Investigate the effectiveness of the Smart Rail Measuring System at Tumela Mine 15 East Shaft

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Abstract
The measurement of rock tonnages in underground hard rock mines has traditionally been conducted using conventional manual methods. These results are incorrect and management decisions are made on this incorrect information and employees are paid bonuses on the incorrect tonnage figures. New technologies now exist which offer a potentially more accurate method to obtain this information in real time. These techniques include the smart rail system currently being used at Tumela Mine 15 East Shaft. This study will compare the smart rail system against the traditional manual method of tonnage measurement. The study is to determine the effectiveness of the smart rail system on the basis of reliability, effective production management and ease of use by comparing the system with the traditional way of tonnage measurement. The results of the assessment could be used to make a decision to eliminate the manual system of tonnage measurement at Tumela Mine 15 East Shaft if they can be seen to be fit-for-purpose and more accurate.

Keywords: Tonnage measurement, Smart rail, manual system, production management.

Introduction

Mine Background
Tumela Mine is located in the Limpopo province in South Africa, between the towns of Thabazimbi and Northam. Tumela Mine is one of the Anglo Platinum operations in South Africa and the mine is 100% owned by Anglo Platinum which is the world’s largest platinum producer “as discussed by Anglo Platinum [1].”

Production
Tumela Mine has two production areas namely Tumela lower mine and Tumela upper mine.

The current working mine infrastructure consists of three vertical and four decline shafts used to transport rock, workers and material. The 15 East Shaft is one of the four declines

Mining is carried out between 160m and 400m below surface. The ore body is extracted using underground mining methods, mostly through conventional breast stoping with strike pillars “as discussed by Anglo Platinum [1].”

Productivity declined from 5.8 m2 per operating employee, to 4.2 m2 per operating employee in 2012 as a result of the 2012 Rustenburg mine workers strike that spread to Tumela Mine. Tumela Mine was voted one of the worst performing Anglo Platinum operations in 2012; “as discussed by Ken [5].” In 2013 the management of Tumela Mine was restructured, a new General Manager was appointed together with three new Production Managers and one Business Improvement Manager.

Project background
Mine management at Tumela requires daily tonnage information derived from hoppers and skips tallies. The measurement of production tonnages at Tumela Mine 15 East Shaft has traditionally been conducted by manually counting the number of hoppers loaded and tipped per shift. Accuracy is dependent on the impartiality and diligence of personnel involved. An employee (tip attendant) will be appointed to stand just before the main tip to count the number of hoppers tipping at the main tip. To covert the number of hoppers counted to tonnages the following formula is used:

\[ \text{Tonnages} = \text{Hopper factor (tons/hopper)} \times \text{Number of hoppers} \]

At Tumela Mine the hopper factor of 5.4 is used to convert the number of hoppers to tonnages and to get this factor an estimated rock density was used. Changes in temperature and pressure have been shown to produce small, but measurable changes in density; “as discussed by Brisnar [3].” At 15 East shaft, a constant rock density of 2.444 is used to calculate the hopper factor. Therefore the
hopper factor value of 5.4 used is also an “estimate”.

Human error also plays a role in getting inaccurate results when using the manual tonnage measurement system. The employee counting the number of hoppers may over count the number of hoppers for bonus purposes or under count the number of hoppers.

Another common human error is to count a hopper as one full hopper when the hopper is not full. This is illustrated in Figure 1 below where a mechanical loader was used to load the hopper in a development end. The two pictures show the same hopper from different points of view. The picture on the left side will be the tip attendant’s point of view when counting the number of hoppers loaded and the picture on the right side shows the same hopper from the top view.

![Figure 1: Hopper loaded with broken rock](image)

Inaccurate tonnage measurement led to the following issues at Tumela Mine prior 2013; “as discussed by Swart [2]”.

- Inaccurate production measurement
- Production bonus paid but not on actual output
- Ineffective shift monitoring and supervision
- Hopper loading not optimized
- Inefficient planning for labour, surge capacity and equipment
- Low efficiency of the plant due to the plant not getting a constant feed
- Increased mining costs
The new management that was appointed in 2013 adopted a new slogan, “You cannot manage what you cannot measure”. They introduced a new system of measuring tonnages. The smart rail system was introduced at Tumela Mine 15 East Shaft in October 2013 in two working levels. To date both the manual and smart rail system are being used at 15 East Shaft, each serving the same purpose of measuring tonnages.

**Problem Statement**

Tumela mine management identified shortfalls of the traditional/manual method of counting tonnages.

**Materials and Methods**

The project was based on investigating the effectiveness of the smart rail system compared to the traditional manual system. The way the smart rail system operates was investigated and the results were analyzed. This study compares the smart rail system against the traditional manual method of tonnage measurement. The comparison will help to determine the effectiveness of the smart rail system on the basis of reliability, effective production management and ease of use. The tonnage data measurements from the survey department will be used as a benchmark for the two methods of tonnage measurement. Due to difficulties in finding exact costs of running the smart rail system, costs analyses between the two systems does not form part of this study.

**Objectives and Methodology**

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<th>Methodology</th>
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<td></td>
<td>➢ Underground visit – observations and pictures of hoppers loading</td>
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**Literature Survey**

The smart rail system has been used underground for a couple of years and the system have been found to be very effective in counting tonnages in hard rock, track bound underground mines. The literature study will investigate how the system works, from how the tonnages are measured and how the information is sent to surface. The benefits of the smart rail system at two South African gold mines will also be reviewed.

**Smart Rail System**

In October 2013 the Smart rail system was implemented at 15 East Shaft on two working levels. To eliminate the manual system and implement the smart rail system on all working levels of 15 East Shaft, an investigation had to be carried out on the effectiveness of the smart rail system.
Accutrak is an electronic and Software Company that designs, develops and supplies unique products to optimize systems of the underground mining industry. Accutrak’s mission is to offer state of the art electronic hardware devices to the underground mining industry to improve and manage production through modern software databases, thereby providing real-time communications and management tool interfaces with live displays; “as discussed by McHardy [6]”.

In addition, integration of smart phone technology provides live dash boards and other live reporting tools. The smart rail system is one of the products of Accutrak. Smart rail is a rail bound tracking and weighing system that monitors and reports volumes of ore mined daily, for the mine as a whole, and each shaft, level works area and box. Software solutions company, Mine ware Consulting, has partnered with tracking solutions company Accutrak to implement a system which allows mines to analyses the amount of rock being transported underground and the grade and movement of each load; “as discussed by McHardy [6]”.

**How the Smart rail system works**

A hopper data device (HDD) is placed on every loco and on all the hoppers (Figure 2). A sign post (similar to a HDD) is installed on each box front in the cross cut. Each HDD has a radio frequency which gives each hopper an identity. When the hopper is loading at the chute, the sign post activates the HDD on each hopper that is loading and the HDD reads and stores the information picked from the sign post so that the ore in each hopper can be matched with the box hole in which the hopper loaded from. With the radio transmitters attached to the boxes, a hopper becomes the courier of information.

Sign posts are used when they are only one box front in each cross cut and this is the case at 15East shaft. Figure 3 also describes data capturing at the loading point of ore or waste (box front). This data collecting system at the box hole is called the beacon and trigger system and this is the system is used when they are more than one box fronts in a cross cut. The data is collected at the loading box that has a unique ID. As soon as the loading box door opens, it triggers the sensor on the door and the sensor sends a signal via radio frequency identification (RFID) to a beacon with a unique ID that in turn sends a signal via RFID to a Hopper Data Device (HDD) that is mounted on the hopper.

![Figure 2: An HDD at the bottom of a hopper](image-url)
The Smart rail Loco weigh bridge system is located in the haulage rails (Figure 4), as close as possible to the main tipping point. The weighbridge is equipped with an antenna, strain gauge, hopper detecting device, cables and a display unit. The strain gauge and the HDD are placed on the rails across the antenna.

When the hoppers are loaded from a box front in a crosscut or from a development end, the loco will transport the loaded hoppers to the tipping point. As the hopper crosses the weighbridge, its mass, identity and place of origin is recorded.

At the weighbridge as each loco and hopper passes, the weight of the loco and hopper causes strain on the rails and the strain gauge measures the strain and this data is sent to the antenna. This whole process of sending data from each hopper’s HDD or loco’s HDD to the antenna must be done in less than ten seconds. For this reason all weighbridges are situated in a straight path of the haulage. If a hopper takes more than ten seconds on the weighbridge, the hoppers that will follow will not be detected and the system will have to be re-started manually. The antenna will send the data to the display unit through the cables.

The display unit sends the information received to the internet pad and the internet pad sends the data to surface. The tonnage data is accumulated on the internet pad underground and is then transferred to software giant Microsoft’s standard query language database on
surface, where the Mine software system interfaces with Smart rail. The interface allows mines software to analyze the amount of rock being transported underground in real time.

The final report on surface of the data sent from underground will show the ore source (shaft name, working level, cross cut), loco number, number of hoppers (loaded or/and empty) on each loco, date and time at which each loco passed the weighbridge, tons per loco and total tones that passed the weighbridge for that shift. The tones shown on the report include the weight of the loco and the hoppers, therefore to get the actual tonnages of ore the weight of the loco and the hoppers has to be subtracted.

The smart rail system also offers a single reporting platform in the form of liquid crystal displays (LCD) which are mounted at shaft access points and management offices. This display portal offers a live report of the actual production as it takes place in the underground environment. This allows management to take immediate action should they see that there is a problem on a particular level/section.

The live display allows the entire production staff from the Mine Manager to the Guard car Operator to get a live picture of the tons delivered in real time. Accutrak operation manager, Ian McHardy, explained that: “since the system now provides an accurate real-time picture of the production, it consequentially leads to employee trust and competition across production levels which then lead to increase in production”. McHardy also added that: “since production personnel are now able to accurately monitor the productivity of their vehicles, they can with confidence remove un-used locomotives from a production section”.

**Mines using the Smart Rail System**

A gold mine in South Africa in the Gauteng Province, one of the biggest gold producers across the globe, started using the smart rail system on one of its production level. Over the past six years the South deep mine has installed the smart rail system on almost every production level. The following are some of the benefits that the mine has experienced from using the smart rail system thus far:

**Production Management**

- Accurate production measurement
- Continuous shift monitoring – better control and supervision.
- Alignment of production team goals
- Mining contractor measurement
- Pay production bonuses on actual output
- Accurately measures contractors’ performance and production output
- Receive production results in real time
- Cross tramming eliminated

**Asset Optimization**

- Redeployment/removal of excess loco’s
- Ensure that loco’s tram with the correct quantity of hoppers
- Optimize hopper loading
- Accurately measure trips per loco per shift.

**Metal Accounting**

- Grade Control improved
- Mine Call factor management

In addition, the system is capable of reporting which locomotive battery the locomotive is operating. This allows engineers to monitor the cycle of batteries, offering better control. This leads to increased battery life and less controller and locomotive motor failures.

Another South African gold mine in the North West Province implemented the smart rail system in 2009. The system was implemented in attempt to decrease the number of lost blasts as a result of late identification and addressing of problems in production areas. The mine management was pleased with the smart rail results and after a year and a half Accuchip was also implemented at this
mine. Accuchip is an underground material car tracking system that operates similar to the smart rail system. The materials car tracking system consists of Accuchip based radio frequency (RF) tags being attached to material carts together with RF tag readers that are strategically distributed throughout the mine. The RF tag data received by the RF tag readers allows tracking and optimal management of material carts. The material car handling system is available in the following two options “as discussed by Hustrulid and Bullock [4]”.

The first option is to ensure that the required material arrives at the intended destination as planned. Production delays can arise as a result of delays to the material transport process.

The second option is to obtain direction of travel information on the respective levels by virtue of the sequence of events on that particular level. At this gold mine, only the first option of the material car handling is being used.

This Accuchip system also gives specific information like how long these specific vehicles have been present on each level and tracking of the vehicles time spent in repair bays. In 2013, up to 55 un-used vehicles from the production section where removed from the underground working stations saving R750 000 per month; “as discussed by Hustrulid and Bullock [4]”.

Results

Traditional/Manual method Results

Graphs in Figure 5 & Figure 6 were drawn for half level 10 using data extracted using the manual method of counting. The graphs show the daily tramming for the day and night shift for the whole half level. The graphs also compare the planned progress versus the actual progress and it also depicts the variance between the two.

![Figure 5: Half level 10 daily tramming data (January 2013 day shifts)](image)

![Figure 6: Half level 10 daily tramming (January 2013 night shifts)](image)

The accuracy of these values is dependent on the human factor. From the graphs above it can be seen that the tonnage variance is relatively high for both shifts. Since this data is for the whole half level one cannot identify which section is underperforming and this
leads to poor shift supervision. From this data the management does not know if the hoppers are being fully optimized or not. Management can only get tonnage data at the end of the shift or the next day. Therefore, if there is a problem that disrupted production that could have been fixed during shift time, in this case it can only be attended to after the shift or the next day.

**Survey data analysis**

Before mining takes place, the surveyors give the estimated progress meters for each section for each month. In January 2013 the planned progress for half level 10 was 1 574m², using a stoping width of 1.3 meters and density of 2.444 the expected tons were 5 000 tons as shown in Error! Reference source not found. below. The expected tons include ore losses and the planned progress of 4 760 tons, exclude losses. Comparing the planned tons for half level 10 to the actual progress it shows more than 80% variance. According to one of the 15 East Shaft employees, production bonuses were paid for this month to some of the sections in this half level.

**Table 2: Survey tonnage data for half level 10 (January 2013)**

| Survey department data (half level 10) (January 2013) |
|-----------------|-----------------|
| Planned Progress (m²) | 1 574 |
| Stoping width (m) | 1.3 |
| Density | 2.444 |
| **Total tons** | **5 000** |

| Logistic department data (half level 10) (January 2013) |
|-----------------|-----------------|
| Planned Progress (tons) | 4 760 |
| Actual Progress (tons) | 865 |
| Variance (tons) | 3 895 |

**Discussion**

Graphs in Figure 7 & Figure 8 are depicted data extracted from the smart rail data reports. The graphs show tons of broken rock trammed every hour of the day shift. The graphs also show what time tramming started and stopped.

The following assumptions were made:

**Table 3: Assumptions**

<table>
<thead>
<tr>
<th>Level 8 West –</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loco (T1700)</td>
<td>10 000</td>
</tr>
<tr>
<td>8’ Hopper</td>
<td>2 000</td>
</tr>
<tr>
<td>Guard cart</td>
<td>2 200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32 200</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 9 West –</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loco (T1200)</td>
<td>10 000</td>
</tr>
<tr>
<td>9’ Hopper</td>
<td>2 000</td>
</tr>
<tr>
<td>Guard cart</td>
<td>2 200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32 200</strong></td>
</tr>
</tbody>
</table>
The traditional/manual method of tonnage counting has been used for years at Tumela Mine. A closer look at this method has shown that this method is an ineffective way of counting tonnages. Accuracy of this method is depended on the impartiality and diligence of personnel involved. It is not possible to determine the performance of each section from the manual method data. The tonnage data only gets to surface after the shift has ended and management cannot determine if the hoppers are being optimized.

Inaccurate tonnage measurement has led to issues like inaccurate production measurement, production bonus paid but not on actual output, ineffective shift monitoring and supervision, hopper loading not being optimized, inefficient planning for labour, surge capacity and equipment, and all this resulted in increased mining costs at Tumela Mine.

The smart rail system is a new technology used in rail-bound mines to count tonnages. In October 2013, the smart rail system was implemented at Tumela Mine 15 East Shaft on two working levels. To eliminate the manual system and implement the smart rail system on the whole of 15 East Shaft, an investigation had to be carried out to determine the effectiveness of the smart rail system.

The results of this report have shown the inconsistencies with the traditional method of tonnage counting which led to the inaccurate tonnage measurement mentioned above. On the other hand, the smart rail system data has been proved to have more reliable tonnage results than the traditional method. Together with the weight of the hopper (to and from the tip), the smart rail tonnage report also gives the date, shift, time and the name of the box from which the hopper loaded from in real time.

**Conclusion**

The smart rail system is more reliable, easy to use and effective in management of production.

**Acknowledgments**

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References

1. Anglo Platinum induction presentation for vacation students 2013