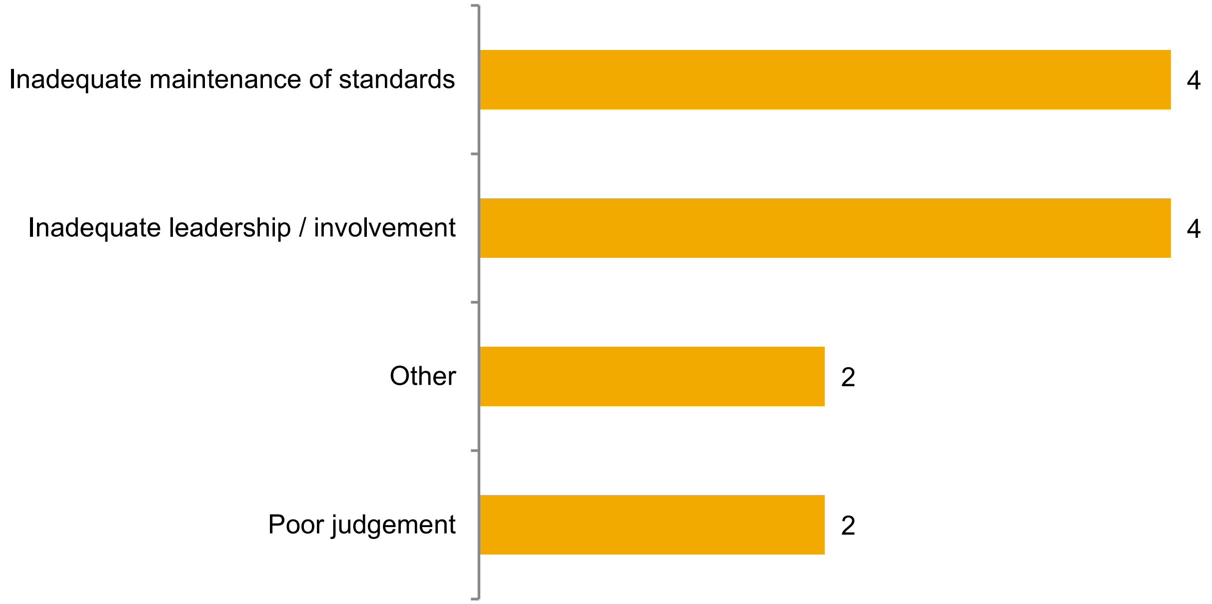
IMMEDIATE CAUSE OF FATALITY



Struck by (43%) and pulled by (29%) winch components account for nearly three quarters of fatalities

WHY ACCIDENTS HAPPEN

Behind each event there is a system failure



Root causes of the 21 fatalities (SAMRASS classification). A further nine factors contributed one fatality each, including lack of on-the-job training, previously ignored deviations, inadequate supervision of hazardous tasks, and shortcomings in risk control systems.

Not new findings.

The same primary and secondary causes identified in 2003:

- Sub-standard practices,
- poor adherence to procedures,
- inadequate training,
- and insufficient management and supervisory effort

The system knows what goes wrong. It has struggled to act on it.

WHO IS AFFECTED

Experience and role do not protect you

49% / 52%

of injuries / fatalities are winch operators — the person with the most direct machine interaction

31–40 yrs

the **most affected age group**: 33% of injuries and 43% of fatalities

15–20 yrs

of experience — where fatalities concentrate (two thirds of fatalities)

Experience does not immunise. Fatalities peak among workers with 15 to 20 years underground experince, these are seasoned people, not novices. This points to complacency, normalised deviation and time pressure rather than ignorance, and it means refresher and behavioural interventions matter as much as induction training.

Exposure is not confined to the operator: stope team workers, team leaders, shift bosses, drillers and material-handling crews all appear among the deceased. Anyone who shares the working place with a live rope shares the risk.

INVESTIGATION FINDINGS

What we found at the operations

Standards exist; adherence is inconsistent

Well-defined COPs and standards are undermined by spares shortages, reactive maintenance, and weak appreciation of the consequences of deviation.

Time-task allocation is not optimal

Improper allocation compresses early-shift safety checks; risk assessments and inspections are rushed, raising accident likelihood.

Hazard identification is compromised

Poor lighting, dust and unsafe worker positioning within the winch system degrade what workers can see and anticipate.

Training builds compliance, not competence

Programmes focus on procedural steps rather than problem-solving for the dynamic underground environment.

PDS pilots show promise and friction

Early scraper-winch PDS trials faced malfunctions and nuisance stoppages; refinement is needed before wide deployment.

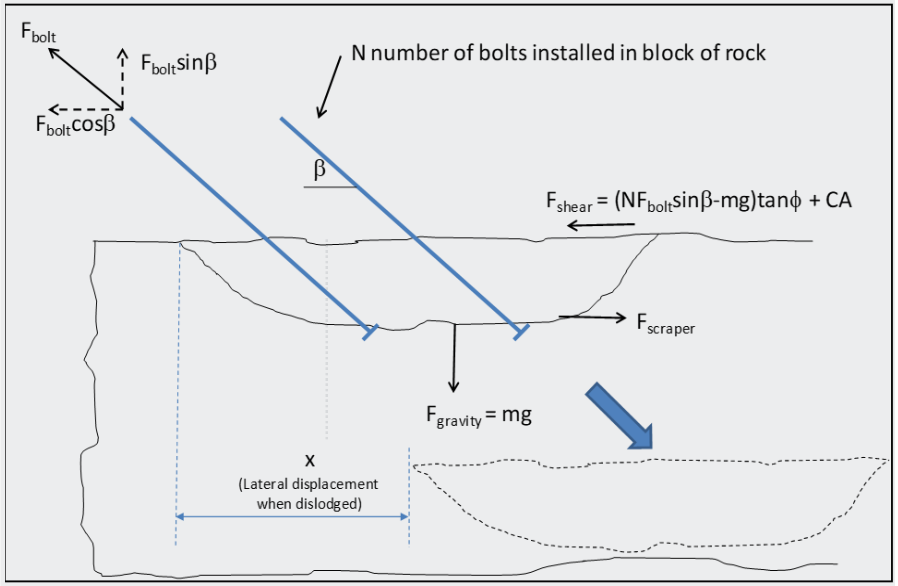
Rope testing is not a legal requirement

Scraper winch ropes are rarely tested, and no discard criteria exist. Guidelines still need to be developed, similar to those for mine winder ropes

SNATCH BLOCK ANCHORING

Rigging: where the rope meets the hangingwall

THE PROBLEM



A block of mass m held by N tendons at angle β, separated from the hangingwall by a plane of weakness. The scraper rigging exerts a horizontal force on the block.

THE FINDING

Do vertical tendons resist the scraper force at all?

$$N = F_{scraper} / (F_{bolt} \cdot \cos\beta)$$

As β → 90°, N is undefined. Ignoring bending strength — and Hydrabolts are weak in bending — vertically installed tendons serve no purpose at the rigging point.

WORKED EXAMPLE

F scraper 20 kN · block 2.7 t

β 60° · φ 30° · C 5 kPa · A 3 m²

F bolt 10 kN

N = 2.06 → at least three tendons

IF THE BLOCK IS DISLODGED

1.06 m

lateral displacement before the block reaches the footwall

Stoping width	**1.4 m**
Fall time	**0.53 s**
Scraper force	**2 tonnes**

Even moderate rope forces throw a large block over a metre sideways.

SPLITSET PULLOUT

In situ tests at a South African platinum mine: with only 300 mm protruding through the block, pullout force is estimated below 2 t — against 1 t assumed above. A thin margin.

Installing tendons normal to the reef dip at rigging points is not necessarily the optimum angle. Rigging point support should be designed, not assumed. Full derivation in a companion paper currently under review with the SAIMM.

EVALUATION OF SOLUTIONS

Three categories of solutions

1. Enhance the current winch

PDS-equipped winches · remote control · rope condition monitoring & discard criteria · training quality · time-task allocation · hazard identification & lighting · worker positioning and barriers

2. Replace with alternative cleaning equipment

Waterjets · ultra-low-profile dozers · armoured face conveyor and reciprocating flight conveyor (trialed historically and not recommended) · (sweepings/vamping)

3. Eliminate via new mining methods

Reef boring · reef cutting · mechanised breast, bord-and-pillar and long-hole layouts that design the winch out

Each solution was evaluated against four criteria: safety impact, implementation feasibility, operational efficiency and cost-effectiveness.

RECOMMENDATIONS · DECISION PATHWAY

Which pathway fits your operation?

START HERE

Which best describes your operation?

IF YOU ARE…
Existing conventional mine — legacy shafts, established scraper layouts, tight capital

IF YOU ARE…
Expanding or modernising — some freedom to change layouts and infrastructure

IF YOU ARE…
New mine or deep modernisation project with design freedom

SHORT TERM

Make the winch you have safer

- Standards, time-task allocation, training, lighting, barriers
- Rope condition monitoring
- PDS-equipped winch
- Remote-controlled winch

MEDIUM TERM

Trial alternative cleaning equipment

- Waterjets — face cleaning
- Ultra-low-profile dozers
- AFC / RFC — assessed, low feasibility
- Continuous scrapers – for centre gully, low feasibility

LONG TERM

Design the winch out entirely

- Mechanised breast, bord-and-pillar, long-hole
- Reef boring and reef cutting
- Non-explosive rock breaking methods
- Layouts designed around equipment from day one
- Strongly favoured for greenfields

The paths can run in parallel. Short-term controls protect people today while medium- and long-term transitions are planned. Every operation should run its own site-specific evaluation against the four criteria: safety impact, implementation feasibility, operational efficiency and cost-effectiveness.

DECISION PATHWAY · EXISTING CONVENTIONAL MINE

Short term: make the winch you have safer

IF YOU ARE… an existing conventional mine — legacy shaft infrastructure, established scraper layouts, capital constraints

Do now — low cost, existing facilities

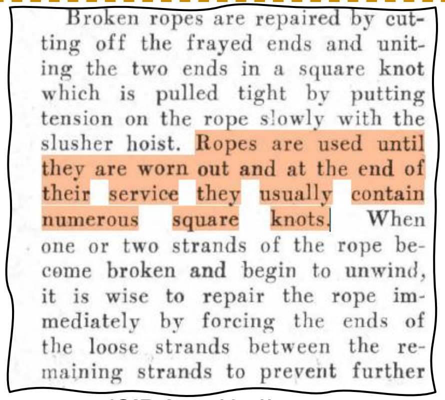
- Enforce standards; involve workers in revising procedures
- Rebalance time-task allocation so safety checks are not rushed
- Competency-based training, not procedural drill
- LED strip lighting for hazard identification
- Demarcate and physically barrier the scraper path

Rated highest on feasibility and cost-effectiveness in the option analysis.

Rope condition monitoring

- Requires a protocol applicable across all mines
- Inspections and potentially sensor-based monitoring
- Specify and adhere to inspection intervals

NO DISCARD CRITERIA CURRENTLY EXIST. Ropes are rarely tested because it is not a legal requirement. Guidelines still need development.



Broken ropes are repaired by cutting off the frayed ends and uniting the two ends in a square knot which is pulled tight by putting tension on the rope slowly with the slusher hoist. Ropes are used until they are worn out and at the end of their service they usually contain numerous square knots. When one or two strands of the rope become broken and begin to unwind, it is wise to repair the rope immediately by forcing the ends of the loose strands between the remaining strands to prevent further

(O'Brien, 1951)

PDS-equipped winch

- Select sensing technology on range, accuracy and non-line-of-sight behaviour
- Integrate with existing winch controls; secure buy-in and compliance
- Phase it in: alarms first, automatic stop late
- Pre-shift checks of tags and signals; record them

UWB accuracy	**<10 cm, nanosecond update**
RFID range	**passive 30 m · active 100 m**
Trial trip zone	**1.5 m**
Detection range	**0.5 → 0.75 m from centreline**

Qian et al. (2022), Report Table 5. Zone values are trial parameters, not standards. Drawbacks: nuisance stoppages, cable damage, cap lamp drain.

Also assessed — remote-controlled winch: compatible with existing infrastructure but requires control-system upgrades, skilled operators and additional training; best paired with PDS. Earlier trials (Rham, 2004; Sulzer, 2017) were unsuccessful on operating cost and set-point overrun. Cost remains the main constraint.

DECISION PATHWAY · EXPANDING OR MODERNISING

Medium term: trial alternative cleaning equipment

IF YOU ARE… expanding or modernising, with some freedom to change layouts and infrastructure

Waterjets — face cleaning

- Deployable in any conventional stope with adequate water pressure
- Most effective where gravity assists (up-dip stopes)
- UG2 caution: water raises mud-rush risk at orepass draw points
- Budget for higher pumping and energy costs

Optimal pressure	**7–10 MPa**
Optimal flow	**3 l/s**
Demonstrated at	**29–30° dip, ~20 t/h**
Panel clearance	**15 m in <90 min**
Reticulation	**50 mm column, 45 m hose**

Union Mine (O'Beirne, 1979); Amandelbult (Fourie, 2021). Outside this window: slower below, higher accident risk above.

(Fourie, 2021)

Ultra-low-profile dozers

- Require layout changes — suited to mechanised breast stoping
- Shaft logistics: may need disassembly on surface, reassembly underground
- Electric or battery preferred — diesel adds heat and particulates
- Predictive maintenance, skilled operators, delivery lead time

Stoping width	**ULP 0.9–1.2 m · XLP <1.2 m**
Dip tolerance	**older >18° struggled**
	newer under trial to 23°
Safety features	**remote control + PDS**

Fourie et al. (2017); Ngwenyama et al. (2024). Dip figures are equipment capability limits from the literature.

(Fourie et al., 2017)

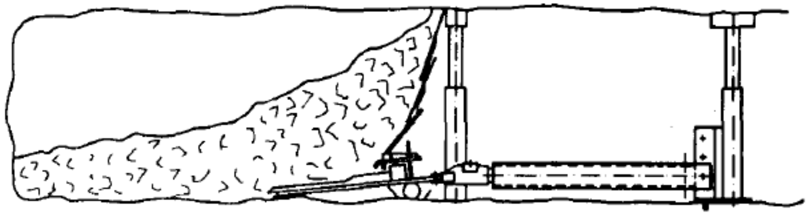
Mechanical Conveyors and Continuous Scrapers

- All adapted from longwall coal mining and need a straight face with room to advance each cycle
- Trialled unsuccessfully in the SAMI — blast damage, high wear rates, and long assembly times

Continuous scrapers — 200–400 t/h over gully lengths up to 280 m at 0.25 m/s

AFC — 200 t/h at 0.2 m/s; trialled at 23° dip; 24 000 t life in quartzite.

RFC — 15 m/month at one shift per day, >30 m²/worker/month; but blast-prone and unsuited to breast layouts..



(Joughin and Buckmaster, 1976 and Du Plessis and Pickering, 2013)

DECISION PATHWAY · NEW MINE OR DEEP MODERNISATION

Long term: design the winch out entirely

IF YOU ARE... a new mine or a deep modernisation project with design freedom

Ropeless mining methods

- Reef boring and reef cutting
- Mechanised breast, bord-and-pillar and long-hole layouts
- Non-explosive rock breaking methods
- Requires layouts designed around the equipment from day one — orepasses, excavation profiles, logistics
- Substantial capital investment and a new skills profile
- Removes the worker — and the rope — from the high-risk zone entirely

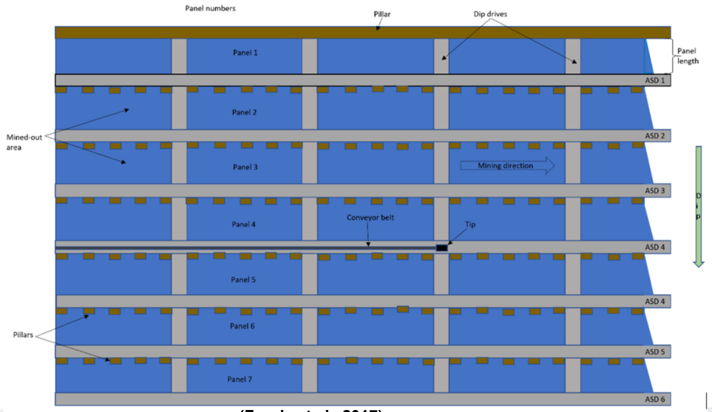
Why greenfields?

Converting a conventional mine is hard.

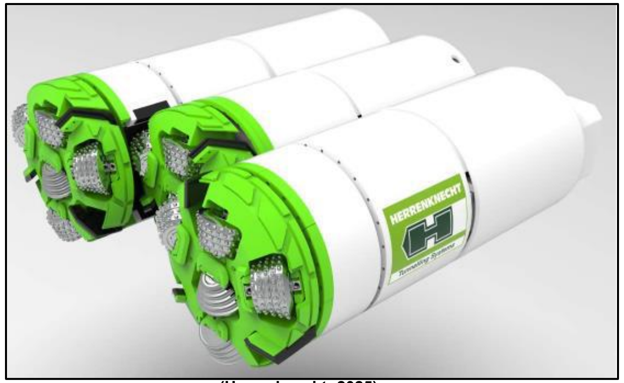
Legacy shafts, established layouts and sunk infrastructure make retrofitting costly and disruptive. Conventional vertical shafts are not suited to moving mechanised equipment from shaft to face, and existing stope geometry is designed around the scraper path, not around a machine.

New operations can optimise for mechanised equipment from the start — excavation profiles, orepass positions, transport routes and ventilation designed together.

This is the pathway that eliminates the rope rather than managing it.



(Fourie et al., 2017)



(Herrenknecht, 2025)

(Master Drilling , 2025)

The transition must be gradual and strategic, balancing safety, productivity and cost, with each operation running its own site-specific evaluation, but the destination is clear: remove the worker from the high-risk zone.

KEY MESSAGES

1. The winch problem is persistent, ±5% of SAMI accidents for over two decades, with the rope behind 57% of fatalities.

2. The causes are known and organisational, standards, supervision, training and time pressure, the same causes identified in 2003.

3. Act now on the current winch: rope discard criteria, PDS, lighting, barriers, time-task allocation and competency-based training.

4. Plan the exit: alternative cleaning equipment in the medium term; ropeless mining methods in the long term. Zero Harm requires removing people from the rope's reach.

Thank you

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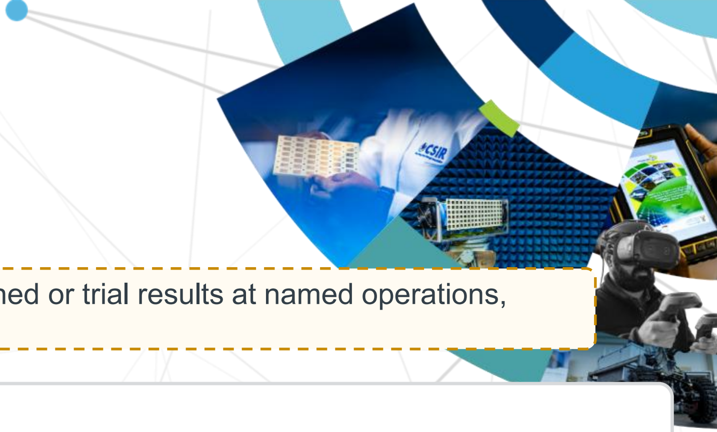
Full report: MHSC CoE 210501



WHAT ELSE IS OUT THERE

Conceptual technologies: a horizon scan

NOT ASSESSED IN THIS PROJECT. Identified through literature and patent searching. Performance figures are vendor-published or trial results at named operations, not independent measurements.

Teleoperated demolition robots

Brokk (Sweden)

- Proven in SA ultra-deep and narrow-vein applications
- Moves unassisted at 30° incline — conventional mechanisation stops at 7–8°
- Drills up to 10 m from the machine
- One SA gold mine: labour cost per linear metre down 60%

Does not clean — drilling, bolting, scaling, breaking only.

Continuous flexible conveying

Flexiveyor · Prairie Machine (Canada)

- Up to 1 200 t/h; corners as sharp as 50°
- Miner Follower tracks the mining machine automatically
- Low-profile and narrow configurations available
- Already in South Africa; ~20 units worldwide

Soft rock only — potash and salt, not hard rock.

Borehole extraction & hydraulic transport

Novamera (Canada) · hydraulic hoisting

- Ore recovered as cuttings or slurry via boreholes
- Removes the stope–gully–orepass path
- Hoisting components proven; assessed for SA platinum
- Anaconda / Memorial adapting oil-and-gas methods

Addresses extraction and hoisting, not face cleaning.

Winch redesign — patent activity

ZA · SI · CN

- WO2017216731 (ZA, Sulzer Hydromining): twin drums, independent variable-speed drives — ceased
- SI26399A2 / EP4321470 (SI, 2022): single-drive winch, freewheel clutches; cites the ZA patent — active
- CN113443345A: bottom-chain-free scraper conveyor

Design effort continues — little reaches production.

None of these is a proven scraper winch replacement for South African narrow reef conditions. The constraint is not invention — it is adapting any of them to a 0.9–1.2 m stoping width, at reef dip, in a drill-and-blast cycle, at depth. That gap is where the research effort is still needed.