Optimization of the loading and hauling fleet at Mamatwan open pit mine

by S.V. Mkhatshwa*

Paper written on project work carried out in partial fulfilment of B.Sc. Eng. (Mining Engineering)

Synopsis

The purpose of the study was to investigate the factors which affect the performance of the loading and hauling fleet and also find possible solutions to eliminate these factors, so that the daily tonnages required could be produced .This is due to the high demand of manganese required by clients.

The investigation strongly focuses on the performances of the three 777D Caterpillar trucks and the R984 C Liebherr Litronic Hydraulic Excavator.

In the content of the study, these machines are used to remove and move the low grade manganese (also known as the top cut overburden) in order to expose the high grade manganese from north pit to dump 4.

The objectives of the project were to determine the actual performance of the loading and hauling fleet per shift, compare the actual and the theoretical performance and identify areas that need to be improved.

To achieve the goals set for the project, a number of activities were carried out.

- Perform a time study to compare the performance of the loading and hauling fleet with the manufacturer specifications
- Match the equipments analysis for Loading and hauling
- Road conditions analysis
- Rolling resistance and Road Gradients analysis
- Operating cost analysis.

Introduction

Mine background and general information

Mamatwan Mine in an open pit mine located some 80 km by tar road north-west of Kuruman in the Northern Cape, approximately 600 km from Johannesburg, South Africa. It forms part of the Hotazel Manganese Mines which are operated in a joint venture between BHPBilliton (which has 60% share) and Anglo American (which has 40% share). Mamatwan Mine employs 505 people including full-time employees and contractors. (Van Antwerpen, 2004)

Geology

The manganese mineralization is hosted by the Hotazel Formation of the Postmasburg Group (Transvaal Supergroup) and occurs as stratiform bodies in the south of the basin and northwards starts to be interbedded with banded ironstone formations. The Kalahari Manganese Field with specific reference to the Mamatwan type ore (rich in a braunite–kutnahorite mineral assemblage) represents approximately 97% of the total manganese resource of the Kalahari deposit. (Figure 1.)

The Mamatwan manganese deposit forms part of the Hotazel Formation of the greater Postmasburg Group—Transvaal Super Group. The Hotazel Formation is a relatively flat dipping manganese horizon of stratiform chemical origin and attains a thickness of 26 metres. (Van Antwerpen, (2004.)

At Mamatwan manganese mine, the manganese layer is 37.5 m thick. It is subdivided into an 18.5 m thick upper uneconomic zone containing 30% manganese with a Mn/Fe ratio of 5, and a lower economic zone which is 19 m thick and contains 37.1% manganese with a Mn/Fe ratio of 8. The ore consists of banded, very fine-grained braunite-kutnahorite lutite containing concretionary ovoids, laminae and lenticles of Mn-calcite with which hausmannite is commonly associated. Subordinate amounts of hematite, jacobsite, and rhodochrosite are also present. The relatively high Mn/Fe ratio of the economic zone makes the ore very suitable for the production of high manganese (76% Mn) alloys. The relatively large carbonate content of the ore, reflected in the CO_2 content of 12 to 16%, makes it virtually self fluxing (Van Antwerpen, (2004.)

* *School of Mining Engineering, Faculty of Engineering and the Built Environment, University of the Witwatersrand.*

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Figure 1—Geographical position of the Kalahari Manganese Basin, showing the position of Mamatwan Mine (Van Antwerpen, 2004)

Mining

Mamatwan Mine is a conventional opencast operation in that the overburden is removed to uncover the manganese orebody using a truck and shovel fleet. The orebody is then drilled and blasted (Van Antwerpen (2004.)

Removal of the overburden is done in stages, where the Kalahari Formation is removed in 3 benches, namely the Sand bench on top, 6 metres high and free digging. That is followed by the Top lime bench, also 6 metres high and consists of soft calcrete which has to be blasted. It is followed by the Middle lime bench, 31 metres high consisting of hard calcrete, gravel and clay. However, this bench is currently being split to accommodate the height of the bench as the COP for strata control indicates that the height of the benches should not exceed 23 m. The lowermost bench for stripping overburden is the Top cut bench, 18.5 metres high, consisting of low grade manganese of the Hotazel Formation. Manganese ore is mined in a single bench 19 metres high. A bench width of 30 metres is used to give enough space for the machines to operate safely and to have sufficient ore insight. (Van Antwerpen 2004.) (Figure 2.)

Hauling of the overburden and ore is done using 80- and 90-ton rear dump trucks (777 Caterpillars). Overburden is either backfilled into the pit, or used to flatten the slopes of existing dumps. The ore is hauled to the 'in-pit' crushing and conveyor system. Mined manganese ore is loaded and hauled from the face to an in-pit primary crusher where it is crushed to -100 mm. The crushed ore is conveyed along a 2 kilometre belt to the primary stockpile. From there the ore is moved by conveyor belt to a secondary crusher and wet screening plant producing lumpy ore (-63 mm to + 10 mm in size), containing 37 to 38 per cent manganese, and fines (-10 mm in size) with a manganese content of 35 to 37 per cent (Van Antwerpen 2004.)

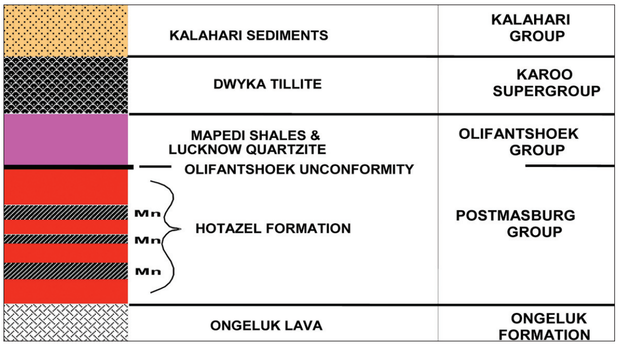

Figure 2—Geological formation of the Mamatwan manganese (Van Antwerpen 2004)

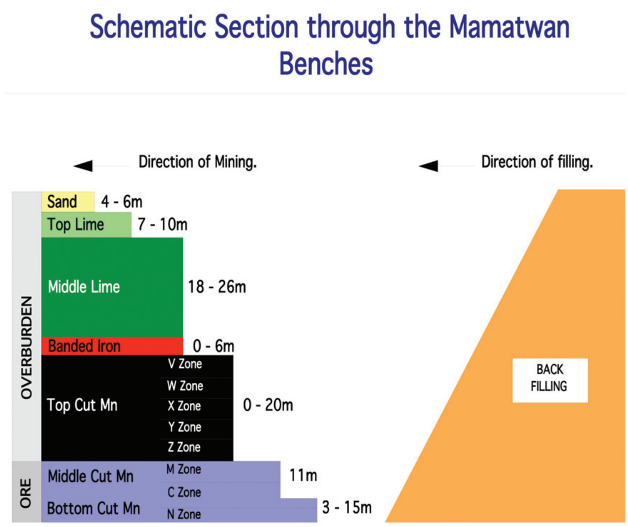

Figure 3—Section through the Mamatwan mine benches (Van Antwerpen 2004)

Mineral extraction

Initially Mamatwan ore was produced only for the local ferro-alloy industry, but exports of beneficiated ore began in 1964 through the harbour at Port Elizabeth. The rest of the ore is railed to ferroalloy plants at Meyerton and Newcastle (Van Antwerpen, 2004.)

The iron content of the lumpy ore varies between 4 and 5 per cent, making it a product with relatively high manganese to iron ratio, very suitable for the production of alloys containing more than 78 per cent manganese. Carbonates present in the Mamatwan ore, reflected in relatively high CaO, MgO, and CO_2 contents, result in it being virtually self-fluxing. The phosphorus content does not exceed 0.05 per cent, ensuring that manganese alloys with less then 0.1 per cent phosphorus can be made by standard production methods in either blast or electric furnaces. A further advantage of the ore is the low aluminium contents, which affords easier smelting, especially in blast furnaces using coke with high ash content. Mamatwan ore is also most suitable for refining when converting silicon-manganese to low carbon manganese alloys. The reactivity of the ore has a greater dependence on its mineralogical rather than bulk chemical composition for specific applications (Van Antwerpen, 2004.)

The natural Mamatwan ore ideally lends itself to upgrading by technologically advanced beneficiation processes. The dense medium separation plant can be used to beneficiate the ore prior to sintering. During the sintering process the ore is calcined and partially reduced. The resultant product is both physically strong and chemically stable. Bucket wheels reclaim the sintered product, which ensures a blended, consistent product as well as minimizing fines generation. The final product is transported to the rail loading facility. Sintered manganese ore has a number of distinct advantages over the natural ore when used in electric furnaces for ferroalloy production. It results in greater furnace productivity through reduced electrical energy and electrode consumption; reduced carbon reductant usage per ton of metal produced; and reduced gas evolution from the furnace. The use of sintered ore should also result in lower furnace maintenance costs and increased furnace availability. (Van Antwerpen 2004.) (Figure 4.)

Project background

Manganese mining is one of the major mining activities taking place within the Kalahari region. Mamatwan Mine is currently the only open pit manganese mine in the region. According to the mine planners, this mine could produce up to 3.2 million tons per year if operating to its full potential. But due to factors which affect the performance of the loading and hauling, such as road conditions, matching of haulers and excavator buckets and other factors, Mamatwan mine produces a maximum of 2.1 million tons per year. (Bezundeinhout, (2007.)

The current weekly production target of the mine that needs to be hauled is 52500 Mn tons and 224000 tons of overburden. But Mamatwan Mine is only able to haul an average of 47 500 Mn tons per week and 162000 tons of overburden per week. (Bezundeinhout,. 2007.) (Table I.)

Table I

Average weekly production rate at Mamatwan Mine before the start of the project (Bezudeinhout. 2007)

	Weekly production rate		
	Actual	**Target**	**Variance**
Overburden	160 000	220 000	60 000
Ore	47 500	52 500	5 000

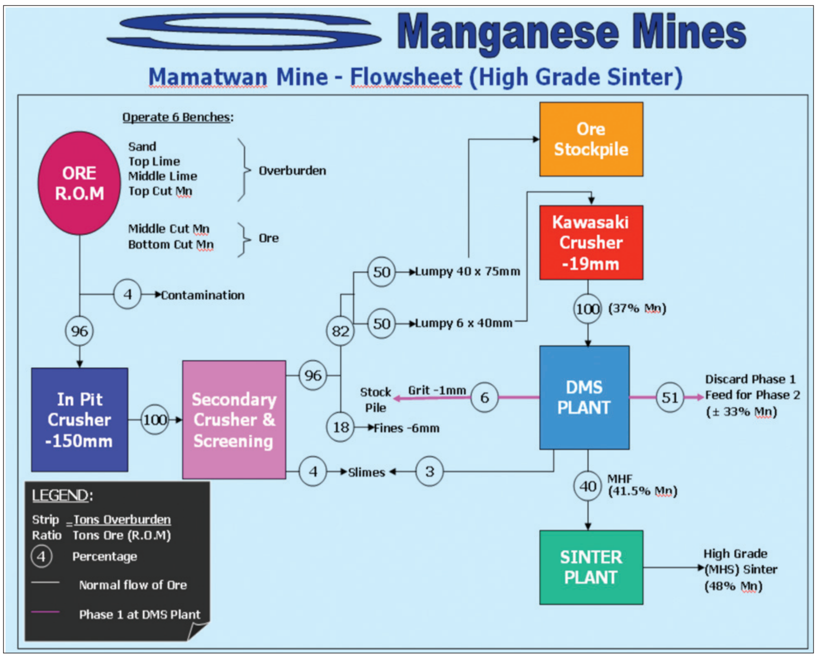

Figure 4—Schematic of Mamatwan ore beneficiation process delivering export and sinter products. (Van Antwerpen, 2004)

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Problem statement

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The investigation strongly focuses on the performances of the three 777D Caterpillar trucks and the R 984 C Liebherr Litronic Hydraulic Excavator.

In the content of the study, these machines are used to remove and move the low grade manganese (also known as the top cut overburden) in order to expose the high grade manganese from north pit to dump 4.

Objectives

The objectives of doing the project were as follows:

- Determining the actual performance of the loading and hauling fleet per shift
- Comparison of the actual and the theoretical performance
- Identify areas that need to be improved
- Conclusions to be reached from all the data collected
- Recommendations.

Methodology

In order to achieve the goals set for this project, the following methods were used:

- Aa time study to compare the performance of the loading and hauling fleet with the manufacturer's specifications
- Matching equipments' analysis for loading and hauling
- Road conditions analysis
- Rolling resistance and road gradients analysis
- Operating cost analysis.

Literature study

The productivity of a hauler/loader operation can be estimated by the stages below:

- Calculate the hauler and loader cycle times
- Determine the number of haulers to be used to maximize production
- Use the loader cycle time to calculate the possible loader production. (Galina, 2007.)

In July 2006, an additional three 777D caterpillars trucks were bought by the mine as a way of trying to improve production. This affected the production with respect to cycle time of the overall haulers as the number of trucks loaded by the one excavator increased. (Bezudeinhout, 2007.)

The haul roads conditions of any open pit mine must be wide enough so that no traffic congestion will result. This will increase production of the mine.

Bunching occurs when the haulers are not evenly spaced along the haul road by bunching into groups of haulers moving very closely together. Bunching reduces the possible productivity of an operation, as the loader tends to wait for prolonged periods for a truck to arrive in the queue. This causes lower utilization so that when the truck arrives, more follow shortly afterwards, thus reducing productivity further due to lower utilization of the bunched trucks. (Galina, (2007.)

Avoiding hidden access points used by other vehicles entering and leaving the haul will increase safety levels.The width of the road should be at least three times the hauler width, plus two metres of shoulder on each side in the case of a two way road. (Taylor, and Hurry 1986.)

Road widths are determined by the type and size of equipment and desireable speed. Serious consideration should be given to providing passing lanes on long adverse grades and in places where the line of sight is seriously impaired (Long, 1968.)

Rolling resistance = is the measure of the force that must be overcome to roll or pull a wheel over the ground. It is affected by the ground conditions and load—the deeper a wheel sinks into the ground, the higher the rolling resistance (Caterpillar performance handbook.)

For a fleet of Caterpillar 777D 91 t payload, 161 gross vehicle mass (GVM) rear dump trucks operating on a 7.3km, 7% incline , if road rolling resistance is reduced from 8% to 4% , the capital cost of equipment necessary to move 5 million tons per annum reduces by 29% while the operating costs reduces by 23%. (Thompson, and Visser, 2003.)

Results

Cycle times

For the purpose of this investigation, cycle time was done to identify the actual production time performance of the hauler in an eight-hour shift.

The cycle time results were obtained by making use of a stopwatch, and observations were done while travelling with the hauler drivers.

The study was carried out on the north pit to dump 4 and back again.

During data collection for the time study, the following definitions were used:

- *Total cycle* (less delay time) is the production time of the hauler from the north pit to dump 4 and back again
- *Arrive time*—is the time of the hauler in which it arrives at the pit
- *Begin load*—the starting time of the excavator to load into the hauler
- *End load*—the ending loading time of the excavator into the hauler
- *Haul time*—the travelling time of the hauler from the pit to dump 4 and back again
- *Begin delay*—start of the delay time

Table II

Minimum haul road width required for an open pit mine. (Galina 2007)

No. of Lanes	Factor x maximum vehicle width
1	2.0
2	3.5
3	5.0
4	6.5

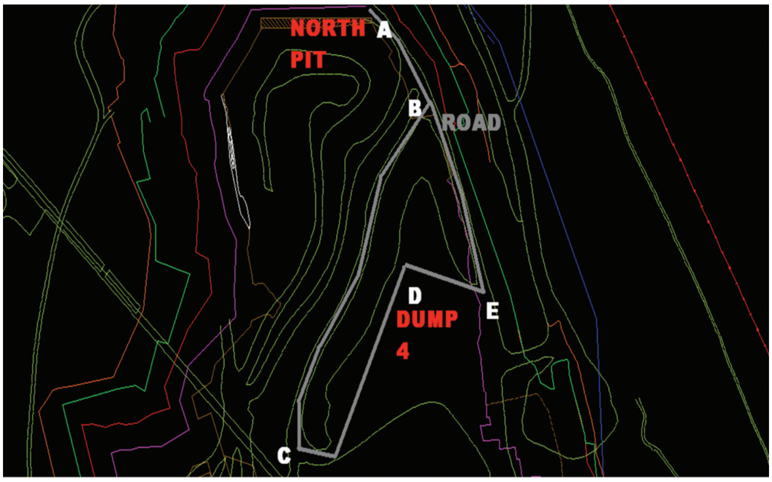

Figure 5—Plan of the north pit section where cycle time data were collected

- *End delay*—end of the delay time
- *Delay time*—total delay time
- *Dump time*—the tipping time of a hauler
- *Return hauler time*—the time of the hauler from when it leaves dump 4 to the pit.

According to the mine planners, the hauling and loading fleet is expected to be utilized for 6 hour 30 minutes in a, 8-hour shift in order to achieve the target production of 52500 Mn tons per week and also 224 000 overburden per week.

North pit to dump 4.

From the plan in Figure 5, the hauler would load at the north pit (A), then travel to dump 4 using route A-B-C-D, then would return to the pit with route D-E-B-A.

The choice of the route was because of a very steep gradient on section B-E of the road.

From the graphs in Figures 6–8, the following definitions can be use:

- *Waste time*—the total time of a hauler per eight-hour shift that is being not utilized for production.
- *Production time*—the total time of a hauler per eight-hour shift that is being utilized to achieve production.
- *Required production time*—the time in which a hauler is expected to be utilized per shift in order to achieve the required weekly target (i.e. 06:30:00).
- *Total shift time*—defines an eight-hour shift (i.e. 08:00:00)

Road conditions

Analysis of the road conditions were mainly focused on the road width.

Properly design haul road can produce minimum traffic congestion, and thus increase on the production efficiency performance for trucks.

During the investigation, the road width was measured on every 20 m interval from the north pit to dump 4 and back again. Measurements were taken using a 50 m long tape. In order to improve on accuracy, the road length was divided into sections.

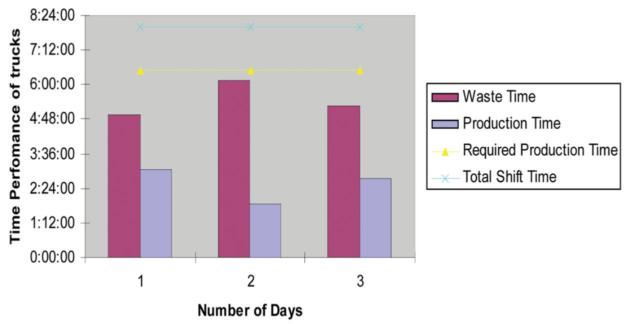

Figure 6—Comparison of production and wasted time to the actual production time required for the morning shift at the north pit section

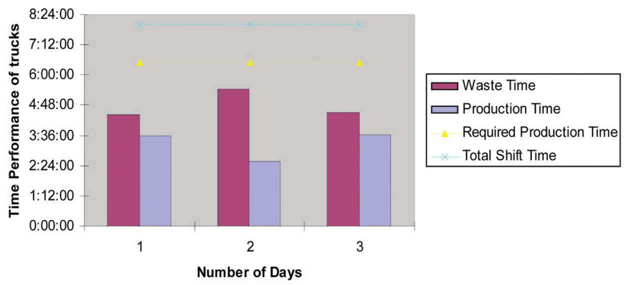

Figure 7—Comparison of production and wasted time to the actual production time required for the afternoon shift at the north pit section

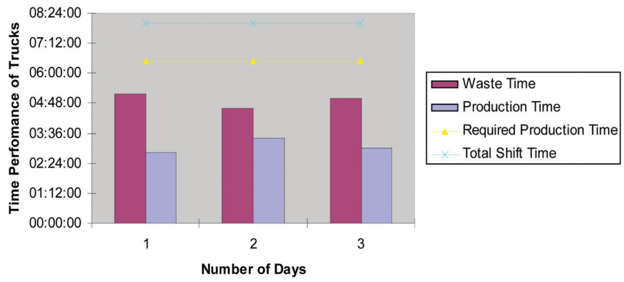

Figure 8—Comparison of production and wasted time to the actual production time required for the night shifts at the north pit section

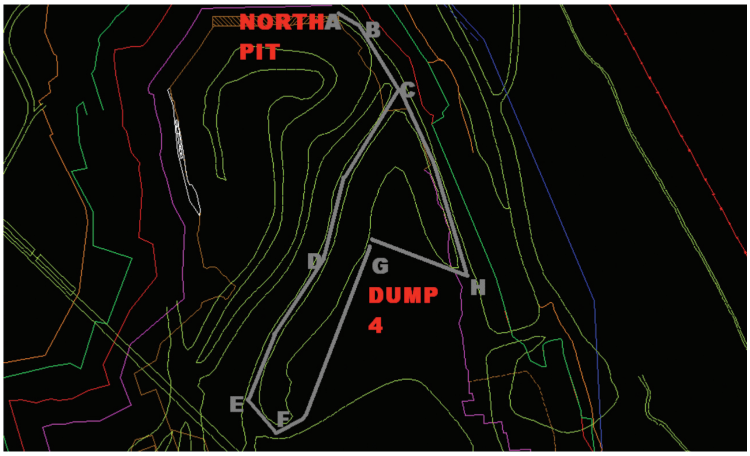

Figure 9—Plan of the north pit section showing the divided section on the road

The hauling roads at the Mamatwan Mine are two-way lanes and the 777D truck width is 6.1 m.

Using the correct haul road design, Mamatwan hauling roads are supposed to be 6.1 m x 3.5 = 21.35 m.

For Figure 10, the following definitions apply.

- *Measured width*—is the actual width that has been measured from the haul roads on every 20 m interval.
- *Target width*—is the width in which the haul roads are supposed to be for a good open pit design.

Rolling resistance and gradients

The method of data collection in this section was by means of dividing the haul road into sections. Then an average of both the rolling resistance and gradient in each section was used.

Information was gathered using the following procedures.

- Practically taking section times while travelling in one of the haulers
- Using a mine plan for distances, heights and gradients
- Using the theory background to determine the road conditions RR
- Consulting the mine surveyor for verification of the data.

From the all the information collected it was then obtained that the average rolling resistance of the Mamatwan haul roads is 5.3% and the gradient is 6.25%.

Excavator and hauler bucket matching

Correct matching of equipment can improve production by minimizing the loading time and obtaining a 95% loading on trucks. The 95% is refered as the loading envelope, since in practice it may be impossible to achieve a 100% load for the trucks (Galina, 2008).

In this part of the report, the data was collected in a six-day shift from 62 different trucks loads. The method used to collect the data was as follows.

- Gathering time performance of the excavator to complete one full load of truck by means of a stop-watch
- Travelling with the trucks in order to get the load weight, from the weight meter reading installed inside the trucks
- Using the technical data from the manufacturer specifications to compare with the results obtained.

For Figure 12 the following definitions apply:

- *Target pay load*—a hauler with 95% load, i.e. 777D caterpillar 90 t truck carrying 85.5 t
- *Truck load*—the weighted truck load at a particular time (these results were read from the weight meter reading installed inside the truck)

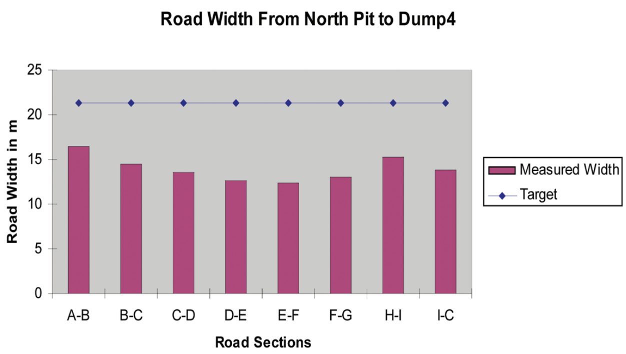

Figure 10—Differences in the targeted road width and the actual measured road widths measured on the north pit

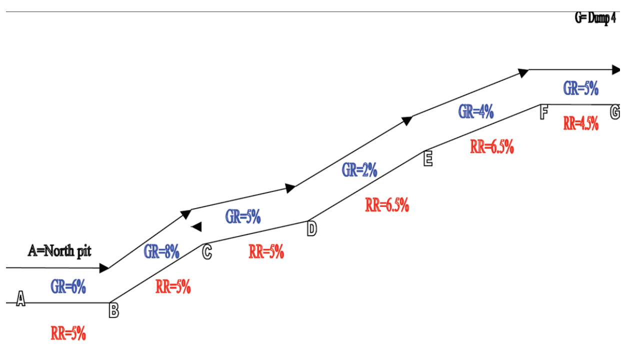

Figure 11—Section view of the hauling road from the north pit to dump 4, with different rolling resistances and gradients in each section

Table III

Average RR, gradient and co-ordinates in each section at the north pit section

Sections	RR(%)	GR(%)	Y (m)	X (m)	Z (m)
A–B	5	6	2113.429	27667.35	1027.424
B–C	5	8	1917.982	27663.26	1045.271
C–D	5	5	1822.392	27801.57	1062.202
D–E	6.5	2	1996.832	2897.611	1078.932
E–F	6.5	4	2002.222	28360.73	1094.334
F–G	4	5	1883.531	28116.33	1083.317
G–H	4	11	1822.392	27801.57	1062.209
H–C	6.5	9	1695.701	28101.1	1103.617

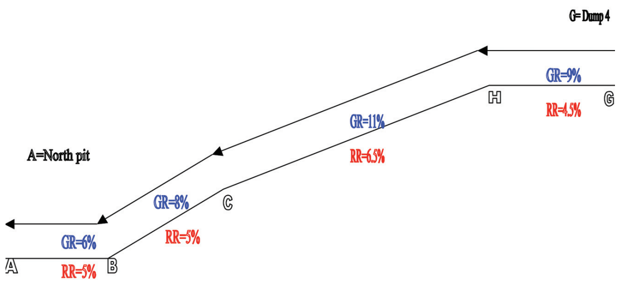

Figure 12—Section view of the return road from dump 4 to the north pit, with different rolling resistances and gradients in each section

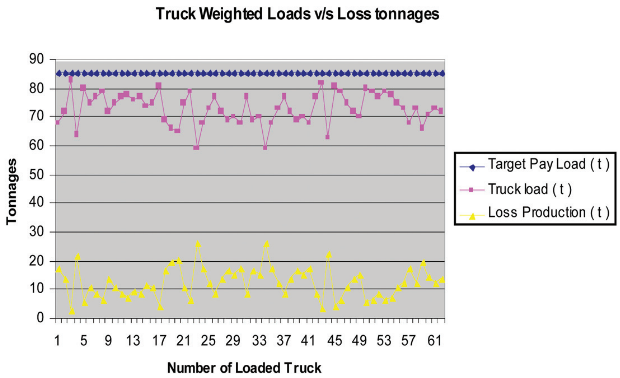

Figure 13—Weighted payload in the truck and the loss tonnages

➤ *Loss production*—the difference of target payload and the truck load (these were fragments that were supposed to be loaded the first time by the excavator to achieve a 95% loading of the hauler).

Analysis and evaluation of results

Cycle times

Using the cycle times data which was collected, an average truck performance was obtained in order the get the number of cycles the truck travels in an hour at 95% efficiency. The data was also used to find the BCM per hour for production.

On the calculations below, the actual production can be compared with the targeted production.

The following definitions apply:

➤ *Actual production*—the current performance of a hauler from dump 4 to the north pit and back again at a distance of 2204.73 m where the average total cycle time (less delays) is 00:18:24, when three trucks are hauling)

➤ *Target production*—the performance of trucks without any disturbances occurring where the average total time (less delays) is 00:11:30, when two trucks are hauling).

It should also be noted that the calculation above applies only to the truck performance from the north pit to dump 4.

For example:

Consider the morning shift cycle time data.

Actual production:

Average total cycle time (less delay time) = 00:18:24

Cycles/h = 60min/h / 00:18:24
= 3.3 cycles per hour
≈ 3 cycles per hour

Average load weight of 777 D truck = 74.5 t = 74500 kg

Bank density = 3650 kg/m^3

Average load = 74500 kg / 3650 kg/m^3
= 20.41 m^3

Production (less delays) = Load/cycle x cycles/h
=20.41 m^3/cycle x 3.3 cycles/h
=100.35 m^3/h

On an average of three hours and thirty minutes production (per production shift) = 100.35 m^3/h x 3.5 h
= 351.23 m^3

Therefore tonnages per shift = 351.23 m^3 x 3.65 t/m^3
= 1281.99 t

Target podução:

Average total cycle time for two trucks hauling hauling (less delay time) = 00:11:30

Cycles/ h = 60 min/h / 00:11:30
= 5.3 cycles per hour
≈ 5 cycles per hour

Actual load weight of 777 D truck = 85.5 t = 85 500 kg

Bank density = 3650 kg/m^3

Average load = 85 500kg / 3650 kg/m^3
= 23.42 m^3

Production (less delays) = Load/cycle x cycles/h
= 23.42 m^3/cycle x 5.3 cycles/h
= 124.13 m^3/h

On average of six hours and thirty minutes production (per shift) = 124.13 m^3/h x 6.5 h
= 806.85 m^3

Therefore tonnages per shift = 806.85 m^3 x 3.65 t/m^3 = 2945.00 t

From the calculations above, the targeted production method proved to be a better method than the actual production.

Road conditions

The hauling roads at the Mamatwan Mine are two-way lanes and the truck width is 6.1 m, which means that the correct road width to be used would be 21.35 m

The data collected shows that planning of the roas at the mine is poor and thus decreases production, due to bunching of trucks during hauling.

Rolling resistance and gradient

In order to analyse the results gathered from RR and GR, the 777D Rimpull-Gredeabilty diagram was used.

The purpose of these calculations was to compare and show the time performance for trucks within the current road conditions, with those of less RR which is required for a good haul road design (Table IV).

Using the 777D Rimpull-Speed-Gradeability diagram (*Caterpillar performance handbook*, p. 32), the following results were obtained.

Actual RR measurements (km/h) = is the measure of the truck speed due to the effect of rolling resistance from the hauling road conditions at the mine.

Targeted RR 2% (km/) = is the measure of the truck speed due to the effect of rolling resistance, if the current hauling road conditions can be reduced to a rolling resistance of 2%.

From Tables VI–VIII, the following performance time was calculated:

Calculations:

Truck fill factor = 83%

Then the average truck weight when loaded = 144925.20 kg

A = is the measured distance per section,

K = 3.6 (is the converting factor from hour to seconds)

Z = is the measured speed, obtained from the Rimpull speed-gradeability diagram

Table IV

Comparison of the factors affected by cycle times of actual production versus targeted production

777D Truc cycle time	Actual production	Targeted production	Loss production
Average total cycle time (less delays) per cycle	00:18:24	00:11:30	00:06:54
Cycles per hour	3.3	5.3	2
Average load per truck (t)	74.5	85.5	11.0
Average load (m^3)	20.41	23.42	3.01
Production m^3 (less delays) per hour	100.35	124.13	23.78
Per shift (m^3)	351.23	806.85	455.62
Per shift (t)	1281.99	2945.00	1663.01

Actual RR:

Travelling time from north pit to dump 4: (truck loaded)

$= A_{A-B} \times K/Z_{A-B} + A_{B-C} \times K/Z_{B-C} + A_{C-D} \times K/Z_{C-D} + A_{D-E} \times K/Z_{D-E} + A_{E-F} \times K/Z_{E-F} + A_{F-G} \times K/Z_{F-G}$

= 350.361 s

= 5.8 min.

Table V

Minimum haul road width required for an open pit mine (Galina, 2007)

No. of lanes	Factor x maximum vehicle width
1	2.0
2	3.5
3	5.0
4	6.5

Table VI

The required RR value for a good design hauling road (Galina, (2007)

Road conditions	Rolling resistance
Hard, well maintained road	1.5%
Well-maintained road with flex	3.0%
25 mm tire penetration	4.0%
25–50 mm tire penetration	5.0%
50–100 mm tire penetration	8.0%
100–200 mm tire penetration	14%

Table VII

Average rolling resistance measurements in different sections from north pit to dump 4 when the truck is loaded

Sections	Actual RR measurements (km/h)	Targeted RR of 2%(km/h)
A–B	13.5	19.0
B–C	11.5	16.0
C–D	16.0	23.0
D–E	18.0	37.0
E–F	16.0	24.0
F–G	17.5	23.0

Table VIII

Average rolling resistance measurements in different sections from north pit to dump 4 when the truck is unloaded

Sections	KM/h (actual measurements)	KM/h (targeted RR of 2%)
G–H	24.5	33.0
H-C	21.5	26.0
C–B	25.0	39.0
B–C	33.0	40.0

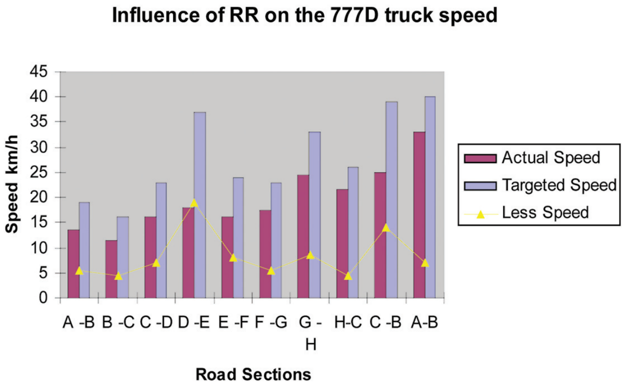

Figure 14—Influence of RR on the speed of the trucks

From dump 4 to north pit:(empty truck)

$= A_{G\text{-}H} \times K/Z_{G\text{-}H} + A_{H\text{-}C} \times K/Z_{H\text{-}C} + A_{C\text{-}B} \times K/Z_{C\text{-}B} + A_{B\text{-}A} \times K/Z_{B\text{-}A}$

= 203.17 s

= 3.386 min.

Assume waiting time of 5.5 min, therefore total travel time = 5.8 min + 3.386 min + 5.5min = 14.686 min.

Targeted RR of 2%

From north pit to dump 4 (truck loaded).

$= A_{A\text{-}B} \times K/Z_{A\text{-}B} + A_{B\text{-}C} \times K/Z_{B\text{-}C} + A_{C\text{-}D} \times K/Z_{C\text{-}D} + A_{D\text{-}E} \times K/Z_{D\text{-}E} + A_{E\text{-}F} \times K/Z_{E\text{-}F} + A_{F\text{-}G} \times K/Z_{F\text{-}G}$

= 236.33 s

= 3.9 min.

From dump 4 to north pit (empty truck):

$= A_{G\text{-}H} \times K/Z_{G\text{-}H} + A_{H\text{-}C} \times K/Z_{H\text{-}C} + A_{C\text{-}B} \times K/Z_{C\text{-}B} + A_{B\text{-}A} \times K/Z_{B\text{-}A}$

= 185.69 s

= 3.09 min

Assume waiting time of 5.5 min, therefore total travel time = 3.9 min + 3.09 min + 5.5min = 12.49 min.

Therefore:

The total production time the mine loses per truck cycle due to rolling resistance:

= 14.686min – 12.49min

= 2.196 min.

Excavator and hauler bucket matching

The mine is currently not reaching its target for moving the overburden to expose the middle cut (high grade Mn).

The purpose of this calculation is to find out, whether the loading buckets which are currently used by the mine are being correctly matched to the trucks. This analysis focuses only on the loading of the top cut overburden (low grade Mn).

Daily target of overburden = 32000 t

If the whole length of the overburden = 78 m and the top cut is 20 m

$= \frac{32000\ t}{78\ m} \times 20\ m$

= 8205.13 t

Therefore top cut to be move/day = 8205.13 t

Density of bank material = 3.65 t/m^3

Density of blasted material = 2.7 t/m^3

Swell factor $= \frac{3.65\ t/m^3}{2.7\ t/m^3}$

= 1.33

BMC of top cut /day $= \frac{8205.13\ t}{2.7\ t/m^3}$

= 3038.93 m^3

From the observation and data collected, the following result was obtained:

- ➤ Truck payload = 90 t
- ➤ Truck fill factor = 83 %
- ➤ Bucket fill factor = 95%
- ➤ Assume 6.5 h production work per shift , therefore h/day.

Hour production $= \frac{3038.93\ m^3}{19.5\ h}$

= 155.84 m^3/h

Material movement /hour = 155.84 m3/h x 1.33

= 207.27 m^3/h

Material volume in the truck $= \frac{90\ t}{2.7\ t/m^3}$

= 33.33 m^3

Truck bowl size $= \frac{33.33\ m^3}{0.83}$

= 40.16 m^3

Volume per 5 passes $= \frac{40.16\ m^3}{5}$

= 8.03 m^3

Required excavator bucket $= \frac{8.03\ m^3}{0.95}$

= 8.5 m^3

And tonnages per 95% Bucket fill factor = 8.5 m^3 x 2.7t/ m^3 x 0.95

= 21.80 t

According to the Caterpillar manufacturer's specification, the best equipment which suits the 777D truck for 5 pass is the CAT 5130B ME Mass Excavator which has a bucket capacity of 8.5 m^3–18.5 m^3.

The mine is currently using an excavator which has a bucket capacity of 5.5 m^3.

This shows that bucket of the excavator is much smaller than that of the truck, and thus it takes a long time to fully load the truck therefore affecting production time.

Operating cost for re-handling of material

The term re-handling in this report means to handle fragmentation which was supposed to be loaded onto the truck by the excavator's bucket, but because of poor blasted material, this material tends to fall back to the ground and thus reduces the bucket's fill factor.

An operating cost was calculated in order to determine the actual cost of the material rehandling.

The operating costs of December 2007 are as follows:

- ➤ 777D Caterpillar truck = R745.00 / hour
- ➤ R 984 C Liebherr Litronic hydraulic excavator. = R515.60 /hour

The total material that needs to be re-handled from 60 loads in 6 shifts/truck (two days) was 1 052 t (and from the current mine operation this would take approximately 1.25 shifts/truck to move 1 052 t) .

- From calculations, each truck is doing 3 cycle/h
- each truck is loading an average of 74.5t/cycle
- Tons moved/hour = 3 cycles/h x 74.5 t/cycle = 223.5 t/hr
- Hours needed to move the material =1 052.0 ton/219.0 t/h = 4.7 hour.

This means that the excavator and the truck will work an extra 4.7 hours for every 60 loads.

Therefore:

777D Caterpillar Truck = R745.00/ h x 4.7 hours = R3501.50

R 984 C Liebherr Litronic hydraulic excavator = R515.60/h x 4.7 hours = R2423.32

Total extra operating cost for every second day of production = R5 924.82

Total extra operating cost for every month of production = R82 947.48

Conclusion

From the average cycle time data of the three different shifts that are being worked at the mine, it was calculated that the average working time per shift is three and half hours per eight-hour shift.

The decrease in performance time is caused by factors such as:

- Daily safety meeting (which takes an average of one hour)
- The daily machine service (which takes an average of one hour, forty-five minutes)
- Leaving the pit about thirty minutes earlier, and other factors.

From the cycle time calculations, it can be seen that production per truck can be doubled if the trucks operate for an average of six and half hours per eight-hour shift.

Incorrect road width design also influences the production performance of the haulers at the mine by bunching. The correct road width at Mamatwan Mine must be 21.35 m, but the current average hauling road width is 15.096 m.

Rolling resistance is also one of the factors affecting production time at the mine. The mine has sufficient road maintenance equipment which can reduce the RR to a desired value of 2%; clearly this equipment is not being utilized effectively.

From calculations, it is clearly seen that if the RR could be reduced to 2% on every road section, then each cycle period per truck can be reduced to 2.196 minutes. This means that there will be a decrease in the operating cost of the hauler but an increase in production.

Poorly blasted fragmentation and incorrect matching of buckets increases the total operating costs. The current bucket size of the excavator is 5.5 m^3. But according to the calculations in chapter 4 and Caterpillar manufacturer specifications, the correct excavator bucket size to match up the 777D Cat truck should be at least 8.5 m^3. It has been calculated that due to incorrect bucket matching, on every second day the operating cost of each truck and excavator increases by R5 924.82, and up to R84 714.32 per month.

Recommendations

The following methods can be implemented to increase production at Mamatwan Mine:

Table IX

Improvement on average weekly tonnages produced at Mamatwan Mine

	Weekly production rate			
	Before		After	
	Actual	Target	Actual	Target
Overburden	160 000	220 000	195 000	220 000
Ore	47 500	52 500	50 300	52 500

- Excavator's bucket should be replaced with one at least 8.5 m^3
- To improve the utilization of machines and increase production, the following can be recommended:
  - Set a daily target for the drivers
  - Control and monitor entry time, working time, break time and knock-off time.

The two above recommendations were implemented after the project was done, and the results can be seen in Table IX.

The following were also recommended:

- Further investigation should be done on the effectiveness on the blasting method used
- The haul roads width should be increased to 21.35 m in order to allow easy passing of trucks for maximum production.

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