The impact of mixed fleet hauling on mining operations at Venetia mine

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Synopsis

Venetia Mine, an open-pit diamond mining operation in the Limpopo Province of South Africa, currently has a mixed haul truck fleet consisting of Caterpillar 785B and C; 789C; modified 793D and 793D. Even in an ideal situation these trucks have different cycle times, which causes queuing at the loading area and their different speeds cause bunching on the ramps, leading to higher overall cycle times and lower productivity. This problem was identified but the root causes of the problem were not investigated and quantified. A time and motion study on the haul trucks was thus undertaken to measure actual cycle times and compare them to ideal cycle times as well as to observe any reasons for deviations. Ideal cycle times are partly evaluated on the basis of simulation and partly from production optimization expert input.

Several areas that affect production were identified and these include: haul road conditions, the control room, dispatching programme and dispatching data management, as well as truck-shovel matching. The investigation was important in establishing control parameters for haul fleet operation since time spent queuing is production time lost, which defers waste tonnes to later in the life of mine, thus decreasing the tempo at which kimberlite is exposed.

Introduction

Mine background

Venetia Mine is situated 80 km west of Musina in the Limpopo Province of South Africa. Two out of the 13 kimberlite pipes in the area are currently being mined using a split shell mining method. This is a modified open pit method, chosen since it can optimize the mine's net present value. The final pit limits for traditional and split shell open pit methods do not differ very dramatically; but the finances used for waste stripping are deferred to a later stage in the life of the mine. As with any method there are both advantages and disadvantages, but this paper will focus on the disadvantages as they affect the productivity of the haul truck fleet to a large degree. The disadvantages include:

- Truck cycle times are increased due to the presence of switchbacks in the pit, as can be seen in Figure 1, specifically the north ramp
- The turning radii of all the trucks present on the mine must be considered in the design of switchbacks to prevent bottlenecks from occurring. Whilst a long-term plan can accommodate the smaller truck sizes, as soon as truck size is increased, road geometric design should be revised to accommodate these vehicles. On a pre-existing road network, however, this revision is often problematic, the more so within a split-shell mining environment. Production time will be lost when trucks have to stop at a hairpin bend turn due to:
  - being unable to spot other trucks and/or
  - having to wait for oncoming trucks as two trucks will not be able to pass on the same section of road
- At intersections where ramps meet, trucks will stop during their cycle, causing an increase in cycle time (as compared with non-interrupted cycles) (Kear and Gallagher, 2002).

Project background

Venetia Mine currently has a mixed haul truck fleet. This is because different haul trucks were chosen at different stages during the life of the mine to minimize total transportation costs for the specific tonnage profiles over a given time period. The current pit layout and size do not allow for the purchase of additional, similar smaller trucks due to the space limitation, thus the decision was taken to buy fewer, larger trucks i.e. – the CAT 793Ds, to deal with the mine's future tonnage profile. The haul truck fleet at the mine consists of the following Caterpillar trucks (Table I):

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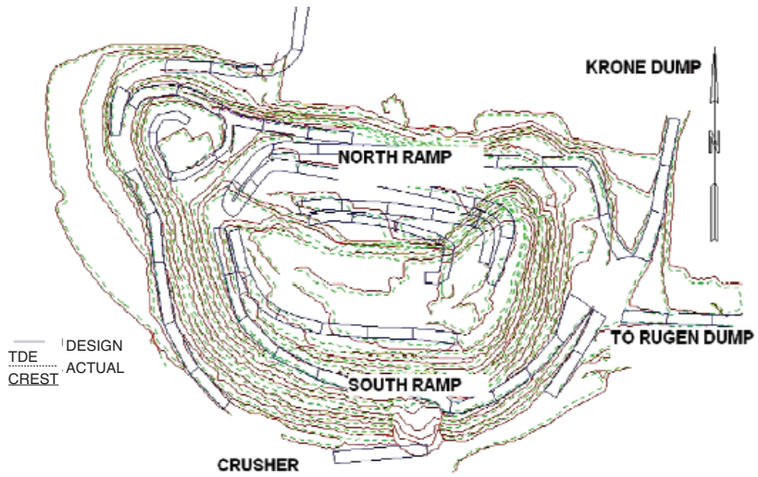

Figure 1—Plan view of pit layout (January 2006)

Table I

Haul truck fleet at Venetia Mine

	Quantity	Payload (t)
785 B & C	9	136
789 C	13	180
793 D (modified)	1	175
793 D	3	220

Due to the worldwide tyre shortage the mine does not have adequate tyre supplies for the 793Ds. A decision has been made to use tyres with a smaller TKPH (tonnes kilometre per hour) rating thus decreasing the truck's payload capability by 45 tonnes. This is the basis of the 793D (modified) in Table I.

All these truck models have varying cycle times, which will cause queuing even in an ideal situation. Figure 2 shows how the speed on ramp would vary for each truck type at various ramp grades. With a mixed fleet, it is inevitable that the maximum speed on ramp will be dictated by the slowest truck on the ramp, more so when traffic volumes are high. This will lead to bunching on ramps and reduced productivity.

Aim and scope of paper

The aim of this paper is to determine and quantify the main factors that affect the productivity of the haul truck fleet at Venetia Mine, especially focusing on the reasons behind the large amount of bunching and queuing time, and the role of mixed fleet operations on fleet productivity.

Current state of the art

Factors affecting haul truck fleet productivity

Time and motion study

The best approach to encompass the factors that influence bunching on the ramps, queuing at loaders and other factors that affect haul truck productivity would primarily be to perform time and motion studies on the haul trucks. This will allow for the collection of actual cycle data. Once the actual cycle data have been collected they can be compared to an ideal cycle situation. Time studies would be performed during day and night shifts to test for any differences. While some data is available on the current operating practice from various sources, the detail behind the data is insufficient to deduce any definitive conclusions on the reasons for the poor performance.

Haul road conditions

Haul road conditions (including loading and dumping areas) must be checked to determine whether they are acceptable and ideally suited to the operation. i.e. the geometric, structural and functional designs are to standard, together with the correct operating practices. This will be done both visually while performing the time and motion study and also using Caterpillar's Vital Information Management System (VIMS). This is truck on-board software that collects data and analyses it to give an ASA (application severity analysis) rating, which shows the mine whether the road conditions on site are acceptable or not, in terms of universally benchmarked minimum and maximum ratings for various truck-/road interaction parameters.

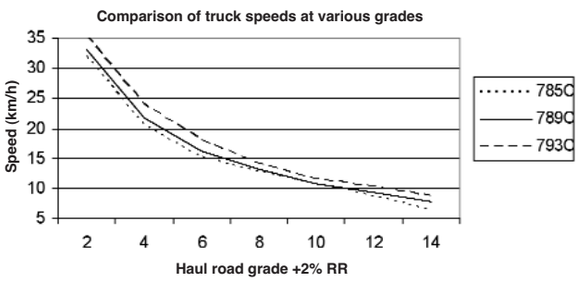

Figure 2—Ideal simulation of truck speeds for three different Caterpillar trucks

Critical to all hauling operations is a safe minimum road width. Table II sets out some recommended widths, which formed the basis for an assessment at Venetia. This is critical since trucks need adequate space to allow for passing and bi-directional travel on the ramps, otherwise trucks will have to wait for one another to pass (either in opposite directions, or where a faster truck encounters a slower truck on ramp), thus increasing cycle times.

The minimum turning radii of the trucks must be taken into account in order for the trucks to have enough room to negotiate bends in a single turn—this is especially important due to the presence of sharp switchbacks in the split shell mining method. It would be ideal if switchbacks were constructed wide enough for two trucks to pass one another without having to stop, but this (as do wider ramp roads) has significant impact on mine planning and stripping ratios.

Not only is correct primary road construction important but the continual maintenance of roadways is critical. It has been said that preventive measures are better than corrective ones, as it can take up to five times longer to repair a road that is badly deteriorated than to continually maintain it (Smart, 2002). In the case of corrective measures, the roadway (or at least part of it) is likely to be closed, which will decrease production rates and restrict traffic flow. Tyre damage occurs frequently on mines due to the cutting of rubber by rocks; hence spillage should be controlled to prevent tyre damage. Spillage itself is often an indicator of some other road design deficiency—excessively sharp curves, no super-elevation, grade breaks on ramps, etc., all leading to pitching, yaw or rolling of the truck with the attendant spillage.

The causes of deterioration of haul roads include mainly poor design and construction standards, which become evident as:

- Wheel rutting (deep tracks which are made by tyres)
- Overloading where wheel loads applied exceed that of the road design value
- Poor geometric design—grade breaks in ramps, sharp curves and spillage
- Water damage that washes away surface layers of the road
- Loose unbound material and dust due to poor surface on road.

Additionally, deterioration can result from:

- Movement of tracked machines destroying the upper layer of road
- Poor skills of operators.

However, while the main haul road network forms the backbone of the hauling operations, as much (if not more) attention needs to be given to the design and maintenance of all loading areas. This is to allow for maximum and constant acceleration and a fast pull-away time of the truck, to enable it to enter the ramp at high speed, therefore helping to increase average speed on ramp. The factors that will permit this to happen most effectively are:

- The loading area must be level and free of any potholes, preferably dressed with crushed material
- There should not be any spillage from previous trucks being loaded and any rocks that may have fallen from the face
- Have no water present as this prevents the driver from seeing protruding objects and also allows tyres to be more easily cut
- Large enough area so that tight turns are not necessary as this causes damage to the truck tyres—especially on full-lock laden maneuvering.

The most important fact to remember is that a haul road starts at the loading area and ends at the dump. Maintaining haul roads is done at the expense of time and money but will keep production running optimally and control rolling resistance to acceptable levels. It will allow the mine to get close to optimal cycle times from the fleet and critically extended tyre life, which will increase truck availability and decrease capital cost. This must be taken into account with the world wide tyre shortage—if a tyre is damaged will it be able to be replaced, or will the whole truck be out of production? Good haul road conditions will increase the number of cycles a truck can do in a shift, which increases productivity. All these efforts will ultimately decrease the rand per tonne cost.

Table II

Safe design width of haul roads (Smart, 2006)

CAT truck	Width of truck (m)	Two-way straight (m)	Two-way corner (m)
785C	6.64	23.24	26.56
789C ; 793C	7.67	26.85	30.68

Simulating ideal operating situation

Two different sources were used to gather data that are used in combination to compile ideal cycles for the various haul truck routes. The hauling and travelling empty times were taken from Talpac (Runge Mining 2006) simulations. Spotting, loading and pull away times were used as suggested by a production optimization expert that was available at Venetia Mine. An analysis was undertaken to ensure that the unimpeded travel times simulated on Talpac were in fact realistic for the truck types and age used at Venetia. In this way, the reliability of the simulation could be used to realistically assess the time study results and, more critically, the deviations in the time study data compared to ideal simulated operations.

Control room

Venetia Mine dispatches all haul trucks via a centralized control room. The control room has to be considered in this investigation to asses whether the problem of queuing and bunching that is seen in the pit is solely due to the different truck models or also stems from incorrect truck dispatch or not using the dispatching program optimally.

Truck-—shovel matching

The final consideration that directly affects queuing at the loaders and in turn further in the cycle is truck and shovel matching. An increased number of loader bucket passes will lead to increased queuing time for the trucks already waiting at the loader. The ground conditions at Venetia were used to

simulate a correct and realistic number of passes per truck-shovel combination used on the mine. The results are summarized in Table III. The mine has three different shovel configurations manufactured by O&K.

- Shovel 306; RH 200; 26 m^3 bucket
- Shovel 307; RH 200; 26 m^3 bucket
- Shovel 308; RH 340; 28 m^3 bucket
- Shovel 309; RH 340; 34 m^3 bucket.

It is important to note that these values depend strongly on the fragmentation that will occur after each blast and on individual operator skill.

Hydraulic front shovels should have load cycle times of 26–28 seconds per pass with 4–6 passes (Caterpillar, 2002). The values that were simulated fall within this region. It must also be noted that with correct blasting and loading techniques it is possible to load well- matched trucks in 4 passes (4 passes @ 30 s each gives 2 min loading time) (MacLeod, 2005).

It is important to note that only 785s are able to tip ore into the current crusher due to the crusher's size limit. This means that, as far as possible, only 785s will be used to load ore by RH 200s (most often) or the CAT 994 front end loader.

Review of current truck fleet operational practice

Data gathering methodology

Time and motion study

Time studies were performed on randomly chosen haul trucks during day and night shifts. Times were taken for each part of the production cycle:

1. Spotting at loading area
2. Loading
3. Pull-away time
4. Hauling (traveling laden)
5. Travelling empty
6. Queuing

The time taken to dump each load was not recorded. Spotting times were taken from when the truck had finished manoeuvering into a position, where it was ready to reverse, till when it was correctly positioned for loading. Any abnormalities in the cycle or reasons for its extension were noted.

Ideal hauling and empty travelling times were simulated on Talpac. Loading and spotting times were not considered directly from Talpac but were sourced (MacLeod, 2005). This was done in order to get the most ideal cycle time that the mine could aspire to. In terms of experiments, it would be the control that results are compared to. Queuing is a normal part of mining operations, but should be kept to a minimum to increase production time.

Table III

Truck and shovel matching

Truck	Shovel	Number of bucket passes
785	RH 200	5
789	RH 200	6
789	RH 340	5
793	RH 340	5

Haul road conditions

Conditions on the mine's haul roads will be monitored and observed mainly while time studies are being performed in the various trucks. In this way it will be possible to correlate poor road conditions to increased cycle times where applicable, and to use this as a basis for rolling resistance values used in Talpac.

Simulating ideal conditions

Inputs used for the various simulations are included below. Assumptions:

- Truck mechanical availability: 85%
- Loader mechanical availability: 85%
- The roster used for all Talpac simulations for the 7 day, 12 hour per day, working week that Venetia Mine operates according to. Scheduled lost shifts are the public holidays that are on the South African calendar
- An average bucket fill factor was used: 80%.

The various possible routes that haul trucks use were simulated in Talpac and all the information combined for different cycles.

Control room

Time will be spent in the control room observing the day-to-day operation of the dispatching system and, critically, how exceptions are managed and data used to support decisions to improve real-time fleet productivity.

Truck-shovel matching

In order to obtain the number of passes per truck–shovel combination and the total loading time, loaders were observed from view points around the pit and times noted. The number of loads will also be measured while time studies are being performed in haul trucks.

Data analysis

Time and motion studies

Results were compiled and represented graphically, as shown in Figure 3, with the reasons for deviations from the ideal cycle also noted. Note: trucks numbered 8–17 are 785s, 18–30 are 789s and trucks 31–36 are 793s.

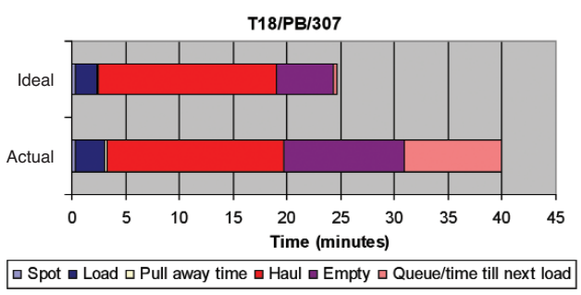

Figure 3—Typical comparison of an actual cycle to an ideal one

In the majority of cases the times that were most excessive were travelling times back from the dump to loader due to empty trucks having to wait for hauling trucks at places where the haul road is not wide enough for two trucks to pass one another. Pulling-off times were large in the case of two loaders that did not have functioning hooters. Loading times varied widely depending on truck-shovel matching, operators involved and rock fragmentation.

When looking at the results presented from the time study one may wonder what difference does a few seconds mean in a cycle of 30 minutes. In order to put a possible improvement in time utilization into perspective, several calculations were performed. Averages for all calculations are taken for the period mid August to mid November 2005. A time saving of 20 seconds per cycle per haul truck can save a total of 57 days in a year for a fleet of eight 785s and twelve 789s. This time can be saved at any part of the cycle; the most time can be saved on queuing—and it would exceed 20 seconds a cycle.

Using averages for the time period mentioned above queuing can be quantified in terms of two very important aspects—firstly tonnes that could be moved during the time when trucks are queuing or on standby and secondly idling costs. (Fuel burnt while idling was estimated at 10% of normal use; depreciation, repair and maintenance, labour, workshops and lubricant were included in costs.) In both these calculations it was assumed that it was normal for five per cent of operating time to be spent on queuing. An extra 7.2 million tonnes could be moved annually and R4.6 million could be saved in idling costs per year for the fleet if queuing time is used for production.

When comparing the variance (as a percentage of the 'ideal' cycle component) across shifts it can be seen from Figures 4 and 5 that actual queuing time differs much less from the ideal during the night shift when compared to the day shift. However, the total cycle time variations are rather similar.

Haul road conditions

Haul road conditions were analysed using VIMS and observations. Both haul routes—up North and south ramps were given unacceptable road ratings with the ASA (Application Severity Analysis) rating system. Below is a short explanation of various VIMS graphs.

Strut pressure graph (Figure 6)

The green line indicates machine racking; this is the difference between strut pressures (L (left), R (right), F (front), R (rear) diagonally across the centre of the truck: (LF+RR)—(RF+LR). These motions tend to twist the frame and load machine components.

Machine bias, indicated by the blue line, is the difference in strut pressure between the totals down each side of the truck: (LF+LR)—(RF–RR). This shows whether significant dynamic loading is occurring as the machine negotiates cross slopes and corners. Both these values should be within the 2 red boundaries—racking and machine bias should be within (+/-) 8 000 kPa for 785s and (+/-) 8 500 kPa for 789 and 793s.

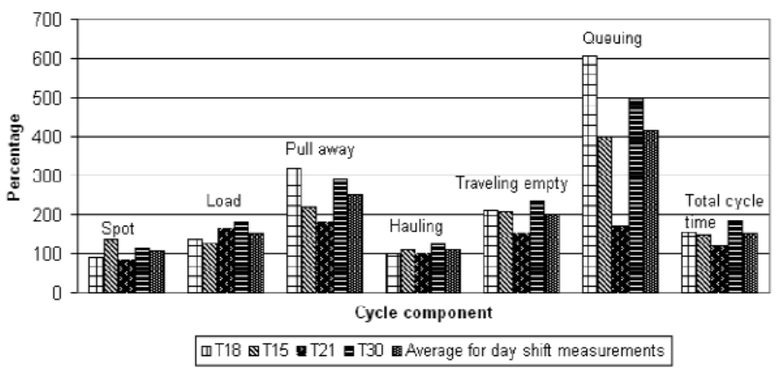

Figure 4—Percentage variance for the various cycle components during day shift

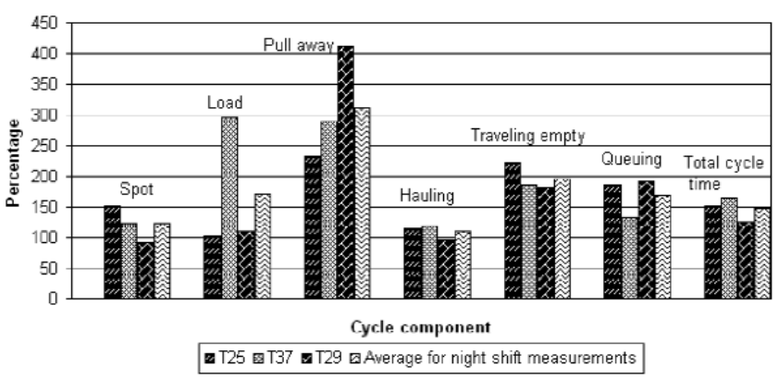

Figure 5—Percentage variance for the various cycle components during night shift

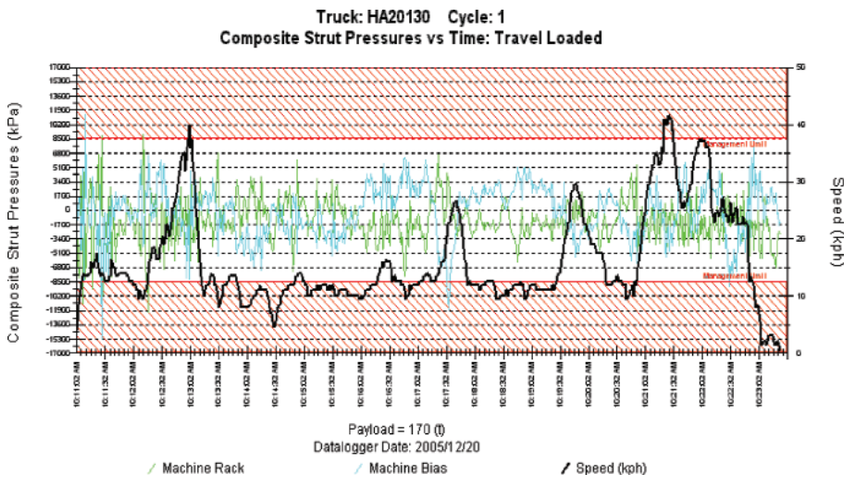

Figure 6—Strut pressure graph from truck 30—North ramp

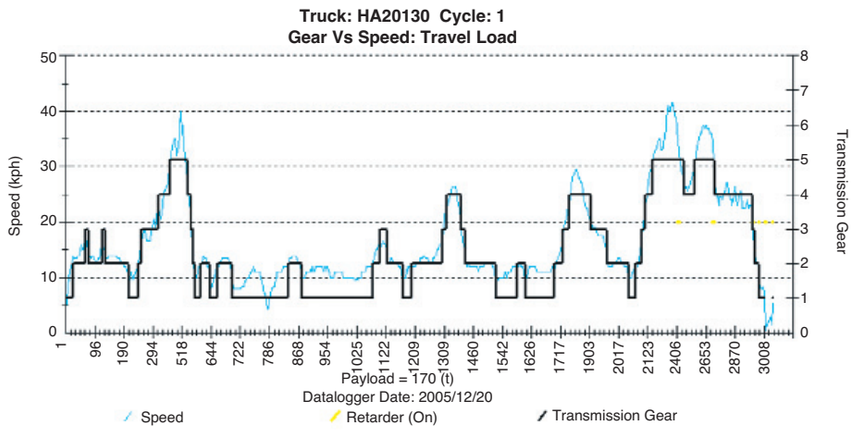

Figure 7—Gearing up and down in truck 30

Gear change graph (Figure 7)

This graph shows the gear changes that the truck driver went through from the loading area to the dump. In an ideal situation gears should be changed only when accelerating on the way out of the loading area and decelerating before dumping, as shown in Figure 8. Any other gear changes can be directly attributed to uneven roadways and/or grade that is not constant (grade breaks). The number of gear changes during the journey is also dependent on operator skills.

Analysis on north ramp

The analysis was done on truck number 30 that had a payload of 170 t. Figures 6 and 7 reflect the conditions on north ramp. Figure 9 shows the rating summary where road ratings range from 1–10, where 1 is the best case scenario and 10 is the worst case scenario. Only the full analysis of north ramp is included in this paper. South ramp was rated as a 10 after the same analysis was performed.

It should be noted that machine bias peaks in the red limit on several occasions, especially at the beginning of the travelling cycle, as can be seen in Figure 6. Machine rack remains within the recommended limits after about one and a half minutes of travel time.

Figure 7 points out the correlation between gear changes and speeds. It is important to note the frequency of gear changes. With each decrease in speed increment the truck will use more power to accelerate to its desired speed. The gear changes cause a jerking motion, which causes spillage to occur out of the back of the truck.

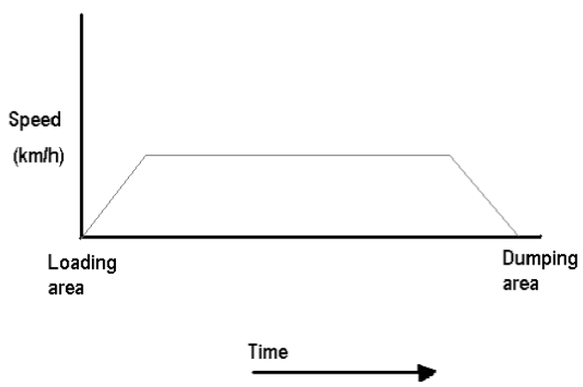

Figure 8—A graph showing the acceleration of a truck in ideal driving conditions

Truck: HA20130 Cycle: 1
Haul Road Condition Index: Travel Loaded

Result: Rating 6 Unacceptable

	> 8500 kPa And <= 12000 kPa	> 12000kPa And <= 16000 kPa	> 16000 kPa
RACK Spikes:	4	1	0
BIAS Spikes:	4	1	0
TOTAL	8	2	0

Figure 9—Road rating for north ramp

Figure 10—Truck leaving the loading area

Figure 11—Two trucks waiting at the switchback for one loaded truck to exit the pit while dozer cleans spillage after gear change

Figure 12—Superimposed picture illustrating one of the sections of north ramp which is too narrow for two-way traffic

Figure 13—Muckpiles along the side of the haul road, reducing road width and potentially damaging to truck tyres

The number of spikes in the rack and bias graphs are recorded and are noted in the various slots: above 8 500 kPa and below 12 000 kPa; between 12 000 kPa and 16 000 kPa and above 16 000 kPa (Figure 9). The result of the road rating is a 6. The unacceptable range lies between 5 and 10.

The ASA ratings were confirmed with observations: haul roads, loading and dumping areas were uneven (Figure 10), thus gear changes happened often; spillage was often encountered en route especially at the switchback out of pit bottom (Figure 11). The haul roads are, in certain sections, not wide enough for two-way traffic (Figure 12) and at times the problem is compounded due, the presence of muck piles that have not been cleaned up (Figure 13).

Simulating results for mixed fleet operations

Simulations were run in order to determine the most productive combinations of trucks in the north of the pit (waste operations) and at pit bottom (kimberlite operations). Figure 14 and Table IV are results as simulated from bench 11 via the north ramp to waste dump.

A visual representation of Table IV is given in Figure 14 where a peak in production is shown for option four, which consists of nine 793s and four 789s.

Table V shows the truck combination that would take waste out of the bottom of the pit and to waste dump via south ramp. The most productive option is number 10, which includes five 785s and nine 789s.

Thus the truck combinations for maximum production from the simulations are summarized in Table VI.

Control room operations

There is currently one system controller in the control room. The person is appointed as a B-band employee, which is the same band as the truck drivers. This ranking is according to the Patterson Grading System where labour is divided from unskilled (A band) to skilled, upper management positions

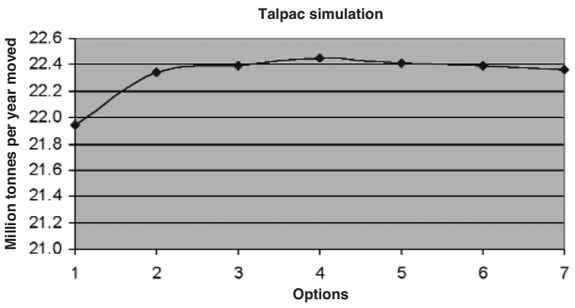

Figure 14—Graph of the truck combination exiting north ramp

Table IV

Truck combination exiting north ramp

Option	793	789	Million tonnes per year
1	9	0	21.95
2	9	2	22.34
3	9	3	22.39
4	9	4	22.46
5	9	8	22.41
6	8	8	22.40
7	9	11	22.37

Table V

Truck combination exiting south ramp

Option	785	789	Million tonnes
1	7	2	11.22
2	8	2	11.96
3	9	1	11.60
4	9	2	12.45
5	9	3	13.02
6	8	4	13.34
7	5	6	13.38
8	5	7	13.58
9	5	8	13.73
10	5	9	13.84

Table VI

Truck configuration for maximum production

Amount	Truck model	Material	Exit	Dump
5	785	Kimberlite	South	Crusher
7	789	Waste	South	Rugen waste dump
4	789	Waste	North	Rugen/Krone waste dump
9	793	Waste	North	Rugen/Krone waste dump
Total trucks: 25				

(E and higher). The system controller is responsible for the dispatching of trucks according to the pit supervisor's instruction, checking in with truck drivers for diesel levels and other technical information (this falls under fleet control), answering of telephones and the truck radio channel. The system controller is trained to understand the basics of the dispatching system. With only one person in the control room having to multitask among the mentioned responsibilities the standard of work is likely to be compromised.

The system is able to go onto auto dispatch function. This is when the system collects times that it takes a truck to do a full cycle; it then averages the time and assumes that it will take the truck that long for the next cycle. This is done for all trucks that are being loaded by two nearby loaders. The system will then optimize the trucks' cycle times and dispatch them to the loader where no trucks are available or where least queuing will take place. The method of calculating cycle times is accurate when cycle times stay constant; however, this is not the case at Venetia where cycle times are highly variable as was shown earlier; thus the system will provide incorrect information when matching trucks to shovels while the system is on auto dispatch. This is evidenced by the fact that queuing is still frequently observed when auto dispatch is utilized—in part due also to truck-shovel matching and loading times.

Truck-shovel matching

Table VII below shows an example of truck-shovel matching observations. A wide range of total loading times can be observed. It must be noted that the shovel operator remained the same throughout this particular study. All trucks except truck 14 are 789s, which are loaded in 5–6 passes. Shovel 308 should be capable of a maximum of 5 passes (4 ideally) with this truck-shovel combination.

With the recommended time of 30 s per pass, loading times often go beyond the recommended time of 2 minutes 30 sec (5 passes @ 30 seconds per pass). The RH340 shovel should be able to load a truck in 5 passes; however, six passes were needed in many cases. This is often dependent on loader operator ability and on the fragmentation of the rock. The pull-away time ranges from 5 to 52 seconds. This was often due to loaders 306 and 307 not having hooters available to give truck drivers the go ahead that the loader is finished loading. The other reason that pull away takes a relatively long time is due to the loading area conditions described earlier. Attention is required both from the point of view of the truck (drivers do not spot in the correct place next to the loader) and the loader (loader operators have to constantly adjust to different truck sizes and thus misplace the load).

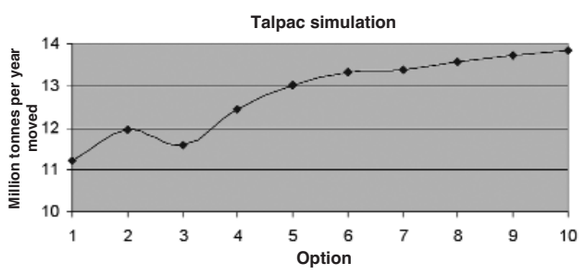

Figure 15—Graph of the truck combination exiting south ramp

Table VII

An example showing split times for each bucket pass for loader 308

Shovel productivity studies
19-Dec-05

Shovel no Lo20308 RH340

T/no- 29		T/no- ?		T/no- 22		T/no- 14		T/no- 21		T/no- 22		T/no- 24	
Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time
1	17	1	0	1	49	1	61	1	20	1	56	1	22
2	34	2	30	2	32	2	35	2	33	2	36	2	39
3	23	3	32	3	31	3	30	3	30	3	36	3	35
4	30	4	32	4	36	4	61	4	32	4	34	4	32
5	35	5	34	5	38	5		5	29	5	33	5	30
6		6	35	6	31	6		6		6	27	6	
7		7		7	33	7		7		7		7	
T/L/Time	2min2s	T/L/Time	2min43s	T/L/Time	3min21s	T/L/Time	2min6s	T/L/Time	2min4s	T/L/Time	2min54s	T/L/Time	2min16s
Time to leave loading area	6s	Time to leave loading area	5s	Time to leave loading area	14s	Time to leave loading area	15s	Time to leave loading area	21s	Time to leave loading area	5s	Time to leave loading area	6s

Grey highlighted blocks represent good spotting times

Shovel no Lo20308 RH340 cont

T/no- 23		T/no- 21		T/no- 28		T/no- 21	
Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time	Q/Loads	C/time
1	39	1	16	1	18	1	12
2	34	2	33	2	32	2	64
3	31	3	30	3	30	3	48
4	35	4	36	4	31	4	37
5	30	5	30	5	34	5	31
6	29	6		6	25	6	31
T/L/Time	2min39s	T/L/Time	2min9s	T/L/Time	2min32s	T/L/Time	3min21s
Time to leave loading area	11s	Time to leave loading area	12	Time to leave loading area	11	Time to leave loading area	11

Conclusions

The split shell mining method used at Venetia Mine does impose certain road restrictions; however, it is still very important to construct and maintain haul roads at correct widths, even and free of spillage. Parts of the cycle that can be most improved upon include decreasing spotting, loading, pull-away and queuing times. Hauling times are most often on a par with an ideal simulation but empty travelling times are often longer than the ideal as a result of the trucks having to wait for hauling trucks due to roadways being too narrow. The control room employee has many responsibilities to focus on while he/she is alone in the control room during the shift. This decreases control room efficiency. Trucks and shovels are well matched but loading times vary considerably mainly due to operator efficiency and rock fragmentation.

Time and motion study

The idealized cycle times and those actually recorded showed slight differences in most activities, except for unladen travel times and queuing times, where significantly longer cycle segment times were recorded. Additionally, the pull-away time of trucks is excessive; the reason for this was identified during the time study, i.e. two loaders did not have hooters and therefore on completion of the final pass, the trucks did not pull away immediatley but waited for visual or radio instructions. The time spent queuing at the loader, due to incorrect dispatching or loader downtime itself can be quantified in terms of extra tonnes that can be moved as well as savings in unnecessary idling costs.

Haul road conditions

Haul roads in the pit are not maintained to standard. Incorrect haul road width at places causes bottlenecking and an increase in truck travelling times. The presence of switchbacks causes trucks to have to stop and wait for each other as they are not wide enough for two trucks to pass. Although temporary in terms of mining, 'temporary' ramps have a permanent effect on production, i.e. they should be as well constructed (especially width and turning radii) and maintained as permanent ramps. This will increase the speed of trucks on the laden haul and contribute to reduced cycle times.

Simulating ideal operating conditions

Talpac simulations indicated that it is possible to run the operation optimally with a smaller fleet than is currently available. Trucks will, however, not be parked but rotated with those that are in for repair and servicing. It is important to note that the economic implication of this decision has not been analysed here. However, it is also important to note that under mixed fleet operating conditions, more trucks in the fleet of various sizes (when loading units are not alo increased) does not necessarily result in commensuratley more tonnage production, queuing time increases and, due to differences in engine power per ton gross vehicle mass, travel times may slow to accommodate the slowest truck on a ramp at any given point in time.

Control room operations

The control room serves as a focal point for improving mine productivity. Consideration needs to be taken whether one

person can effectively deal with all the requirements or if changes should be made to the control room staff, or how the information received by the control room is reviewed and used as a basis for optimal management of the operating fleet.

Truck-shovel matching

Trucks and shovels should be matched as per above discussion in order for loading times to be reduced. The results show that there is room for improvement and the possibility remains to load a 789 with a RH 340 or 785 with a RH 200 in 2 minutes or less. The variability of bucket cycle times indicates variable fragmentation or muckpile conditions and the impact of diggability on these times should be further investigated.

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