Prerequisite for Safe & Effective Underground Rail-bound Transport

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Kopanang Mine
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Introduction

• The highest source of injuries arising from accidents underground in mines, after falls of ground incidents the tramming activity took second place.
• About 30% of the fatalities and about 50% of injuries were attributable to this source, mainly from derailments, runaways, unstable track work and mechanical failures.
• Improved performance in this area has been achieved by the combined effect of a number of interventions and the work done at Kopanang mine, serves as a case study for other operators on how investment in infrastructure has a pay-off in improved safety and reduced costs.
Introduction

• These are both ongoing areas of concern, and while safety can be maintained by adherence to standards, it is the inverse relationship between the life of a mine and its tramming cost that makes cost-reduction particularly important.

• The relationship is a direct result of the increasing distance over which men, rock and material have to be transported as the workings move away from the point of access.

• The increased trend in legal compliance requirements force users to improve construction standards.
The “Prequel” to Kopanang initiative

• The steps taken to address the problem encountered, at Tshepong mine during the late 1990s, serves as a background insofar as it provides the basis for the interventions which would later be undertaken at Kopanang.

• The problem areas identified at that time included:
  – unacceptable accident statistics
  – excessive repair costs
  – insufficient training
  – inadequate standards
  – absence of control
  – sub-standard track conditions
  – unclear responsibilities
Questions??

• If transport is such a big deal, how much time do you spend on engineering it to be safe & efficient?

• Where is the quickest and easiest place to save money?
  – Haulage maintenance!!

• Do you know why you use what you use?

• Dirt water, biggest contributor to underground tramming & transport accidents / incidents
  – Are yours controlled?
The "Prequel" to Kopanang initiative

- The three years spent on Tshepong Mine, 1996 and 1999 where the following results were achieved.

<table>
<thead>
<tr>
<th></th>
<th>1996</th>
<th>1999</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>34</td>
<td>15</td>
<td>56%</td>
</tr>
<tr>
<td>Construction productivity</td>
<td>5</td>
<td>14</td>
<td>180%</td>
</tr>
<tr>
<td>(m/crew member)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost (R/m)</td>
<td>440</td>
<td>273</td>
<td>38%</td>
</tr>
<tr>
<td>Monthly cost of wheel repairs</td>
<td>70 000</td>
<td>54 000</td>
<td>23%</td>
</tr>
<tr>
<td>(R)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of operating locomotives</td>
<td>71</td>
<td>64</td>
<td>10%</td>
</tr>
<tr>
<td>Tonnes hoisted per month</td>
<td>114 000</td>
<td>141 000</td>
<td>24%</td>
</tr>
<tr>
<td>m² broken per month</td>
<td>24 000</td>
<td>31 500</td>
<td>31%</td>
</tr>
</tbody>
</table>

- The main lessons learned were that:
  - such a project required a long-term commitment
  - significant improvements were possible in the areas of safety, cost and efficiency performance
  - the importance of the work required, needs ongoing reinforcement to ensure motivation
Kopanang’s situation in 2001

• At a Strat session it was identified that the mine needed a serious intervention to save it from the brink of closure

• Several initiatives received impetus
  – Power team training
  – Move centre of gravity
  – Big ore trains
  – People transport systems
  – Drainage systems to dry up the mine
  – Vent strategy
  – Rail track and fleet upgrade and maintenance to give us a cost effective and safe infrastructure
Kopanang’s situation in 2001

• Haulages and crosscuts were muddy, derailments were frequent, and the number of operational locomotives was inadequate due to mechanical and electrical breakdowns.
• Morale among tramming crews was low due to the long hours of work and perceived inadequacy of compensation.
• The production operation was severely hampered by the shortcomings of the tramming and transport facilities, and people were being hurt in accidents.
• The mine’s return air capacity was constrained, and environmental conditions were unpleasantly hot.
• A comprehensive programme was developed to address all of the strategic issues and thereby to extend the mine’s life.
The Context of the work

• Kopanang mine as it is known today produced its first gold in 1984, shaft sinking having begun six years earlier.

• The workings extend to a depth of 2400m below surface and principally exploit the Vaal Reef; a secondary reef, known as the “C” reef, is also mined.

• Stoping takes place over ten levels and is scattered in nature due to the complexity of the geological units and inconsistencies in both their development and their gold-bearing characteristics.

• The programme to address the strategic issues of ventilation, ore handling and drainage, involved the drilling of thirty inter-level raisebore holes, ranging in diameter from 1,8m to 3,0m, and seventeen inter-level NX holes.
The Context of the work

• Rock transport was optimised through the creation of so-called “centre-of-gravity” ore passes. This reduces the tramming distances from loading boxes to main inter-level tips.

• The strategic plan also involved consolidation of stoping to four mining levels on the southwest of the shaft, and two mining levels on the west side of the shaft.

• This concentration of production meant that the rail track quality serving the areas had to be brought up to an acceptable standard if the expectations were to become reality.
Elements in the upgrade programme

**Drying the mine:**

- The mine was hot and wet. If any progress was to be made in improving the condition of track work, then the worst enemy of footwall construction, namely water, had to be defeated.
- The network of drain holes were drilled close to the mining areas to accumulate the water on two levels, namely 53 level for the upper areas and 70 for the lower areas. From there it is piped to the settlers on 73 level.
- The vertical spindle pump installation was improved through the inclusion of a non-return valve and use of a lateral for the inflow into the main column.
- Properly constructed sump excavations were incorporated, deep enough to provide positive suction for the pump and was separated from the drain by a weir behind which mud was trapped.
- Drains themselves were improved through the addition of bund walls to provide adequate capacity.
• **Round sump**

- Removable grid
- Drain inlet
- 1 m dia. Round sump
- Maximum water level: 700 mm
Elements in the upgrade programme

• **Specialist skills:**
  • For the track on 70 level, where the high-speed high-volume “Big Mamma” was to operate, qualified plate-layers were recruited from South African Transport Services (SATS) to construct the Class 1 rail installation which was required there.

• **Introduction of contractors:**
  • Haulages were split between “Main” and “Sub” haulages
  • For the work on the “main” haulages, outside contractors were employed to perform the upgrade. It was felt that their experience would ensure a speedy completion of the work
  • The mine undertook the rehabilitation of the “sub” haulages and the crosscuts as well as all new construction through the dedicated section.
Elements in the upgrade programme

**Construction standards:**

- Tshepong’s standards at that time was used to enhance Kopanang’s standards, which only covered the construction performed as part of the primary development activity.
- However, the passage of time and the influence of local conditions and experience resulted in progressive modifications. This process continues to the present day, adopting suitable technological and design improvements as they arise or are created.
- The full set of applicable standards contains the following items:
  - permanent equipping of a haulage
  - permanent equipping of a sub-haulage (the principal difference between the two lies in the concrete support for the rails in the latter)
  - permanent equipping of a crosscut (fewer and smaller diameter pipes than in a haulage, and concrete thrown across entire width of the excavation, not just below rails)
Elements in the upgrade programme

- **Construction standards:**
  - The full set of applicable standards were developed for Kopanang Mine:
    - permanent equipping of a crosscut top entrance (i.e. no rock tramming takes place here, ballasted foundation for rails without concrete)
    - compressed air and water reticulation standards (includes pipe and valve sizes)
    - drain hole equipping
    - vertical spindle pump installations
    - arresting devices
    - tools and personal protective equipment (PPE)
    - equipment and material (as used by construction crews)
    - precautions to be taken when working in haulage ways
    - track installation
    - locomotive safety checklist
    - hopper safety checklist
    - rolling stock couplings
    - development, equipping and use of tramming spurs
Elements in the upgrade programme

• **Construction standards:**
  
  • The creation of specific standards for construction over and above those being taught to the development crews meant that a purpose-built training facility was also necessary.
  
  • Rail track maintenance remains the responsibility of the Mine Overseer within the boundaries of his section. Should a problem develop which exceeds the ability of the maintenance crew, then the dedicated section provides assistance in the form of a so-called “uplift crew”.
Construction Standards

- **Excavation and construction:**
  
  - To reduce the amount of work required for construction a modification was made to the development drilling round.
  - Sliding rails are installed 2.1m below the grade line;
  - Jump sets are placed 2.0m below it.
  - Temporary track is lifted a further 0.2 metres and
  - The permanent installation is 1.5m below it or 300mm above the temporary track.
**Construction Standards**

- **Excavation and construction:**
  - To put this into context, a fully equipped haulage is also illustrated.

**NB:**
- SURVEY NOTE WILL INDICATE WHICH SIDE PIPES WILL BE SUSPENDED
- 9mm STRAINING WIRE FOR NORMAL CABLES AND 5mm FOR INSTRUMENTATION
- CABLES SUSPENDED FROM PIGTAIL EYEBOLTS AT 5.0m INTERVALS
Construction Standards

- **Sleepers, track work and ballasting:**
  - The condition of track work is a reflection of the environment in which it has been constructed, and of the quality of the workmanship that went into it. The main factors are:
    - uncontrolled water
    - inaccurate geometry
    - excessive joint gaps
    - poorly compacted ballast
    - quality of maintenance
  - Most of these factors can be controlled by good supervision, correct design and adherence to standard procedures.
  - A careful selection of the components can also achieve the aim of low maintenance, then in terms of overall cost per tonne transported, some sort of premium can be justified when evaluating the prices of competing alternatives.
Construction Standards

• **Sleepers:**
  - Aside from the environmental aspects of consuming hardwood at an unsustainable rate, wooden sleepers have been superseded by concrete for a number of reasons.
  - Chief among these is the ability to design characteristics into the concrete sleeper to meet the requirements for an efficient and low maintenance installation.
  - The so-called 10-tonne pre-stressed concrete sleeper possesses the following advantages:
    - its mass provides stability
    - pre-stressing provides it with durability
    - the moulded construction ensures that sleepers are identically shaped
    - casting provides built-in cant for better wheel contact and less flange wear, therefore enhanced traction and extended wheel life
    - casting ensures exact gauge
    - gauge widening can easily be catered for through the use of gauge plate inserts (GPI)
    - connectors can be installed more efficiently than dogspikes; a resilient pad provides a damping effect to reduce vibration
Gauge plate insert (GPI)

Resilient pad
Construction Standards

• Rail attachments and rails:
  • Pandrol clips were used to attach the rails to the sleepers, but in their original design, a derailment could have the effect of tearing many of them loose.
  • A design modification has reduced this possibility. The Mineclip has replaced the Pandrol.
  • It is shown in the photograph below.
Construction Standards

- **Rail attachments and rails:**
  - Fishplate bolts are now installed with spring washers and not locknuts. Not only is this a cost-saving, but the problem of them becoming loose over time is also reduced.
  - The construction standard covering this aspect is included below.
  - 30kg/m rail is the smallest size that can effectively be applied in a main tramming environment. It will work with the 10-tonne sleeper, fishplates fit the web well and joints can be properly supported.
Construction Standards

- **Trackwork:**
  - The turn radius for crosscut breakaway rail switches was changed (30m) after it was determined that excessive wear on hopper wheel flanges was attributable to the short (4.8m) switches which were being installed.
  - Initially without taking the excavation dimensions into account, so to achieve the necessary clearances, several crosscuts needed sidewall sliping.
  - The modification to the standard was effective in reducing the wheel flange wear rates, but it shows that all aspects of a change need to be considered before the final determination is made.
  - Where sharp radius curves are unavoidable, rail flange lubrication provides a reduction in wear, and thereby enhances safety.
Construction Standards

• **Ballast:**
  - Ballast provides for stability of the rail track installation, distribution of the load, some elasticity and drainage.
  - The size range of the material should be small enough to guarantee that point loading cannot occur.
  - The material chosen should be easy to maintain.
  - Rather than utilise the randomly sized product from development, long-term benefits have been enjoyed using 25x50mm washed ballast.
Elements in the upgrade programme

- **Equipment improvements:**

  - Close attention to the construction activity inevitably brought the rolling stock into sharper focus.
  - Changes and improvements were made to buffers, couplings, lubrication seals for hopper wheels, and the lubricating grease itself, as well as to the locomotive motors.
Equipment improvements

- **Hopper axles:**
  - Axle failures were found to be the result of water and mud ingress into the wheel bearings.
  - Over a tramming distance of the order of 6km bearings became hot. If they were then plunged into cold water due to uneven track work and poor drainage, and the water became mixed with mud, a very effective grinding paste was then created with severe wear results.
  - A more effective seal, used with a more tacky grease produced a measurable reduction in the number of axle failures. In addition, protective plate work has been added as shown in figure 6.
  - The wheel bearing is enclosed by a strap; splash plates and a bottom plate serve to reduce the accessibility of water to the wheel bearings.
**Equipment improvements**

**Hopper buffers, shackles and pins:**

- Until 2003, hoppers were fitted with “Kudu” type buffers. These have a relatively large number of components, and require more maintenance than simpler designs.
- A semi-automatic coupler, known as the “Bison” replaced the “Kudu”.
- It consists of a solid casting and the latch is an integral part of it. Manual operation is required to release the pin, but connection takes place when the shackle is pushed into the body, thereby removing the latch which then drops the pin into place under gravity.
- A reduction has been noted in hand and finger injuries, and less maintenance is required.
- In the illustration below, the carrying handle of the shackle and the sling suspension for the pin are shown. These provide protection from hand injuries during the coupling operation.
Equipment improvements

- **Trunnion plate:**
  - Prevention of finger injuries was also the driving force behind a modification to the trunnion.
  - The addition of a plate effectively prevented fingers being inadvertently caught in it during hand-shunting activities.
Equipment improvements

- **Bucket stoppers:**
  - Overtipping of the bucket is prevented by the addition of brackets.
Equipment improvements

- **Hopper repair process:**

  - Minor hopper repair had been undertaken underground, but breakdown repair was dealt with as an off-site activity performed by contractors.
  - The length of time that hoppers remained out of use in this arrangement resulted in a reluctance to send them for repair.
  - Thus leakage of mud and ineffective rock transport was widespread.
  - Following the establishment of a hopper repair facility on surface, the off-site contractors were replaced with the labour force already in service and a scheduled service-exchange system was introduced.
  - Initially, it was provided for the stoping sections, but it has since been extended to include the development sections as well.
  - Apart from the expected improvement in rock transport effectiveness, that is from trains running with a full complement of hoppers, there is less spillage and haulages are cleaner as a result.
  - Measurable financial benefits have also accrued as shown in the tabulation below.
Equipment improvements

**Hopper repair process:**

- Measurable financial benefits have also accrued as shown in the tabulation below.

<table>
<thead>
<tr>
<th>Cost elements</th>
<th>On-site</th>
<th>Off-site contract</th>
<th>On-site advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>R1483</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>R9867</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>R11350</td>
<td>R22000</td>
<td>48%</td>
</tr>
<tr>
<td>Turn round time</td>
<td>1 day</td>
<td>3 days</td>
<td>66%</td>
</tr>
</tbody>
</table>

KOPANANG MINE - HOPPER WHEELS

- Linear (HOPPER WHEELS)
Equipment improvements

- **Surface mock-up:**
  - Included in the surface repair facility is a mock-up of an underground tip. It serves two purposes.
  - Refurbished hoppers are tested on it before being passed by the quality control process for deployment underground.
  - It is also used for training purposes.
**Equipment improvements**

**Locomotive motor improvements:**

- With a fleet of 120 locomotives in 2002.
- As a result of water ingress, bearing and armature failures meant that about 30 motors per month were having to be replaced.
- In addition some modifications were also made to the 75D locomotive motor.
  - These were a conversion to a 12-ball bearing on the drive side;
  - A breather to draw off carbon dust from the brushes which had an additional effect of cooling the motor;
  - Changing the brush gear from spring-feed to constant-feed which provided better contact on the Commutator and longer brush life;
  - A field coil conversion utilising a more water-resistant resin and longer service interval.
- The effect of these changes have been to reduce the number of motors requiring replacement to six per month, and it was been possible to reduce the fleet size to 101 due to greater efficiency.
Equipment improvements

- Locomotive motor improvements:

KOPANANG MINE - LOCO MOTORS

- SPENT
- DC MOTORS
- Linear (DC MOTORS)
Equipment improvements

- **Locomotive wheels:**
  - No modifications were made to locomotive wheels; however, longer life has resulted from the improvements to the railtrack installation and to the changes in the standards, for example, the longer switches.
## Equipment improvements

**Locomotive & Hoppers:**

- In average cost terms, these achievements are represented in the following summary.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hopper wheels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average number per month</td>
<td>120</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Rate per unit</td>
<td>R 2 800</td>
<td>R 2 800</td>
<td>R 2 800</td>
</tr>
<tr>
<td>Average cost per month</td>
<td>R 336 000</td>
<td>R 280 000</td>
<td>R 252 000</td>
</tr>
<tr>
<td><strong>Locomotive wheels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average number per month</td>
<td>14</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Rate per unit</td>
<td>R 6 000</td>
<td>R 6 200</td>
<td>R 6 800</td>
</tr>
<tr>
<td>Average cost per month</td>
<td>R 84 000</td>
<td>R 62 000</td>
<td>R 54 400</td>
</tr>
<tr>
<td><strong>Locomotive motors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average number per month</td>
<td>14</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Rate per unit</td>
<td>R 22,143</td>
<td>R 28,000</td>
<td>R 28,000</td>
</tr>
<tr>
<td>Average cost per month</td>
<td>R 310,000</td>
<td>R 280,000</td>
<td>R 224,000</td>
</tr>
<tr>
<td><strong>Average total cost per month</strong></td>
<td>R 730 000</td>
<td>R 622 000</td>
<td>R 530 400</td>
</tr>
<tr>
<td><strong>Improvement year-on-year in Rand terms</strong></td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Elements in the upgrade programme

- **Piping:**
  - Steel pipes previously used for chilled water, drain water and compressed air in main haulages have been replaced by UPVC.
  - Not only is the internal friction lower, but the lack of corrosion means that they need to be replaced less frequently, and having less mass they are easier to change.
Elements in the upgrade programme

- **Safety Practices:**
  - A chain placed across the entire width of the haulage, from which a “stop” sign is suspended has been introduced as a replacement for the portable sign which was erected between the rails.
  - This was the response to the realisation that the portable sign was not easily seen by locomotive drivers, and a number of injuries had resulted from collisions.
  - As a further precaution, track maintenance crew members retire to cubbies before a train is allowed to pass them, rather than merely standing beside the track.
  - Haulage maintenance also includes making safe the sidewalls and hanging by barring and this work is performed by the construction crews.
Elements in the upgrade programme

• **Training:**
  
  • Kopanang Mine established its own construction crews under a mine Overseer section
  
  • Suppliers were involved with the best selection of what we wanted to do.
  
  • The fleet and equipment was supplied according to standard.
  
  • The crews were trained in the Training Centre for 4 weeks on what we wanted, by doing it practically and also getting their feedback and inputs of what they wanted (e.g. like scaffold casting plates and bund walls)
Elements in the upgrade programme

• **Process of construction:**
  - Find the Rails
  - Remove the mud & dirt to F/W (60m/mth)
  - Straighten rails & replace fish plates and bolts
  - Install drain mould & bund wall
  - Balast, line and tamp
  - Final clean up
Elements in the upgrade programme

- Labour efficiency of crews:

Kopanang Mine
Rail Maintenance

<table>
<thead>
<tr>
<th>Months</th>
<th>Metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul-06</td>
<td>2000</td>
</tr>
<tr>
<td>Aug-06</td>
<td>3000</td>
</tr>
<tr>
<td>Sep-06</td>
<td>4000</td>
</tr>
<tr>
<td>Oct-06</td>
<td>5000</td>
</tr>
<tr>
<td>Nov-06</td>
<td>6000</td>
</tr>
<tr>
<td>Dec-06</td>
<td>7000</td>
</tr>
<tr>
<td>Jan-07</td>
<td>8000</td>
</tr>
<tr>
<td>Feb-07</td>
<td>9000</td>
</tr>
<tr>
<td>Mar-07</td>
<td>10000</td>
</tr>
<tr>
<td>Apr-07</td>
<td>11000</td>
</tr>
<tr>
<td>May-07</td>
<td>12000</td>
</tr>
<tr>
<td>Jun-07</td>
<td>13000</td>
</tr>
<tr>
<td>Jul-07</td>
<td>14000</td>
</tr>
<tr>
<td>Aug-07</td>
<td>15000</td>
</tr>
<tr>
<td>Sep-07</td>
<td>16000</td>
</tr>
<tr>
<td>Oct-07</td>
<td>17000</td>
</tr>
</tbody>
</table>

Notes:
- Metres: 0.0 to 60.0
- m/Man: 0.0 to 60.0

Legend:
- m/man
- metres
Results

- Monthly hoisting at Kopanang is of the order of 200,000 tonnes, although up to 265,000 tonnes has been achieved.
- Only about 40,000 tonnes per month of this total is waste rock.
- Simple arithmetic provides the result that each underground locomotive moves on average about 2000 tonnes per month, or about 90 tonnes per day.
- Over the course of the changes and improvements, the number of derailments has reduced by about 30% and a dramatic reduction in the number of accidents has been achieved.
- To indicate the scope of the work within which these achievements have occurred, the table below shows what has been done.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Main haulage metres upgrade</td>
<td>35,969</td>
</tr>
<tr>
<td>Sub haulage metres upgrade</td>
<td>24,654</td>
</tr>
<tr>
<td>RAW metres upgrade</td>
<td>690</td>
</tr>
<tr>
<td>Crosscut metres upgrade</td>
<td>44,032</td>
</tr>
<tr>
<td>Total metres upgrade</td>
<td><strong>105,345</strong></td>
</tr>
</tbody>
</table>
Results

• The savings have been achieved as a result of investment in improved track work, but for a full financial analysis to be performed, the savings attributable to the improved safety performance would also have to be included.

• Suffice to say that this work, together with the other initiatives has enabled Kopanang to extend its profitable life for at least another twelve years.
Results

- **TRAMMING AND TRANSPORT TREND**
Elements in the upgrade programme

• **Before improvements:**
Elements in the upgrade programme

- After improvements:
Conclusion

- Proper construction and maintenance is a prerequisite for safe and efficient transport.
- Kopanang experienced an increase in production with less equipment required and a significant reduction in tramming & transport incidents.
- The benefits from safe and efficient rail bound operations outstrip the costs.
- Good housekeeping, better moral, and less fatigued workforce is our most valuable asset.
QUESTION??

Can you still afford not to improve on your transport section??