Journal Paper

Safety considerations in underground logistics—a look at vertical, horizontal and in-stope transportation systems

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Synopsis

Transportation accounts for some 26% of all mine accidents in South Africa. Although this figure may not be as prolific as fall of grounds accidents or accidents caused by seismic events, the enormity of transportation accidents demands attention, especially as many of these accidents are avoidable.

This paper investigates vertical (i.e. shaft), horizontal (i.e. haulages), and in-stope transportation systems and their function as it applies to safety. Recent transportation accidents are discussed looking at current trends within the three transportation areas. In the shaft area, discussions will focus on handling of material cars, loading and off-loading of the workforce and management of shaft orepass systems. The horizontal component will focus on personnel transportation, safety around trains and hoppers, and handling of material in the cross-cut. The discussion on in-stope transportation will focus on the general congestion of the stope environment and how it affects the overall movement of personnel, material, and rock. Of concern are the large numbers of material handling and scraper winch accidents that occur and which will be discussed in some detail. The paper will conclude with a section on proposed guidelines within the three above-mentioned systems for mine engineers to consider in mine design and life of mine planning and scheduling.

Keywords

Underground logistics, safety in material handling.

Introduction

The object of underground logistics is to transport personnel, material, and rock from their point of embarkation, either from surface or from the working face, as quickly and safely as possible. Logistics play a significant role in the overall safety in mining. Mine transportation represents the third highest category (20%) of all accidents in South African mines (Figure 1), behind rockfalls which represent 35% and general mining at 22%. Interestingly, mine transport ranks slightly above rock and strain bursts (19%).

Figure 2 shows that the four highest factors contributing towards transportation fatalities (1988–1994) are 'falling in/from' (37%), 'locomotives and hoppers' (35%), 'conveyance (skip/cages/kibbles/car/chairlifts' (17%), and 'transporters' (11%).

Review of recent mine fatalities from 2007 to 2009 supports the above safety data and also highlights safety concerns around scraper systems.

The purpose of this paper is to provide to the mining engineer a summary of underground logistics issues, which should be considered for the improvement of safety. The paper concludes with guidelines specifically for shafts, haulages, and in-stope transportation systems.

Shaft systems

Introduction

Shaft systems are considered to be an efficient system requiring few new technology advances, but may need improvements on management systems. Shafts are generally a safe environment compared to the haulage and stope environment. However, when accidents occur, they tend to be severe and in some cases even catastrophic, especially when one considers that a typical shaft transports between 2 000 and 6 000 workers per day, and 6 000 material cars per month. In 1993, a number of workers were trapped for several days when a hydropower column collapsed in the No. 3 sub vertical shaft. In 1995 a horrific accident occurred at Vaal Reefs where 105

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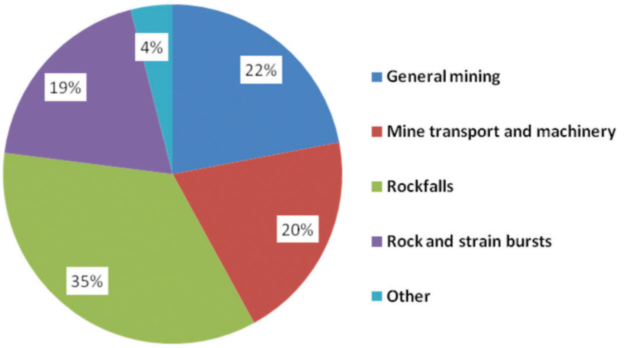

Figure 1—Fatality causes within South African mines (2008)[1]

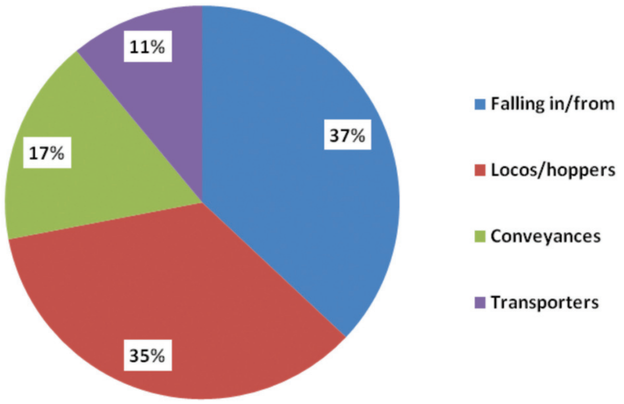

Figure 2—Four highest contributing factors towards transportation fatalities[2] (1988–1994)

people lost their lives when a locomotive failed to stop at a shaft station, plunged down a shaft, and collided with an upcoming personnel conveyance. As recently as 2007, South Africa made worldwide news when 3 200 workers were trapped underground after a pressurized air column snapped and tumbled down the shaft.

This paper does not propose to examine the engineering aspects of shafts and winder plants; this is an area which has dedicated symposiums discussing the various aspects of shaft engineering, e.g. Mine Hoisting 2010 and Association of Mine Resident Engineers. However, it may be worth highlighting some aspects of shaft and winder plant safety. A paper in 2000 by Zondi[3] highlighted data that showed a total of 164 persons had lost their lives between 1994 and 1999 in accidents associated with shaft transportation. This statistic was significantly influenced by the 1993 Vaal Reefs incident. During this period, 16 persons lost their lives when they were struck by conveyances in motion and the third highest incident was where people (5) were struck by a kibble during shaft sinking. In non casualty accidents, jamming or fouling of the conveyance represented 46% of all incidents, followed by fracture or failure of rope connections (20%), fracture or failure of drums (11%), overwind or overrun of the conveyances (7%), and derailing of winding plants (6.5%).

Zondi further highlighted the following scenarios that could lead to a disaster:

- Rope fracture
- Brake failure
- Clutch disengaging
- Failure of winder shaft
- Slinging of material
- Objects falling down a shaft
- Seismic events
- Shaft pillar extraction
- Ageing of shafts and equipment
- Shaft equipment fouling shaft compartments.

In the early 2000s, the author was involved in reviewing shaft systems with the idea of identifying positive and negative aspects of mature shaft systems[4]. Based on interviews with shaft engineers and shaft managers/mine overseers, the following issues affecting the safe and efficient operations of shafts were identified:

- Non standardization of material cars
- Material blockages and mudrushes
- Cage-holding devices not installed or ineffective
- Lack of appropriate materials-handling devices at stations/bank
- Lack or ineffective access controls on the station to restrict personnel
- Stretching of the rope at depths of 1 00 m or more, which creates problems with the loading of the shift as the cage moves downward as the shift is loaded into the conveyance.

The above highlight areas of safety that our engineering colleagues are busy addressing. They emphasize the need for mining personnel to be aware of the importance of proper shaft pillar design and extraction methodologies. Furthermore, the commentary of the ‘ageing of the shafts and equipment’ should not go unnoticed and will be more of an issue as shaft systems are extended beyond their design life. Similarly, the slinging of material has always been seen as a task requiring great care. To ensure the safety of the shaft, mines should have in place strict standards and procedures to mitigate the risk associated with slinging of material.

Between January 2007 and December 2009 there were seven fatal incidents in the shaft area; a forklift overturned on a dirt road, a worker was struck by a conveyance, a decline rope snapped, a conveyance was lowered into a flooded shaft, a worker was struck by cable bracket that fell down a shaft, a worker fell into the measuring flask of a loading box while trying to remove an obstruction, and a spillage conveyance rope broke.

Surface area

The shaft surface area consists of the immediate bank and subbank area. The crush and lamp room form part of the shaft surface area, and a low risk is associated with this area. The main concern here is to ensure that personnel don the appropriate clothing, are supplied with the necessary personal protective equipment (PPE), and supplied with the appropriate safety appliances, i.e. cap lamps, rescue packs, methane detectors and calibration of detectors.

The surface bank area provides a marshalling area for material that is to be sent underground and a moderate risk is associated with the handling of personnel, rock, and material. The use of mobile equipment in the bank area probably has the largest risk associated with the surface area. A separate floor, either at basement elevation or above bank, frequently provides personnel entry and allows for the separation of personnel and material traffic. Falling rock from the tipping operations is a source of concern but is largely mitigated by screening off the tipping compartment.

Underground bank and stations

Underground bank and station safety considers the loading and offloading of personnel and material. In deeper shafts, rope stretch represents a real risk when loading a shift as workers are often required to negotiate elevation distances of 0.5 m, and in extreme cases distances over a metre. This consequently creates the potential for workers to fall between the station platform and the cage. Similarly, offloading of material cars can be hampered by rope stretch, as the material car moves forward and the weight of the car is transferred from the cage to the shaft station. In extreme cases rope stretch can potentially propel/flip the material car as the cage moves upward. The use of cage holding devices improves the loading and unloading operation by holding the cage in the correct position, thereby negating the effect of rope stretch; however, cage holding devices are not always found to be a safe and reliable system.

Material handling on the bank/station area represents a moderate risk with non fatal injuries much more common than fatalities. Injuries are largely associated with handling heavy material. In the bank station area the use of a mechanized means to propel material cars to the shaft area is advocated. Nevertheless, some physical manipulation of material cars is necessary when loading and offloading cars and therefore the weight of material cars needs to be monitored. Another issue surrounding shaft material handling is the stacking of empty flat material cars. This is done to increase the number of materials cars that can be hoisted out of the mine. However, cars need to be standardized otherwise there is a risk of the cars overturning. In at least one incident in the past three years this practice has resulted in a fatality.

The movement of workers in the shaft area remains a low risk. The introduction of shift control gate promotes better control for handling personnel when loading cages. Movement of the shift from one shaft to another requires dedicated routes ideally removed from other activities such as tramming or shunting of material cars. Crossovers should be provided where the shift is required to traverse busy haulages or tip cross-cuts.

The offloading of waste and ore in the station cross-cut represents a moderate to high risk especially when operating in the tip area. Tips are notorious for accidents associated with tipping and breaking of large rocks. In the past falling into the orepass has occurred. In addition, the tip and material cross-cut areas suffer from congestion, which increases the safety risk with the movement of personnel, material and hauling of ore/rock, which often happens at the same time during shift periods.

Bank and shaft station designs should be closely matched and standardized. This greatly simplifies operation and enhances safety. A double track should be provided immediately adjacent to the shaft in an amount that is not less than the product of the average length of a material car and the maximum number of cars which are expected to be handled on one shift. For example, if cars are 3 m long, and 60 cars are handled on a shift, then 180 m of double track is necessary. Some means of moving cars forward to the shaft must be provided. Capstan winches, purpose designed pushers, and modified locomotives may be used for this purpose.

Shaft loading levels and shaft bottom

There are several risks associated with the shaft loading levels and shaft bottom. The risks of mudrushes are real while 'pulling' shaft ore and waste passes, and over the years a number of serious accidents have occurred. Shaft bottom, also has had a number of incidents over the past few years, including the failure of a spillage conveyance rope as well as a cage being lowered into a flooded shaft.

Shaft barrel

Working in the shaft barrel is always a high risk occupation. However, due to the high awareness of the risks by workers involved, accidents are rare. While conducting maintenance in the shaft, personnel must remain diligent in terms of risks associated with this work. Based on recent incidents, the biggest risk in the shaft barrel is the condition of the infrastructure and its ability to interfere with the operations of the shaft.

Recommendations for shafts

Recommendations made for the improvement of shaft systems in terms of safety are listed below:

➤ Crossovers should be provided where the shift is required to traverse busy haulages or tip cross-cuts.
➤ Stations should use cage holding devices for personnel and material cages to prevent cages from moving when being loaded or unloaded on a level. This should also remove the danger of personnel falling into the shaft during man-loading operations.
➤ Counting turnstiles at banks and stations are recommended for good access control; shift control gates should be installed on the station, preferably in a recessed position to prevent shoving at the end of the shift.
➤ Maintenance of shaft services must be prioritized to ensure ageing equipment does not foul shaft compartments.
➤ Slinging of material must be done strictly according to mine standards, and equipment used for slinging needs to be checked on a regular basis.
➤ A form of mechanical means (winch) should be used to move material to the station bank area.

Haulage systems

Introduction

In 1986, Binks[5] conducted a study of underground transportation following the mining industry's concern about the high rate of fatalities and injuries associated with underground transport. Binks identified the six main causes of accidents related to underground transportation, as shown in Figure 3.

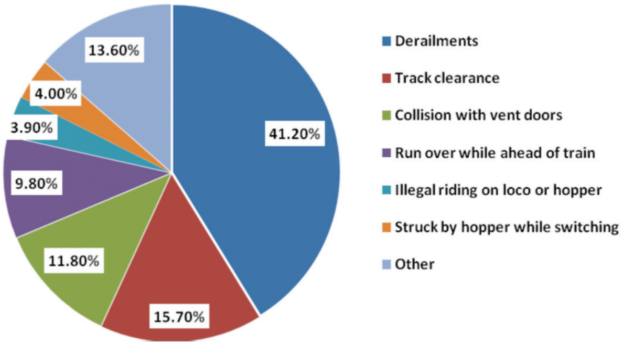

Figure 3—Main causes of underground horizontal transportation accidents (1986)

The causes of horizontal transportation accidents are as relevant today as those identified in 1986. A look at recent accidents from January 2007 to December 2009 shows similar types of accidents still occurring. The biggest risk to the workforce not involved with the transportation process is being struck by a locomotive/train. Areas of minimal clearance in the haulage should be identified and all workers should be trained to recognize the hazard surrounding trains, i.e. clearances, derailments, and the limits of the driver's visibility.

General transportation issues

The congestion of trains is a source of concern in underground transportation, and simply stated: 'more isn't always better' when it comes to underground transportation. Requesting trains to reverse numerous times during the course of travel is unproductive as well as unsafe as often the train driver is reliant on the guard to provide adequate warning of personnel and oncoming traffic. Several fatal accidents have occurred over the past three years due to collisions with other trains. Minimizing the shunting of trains through the use of passing loops, able to accommodate at least one train length should be available at regular intervals to promote safer tramming conditions. Signalling devices should also be incorporated within the loops to control traffic at regular intervals.

Coupling of material cars and hoppers is a high risk task and the subject of a Safety in Mines Research Advisory Committee (SIMRAC) study. The 2002 study, Coupling systems and design in use in the Gold and Platinum Sector[6] concluded that dedicated well trained tramming crews should be used for coupling and uncoupling cars. Systems used should allow for coupling and decoupling to take place such that the guard can stand outside the line of the vehicles while they are in motion. Coupling designs should be modified, or alternatively new couplings developed that minimize the backlash and can withstand the impact forces experienced without plastic deformation.

Track work

Although there have been guidelines for underground transportation equipment for a number of years, derailments continue and accidents associated with derailments still occur. Over the past three years there have been three fatalities involving the derailment of hoppers and three involving material cars. High quality track installation and maintenance is an area that has yet to be widely adopted by mines and is an area that must receive serious consideration. Conditions, as shown in Figure 4, should be seen as an industry norm rather than as an exception, as is the current case. More work is required within the industry to promote the positive upside of good track work.

Maintenance, whether performed by mine personnel or by contractors, must be done on a continuous basis. A maintenance schedule should be drawn up for haulages, which includes daily, weekly and monthly examinations. The personnel required for haulage maintenance should be based on realistic productivity targets. One worker per 2 km of track is appropriate for haulages that are shotcreted and where trackwork is initially installed to a high quality standard (Figure 4). In addition, some form of quantity and quality surveying should be done to monitor track installation and maintenance.

Loading

Loading operations from stope boxes/orepasses are a high risk operation. Mud rushes from these orepasses should never been allowed to been seen as a common event. Management of in-stope water and backfill is necessary. Remote control of loading chutes is beneficial to remove operators from exposure to mud rushes. In addition, mud rush control chutes may be an additional option. Reducing the amount of water used in the stoping environment decreases the risk of mud rushes or spillage of ore. Water usage should be limited to a maximum of 2 tonnes of water to 1 tonne of rock.

Ventilation doors

In the past three years, five fatalities have occurred involving ventilation doors. Ventilation doors should be automated so that the trains do not have to stop on either side of the doors, which must be manually opened and closed (Figure 5). Stop blocks should be removed from main haulages thus precluding the driver or guard from leaving the locomotive to remove or replace stop blocks. Redundant ventilation doors

Figure 4—Well constructed haulage

must be removed as soon as possible while other unmoveable obstructions should be clearly marked and preferably well illuminated.

Personnel loading bays

There have been two occasions since 2007 when persons have been struck by trains. The use of personnel carriages or dedicated times for personnel transportation is one way to minimize accidents between personnel and trains. Personnel loading bays, near the working places, should be provided on a regular basis, every 600 m to 800 m. These loading bays could consist of a concrete platform or a section of double track equivalent to the length of the train (Figure 6). Personnel should be transported in ergonomically designed personnel carriages with the exception of travelling distances less than 1 km, when personnel should walk to the workplace. Another way to minimize interaction between trains and personnel is to control access to the haulage so that the haulage is free of personnel at all times, except for maintenance personnel and supervisors. Pedestrians should be required to request permission from a controller before entering the haulage. The use of proximity devices is another method to minimize risk in the haulage.

Illumination

Better lighting improves haulage conditions as problem areas can easily be identified. All junctions, ventilation doors, personnel loading areas, and places where workers congregate should be illuminated and in non-illuminated haulages, the sidewalls should be whitewashed to improve lighting. High-speed haulages should be well illuminated to improve visibility and reduce braking distances. Every train should have bright lights, shining in the direction of travel, of sufficient strength to illuminate the full distance required to bring a fully loaded train to a standstill.

Light coloured walls reflect light, hence the use of whitewash should not be underestimated. The use of contrasting colours can also be used to warn of physical hazards and to mark obstructions[8].

Communication

Communication systems are required between the train and a central control room as voice communication reduces congestion and improves the overall efficiency and safety of tramming operations. An effective two-way means of communication between the driver and the guard must be provided, taking into account noise, visibility and the environment.

The use of interactive tags, which are placed on locomotives, and tag readers increase management capabilities as information is supplied on a real-time basis.

Signal devices are required to ensure oncoming traffic can be controlled, allowing a smooth flow of traffic. Fans or other significant sources of noise should not be installed at points adjacent to signalling or communications nodes.

Recommendations

The following are recommendations for underground transportations:

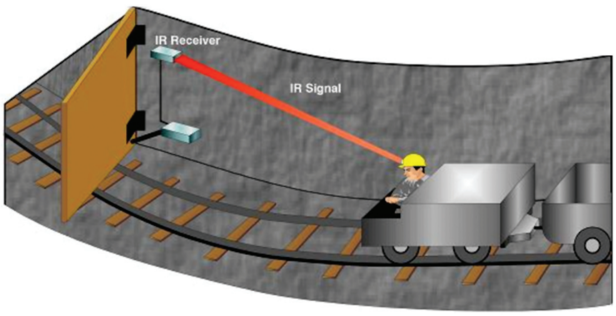

Figure 5—Automated ventilation door[7]

Figure 6—Personnel loading bay

- Based on the SIMRAC GAP 520 report, Investigate safety of rail vehicles and systems operations in SA Gold mines[9]
  - Improve workers cognitive skills during training.
  - Apply stricter disciplinary measures when workers, and in particular supervisors, are found to be working unsafely
  - Adherence to COPs
  - Promote self-policing
  - Promote a co-operative attitude versus a confrontational attitude; regular audits, especially during nightshift, as this is when conditions are at their worst
  - Accept and apply stronger disciplinary measures against offenders.
- Material should not be stacked in the main tramming haulages. Where material is stacked in haulages or cross-cuts, it should be well clear of track and opposite the travelling way side.
- Sidewall to be slipped where clearances are less than the spacing recommended in the mine standard procedures.
- Where obstructions are not removable, e.g. water doors, ventilation doors, etc., they should be clearly marked and preferably well illuminated. Unnecessary structures, e.g. disused vent door frames, should be removed as soon as they are redundant.
- Refuge cubbies in haulages/cross-cuts should be provided where necessary.
- Good communication between driver and guard is of vital importance.
- A traffic control system is recommended for busy levels and could be by means of token or robot controlled system.

Figure 7—Congestion due to lack of a material bay

- Excessive noise can lead to locomotive drivers being unable to hear signals by guards. Fans silencers should be used at fans and filters in haulages and cross-cuts.

In-stope transportation

Introduction

The stope is a confined area with personnel, material and ore sharing the same excavation and often competing for the same space. Ideally the best way to improve the situation is to separate the three from each other.

In extreme cases, personnel, material enter the cross-cut/stope at the same time and as ore is being loaded from the stope-boxes. Figure 7 depicts a congested cross-cut where personnel are required to navigate between material on the footwall and material cars. In recent years at least one fatality has been associated with a worker being crushed between a hopper and material stored in the cross-cut.

In-stope transportation begins from the stope entrance in the cross-cut and is hampered by the need to move multiple items, i.e. personnel and material, to and from the face or other places of work, and rock from the stope panels and gullies. Traditionally personnel, material and rock often share the same excavation from the dip gully through the strike gully and to the stope panel. Figure 8 is an example a typical in-stope access way—difficult to manoeuvre over cleaning equipment in a confined gully, which is often full of blasted ore. In terms of the face, even in ideal conditions where the face is clean, travel is hampered due to the flat dip and narrow nature of the orebody.

Traditionally monowinches caused injuries, with fingers being drawn into monowinch pulleys, as workers inadvertently used monowinches as handrails or they lost their balance while travelling. Manufacturers have gone a long way to introduce pulleys that are nearly impossible to introduce hands/fingers into.

In contrast, scraper rope accidents remain a major concern to the industry as workers continue to be fatally injured. In the past three years at least 12 fatalities related to scraper winch systems have occurred. In 2003, SIMRAC commissioned a study into the causes of scraper accidents in the gold and platinum sector, with guidelines being recently submitted to SIMRAC.

In-stope transportation

Starting from the stope cross-cut area, ideally, it is best to separate personnel travelling, material handling, and rock transportation. Placing orepass systems (Figure 9) away from the stope entrance reduces congestion and moves loading operations away from the stope entrance. The use of material bays offers further improvements as material is stored and loaded onto the monowinch away from the tracks.

The schematic as depicted in Figure 10 shows a properly executed stope entrance: personnel travel on one side of a barrier with material being transported via the monowinch on the other side. Similarly, the dip travelling ways can be separated from the monowinch rope, as shown in Figure 11. In cases where the centre gully is required for ore scraping, travelling/material ways should be developed either side of the centre gully. Although this introduces additional dilution

Figure 8—Typical strike gully travelling

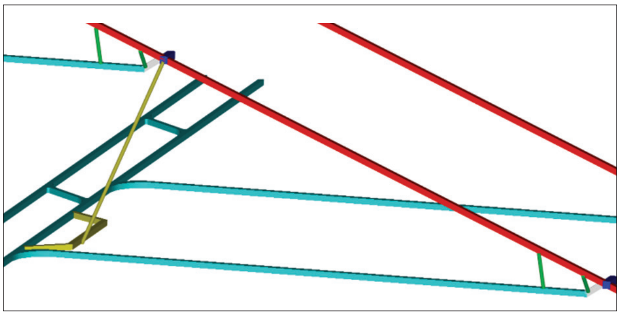

Figure 9—Boxhole layout[10]

and additional time for ledging, it must be seen as a 'must have' to improve in-stope transportation, safety and productivity.

In-stope transportation in the strike direction is reliant on sufficient working height in the gully for the movement of personnel and material, and reliant on strike gully cleaning being sufficient not to allow an excess of ore to build up.

In terms of material handling, current in-stope systems are not configured and specified to deliver material where it is required. Factors include a considerable amount of re-handling, sharing of common travelling ways for personnel movement, and the exclusive use of manual labour in the immediate face area. None of these is conducive to safe operation. The batch nature of the mining process further aggravates this situation. The following practices should be considered to address these problems:

- ➤ Illumination along the face should be considered, as there is a direct correlation between safety and productivity and levels of lighting levels.
- ➤ In-stope travelling ways must account for the anticipated stope closure expected over their useful life. As a guide, a travelling way should be 2.2 m high, which will permit approximately 0.4 m closure. Travelling platforms or bypasses should be provided around orepasses. Bridges are recommended for safe and frequent travel over strike gullies.
- ➤ Panel lengths must match the cleaning rates attainable in the strike gully. This will help to prevent the strike gully becoming congested with rock and restricting the movement of personnel. In addition, strike scrape distances should not exceed 100 m as distance beyond this do not allow efficient cleaning of the gully.

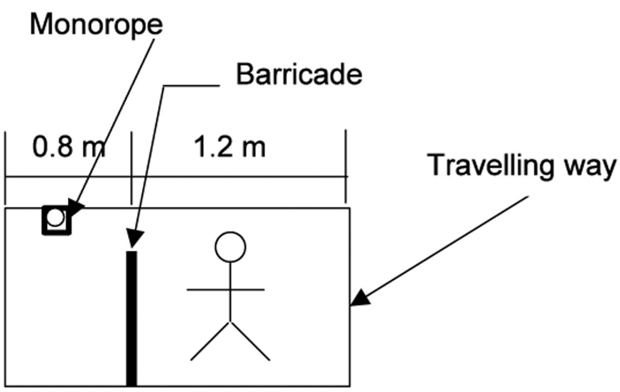

Figure 10—Travelling way and monowinch system combined with barricade

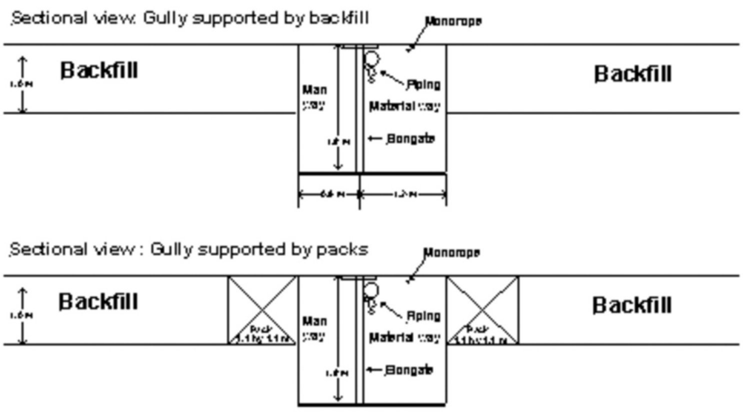

Figure 11—Ideal in-stope dip travelling way

- Blasting techniques must be employed that improve hangingwall and footwall conditions. Water jet assisted cleaning should be used wherever possible to assist panel cleaning.

Traditionally transport has been viewed as a series of independent activities; however, this is not conducive to an efficient transportation system. A culture to move personnel, material, and rock safely, quickly and efficiently must be created, and this requires a mindset change.

Scraper winches

The following section is largely based on SIMRAC report on the investigations into the causes of accidents on scraper systems in the gold and platinum mining sector[11] in which the author was involved.

Scraper cleaning is widely used in the South African mining industry and is commonly used underground to clean broken rock from the stopes after the blast. In terms of transportation accidents, scraper systems account for 23% of the accidents in the gold mining sector and 36% of the accidents in the platinum mining sector. From Table I it is noted that most injuries occur during the morning shift (59%). This is probably due to the fact that most of the workers are in the stope, transporting material, or travelling to the stope face while the scraper winch is in operation. At the other extreme, Table I also indicates that most workers are killed (59%) during the night shift. This may be due to the fact that there is less supervision on a night shift and that a night shift is primarily a cleaning shift.

Table II shows the breakdown by occupation of those involved in scraper winch accidents. This analysis by occupation indicates that only five occupations are involved in 98% of the accidents due to the scraper winch system. The analysis also indicates that winch drivers (43.9%) are prone to scraper winch accidents. Surprisingly, 26% of personnel involved in scraper winch accidents are shift bosses and general miners. Scraper winch hazards need to be highlighted for skilled workers, especially those in supervisory positions.

Underground observation noted that rigging, signalling devices and winch start-up warnings were often not adhered to. Although these issues were dealt with in terms of the mine safety standards and procedures, underground visits indicated that mines fail to implement their own mine standards and procedures. The following recommendations were made:

- Formulate procedures to address the standing and sitting of workers in safe position while the scraper is in operation.
- Review starting-up procedures of the scraper winch.
- Effective warning devices are required, i.e. better communication between workers and the winch operator.
- The stope layout needs to include the separation of workers from the scraper path, i.e. stope travelling procedure.
- Training strategies are needed to improve hazard recognition, awareness and rigging procedures.
- Review of coiling mechanism, rope splicing and regular rope test needs to be performed to determine the rope life.
- Winch operator ergonomics needs better understanding due to confined stoping environment.

Management

No transportation system, however, modern or well designed, will operate efficiently and safely unless it is operated within a well organized and managed structure. Scheduling and controlling are tasks that have been identified as being crucial in promoting safe underground transportation systems. Scheduling is required to co-ordinate all operations within the transportation system to ensure that the system

Table I

Time of accident—fatality report

Description	Percentage of injuries	Percentage of fatalities
Day shift	59%	28%
Afternoon shift	5%	14%
Night shift	37%	59%

Table II

Scraper winch accidents by occupation

Occupation	Percentage of total
Winch operator	43.9%
Stope worker	17%
General miner	13.1%
Shift supervisor	12.9%
Rock drill operators	10.9%
Winch transporter/erector	0.8%
Aquajet operator	0.8%
Rigger and ropeman	0.3%
Learner official	0.1%

Table III

Risk summary

Item	Relative risk
Shaft area	
Surface	Low
Bank and station	Low to moderate
Loading levels and shaft bottom	Moderate
Shaft barrel	High
Horizontal transport/haulages and crosscuts	
Haulage	Moderate to high
Cross cut	Moderate
In-stope	
Stope entrance	Moderate
In-stope travelling	Moderate
Scraper systems	High

operates as and when required, i.e. dedicated times for personnel movement unhindered by material and rock transport. Prioritizing transportation systems is advocated to ensure delivery, whether personnel, material, or rock.

Haulages, similar to those used for the transport of personnel, material and rock through vertical shafts, should be operated in accordance with strict schedules. A process management system combined with prioritized scheduling is recommended.

Emphasis should be placed on the establishment and maintenance of a good track work that enable conditions conducive to safe transportation, to the point where any derailment becomes a serious incident demanding immediate investigation and rectification.

Mine design must adopt an integrated approach that considers all transportation requirements. Design decisions must not be sacrificed at a later stage due to time or financial constraints. For example, mine design should allow sufficient operating room in the tip and material cross-cuts promoting safe working conditions and sufficient room for personnel to travel freely within these areas without being exposed to any risks associated with material and rock handling.

Management needs to apply stricter disciplinary measures when workers, and in particular supervisors are found to be working unsafely. Several reports have indicated a low level of discipline among workers, which must be addressed by management.

However, safety is not only the responsibility of management, and the workforce must be also encouraged to take responsibility of their own and their fellow workers' safety.

Conclusion and recommendations

Much effort has been placed on reviewing transport safety issues with the shaft and horizontal areas of underground logistics; however, with the exception of scraper winch systems, little has been done in the area of in-stope logistics. More research is required to encapsulate safe transport practice within the stope area.

Based on the above sections, a summary of the perceived risks is given in Table III. Working in the shaft, due to the nature of the operations, is a high risk task. Due to its dangerous, nature workers are well trained and safety awareness acute. However, that is not always true for the haulage, in-stope and in particular scraper winch systems.

In terms of the research in underground logistics conducted over the past 25 years, a reoccurring theme is prevalent—management must lead the safety process. Much work has been completed on improving the physical components, e.g. winder plant, locomotives, monowinch pulleys. However, although standards and COPs exist, there seems to be a tendency for noncompliance and a general disregard of many of the rules. In conclusion, supervision must improve to ensure people work to procedures, and equipment/infrastructure must be well installed and maintained, whether in the shaft, haulage or stope.

References

1. Adapted from: Mine death causation factors pie chart from *Creamer's Media Mining Weekly*, February 1–7 2008. p. 8.
2. Maslin, N. Track Work Guideline. Personal Communication. 1999.
3. Zondi, M.M.A. Mine Health and Safety Legislation on Winding Plant and Shafts. *Mine Hoisting 2000*, Johannesburg. The South African Institute of Mining and Metallurgy, 2000, pp. 5–9.
4. Dohm, M. Rupprecht, S.M., Rupert, C., and Govender D. Audit of Current Shaft Systems. *Deepmine Collaborative Research Programme*, December, 2000.
5. Binks, T.J. Underground Transport Accidents—Investigations and Recommendations. *Underground Transport Symposium*, Edgar, R.C.R. (ed.) Johannesburg. Association of Mine Resident Engineers, 1986, pp. 197–217.
6. van der Walt, P.G., Naude, J., Lubbe, S.W., Hutcheson, P.J., Meyer,J.P., and Spencer, K.C. Coupling system and design in use in the Gold and Platinum sector. Safety in Mines Research Advisory Committee, September 2000.
7. Kononov, V A. Personal communication. October, 2002.
8. Working Environment Minerals Industry Safety Hand Book Sect 4.4.3.3, Part 4, January 2004.
9. Page, T.P.T., Morton, G.A., and Vermaak, A. Investigate safety of rail vehicles and systems operation in South African Gold mines. Safety in Mines Research Advisory Committee, May 2005.
10. Rupprecht, S.M., Williams, S., and MacNulty, N. Transportation as associated with different mining layouts. Deepmine Collaborative Research Programme, December, 2000.
11. Moseme, R., Foster, P.J., Demana, R.L., and Rupprecht, S.M. Investigations into the causes of accidents on scraper systems in the Gold and Platinum mining sectors. Safety in Mines Research Advisory Committee, November 2003. ◆