Optimizing LHD utilization

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

Synopsis

The purpose of the project was to optimize load haul dump (LHD) machinery use as they were spending too much time doing what they should not be doing. During the investigation, the author found that the machine's actual availability was 86% and the utilization ranged between 30% and 42%.This shows that the availability of the machine has met its target. Therefore the main problem was with the LHD utilization and that is what the project focuses on. To satisfy the objectives, the author firstly studied the existing mining data like the key performance indicators (KPIs) in order to analyse the machine's availability and utilization; this is what gave direction to the problem. Secondly the author did a literature review on mines with similar problems. This gave the author ideas on what to look at in approaching such a situation. Thirdly, the author gathered information on what the LHDs are doing on a daily basis by doing a time study. This gave the author an idea of how long it took the LHDs to complete a specific task. The author also interviewed operators and their supervisors in order to find the best practice work. This helped in identifying the problem areas when comparing the best practice work with what the LHDs are actually doing. According to the project results, it was found that the LHDs are underutilized due to shortage of drivers and the long distances the LHDs have to travel for material loading and refuelling. The author recommended that the machine utilization should be improved by training more operators in order to eliminate the 'no operator' downtime; the cost arrangement of this recommendation is included in the report. The author also recommended that the travelling time should be reduced by using tractors instead of LHDs when long distances need to be travelled for material loading. Another recommendation for reducing travelling time was to bring the mobile fuel tank closer to a section; the cost arrangement for this recommendation is also included in the report.

Keywords
Optimizing, LHD utilization, LHD availability, key performance indicators (KPI), shortage of drivers, long distances, mobile fuel tanks.

Introduction

The author was given an opportunity to complete a project in a space of eight weeks at New Denmark Colliery. The scope of the project was to optimize load haul dump (LHD) machinery utilization as it was found that LHDs are spending too much of their time doing what they should not be doing.

This report will cover the following:

- Locality of and background of New Denmark Colliery
- Project objectives
- Project methodology
- Literature search
- Project results
- Project conclusions
- Project recommendations
- Cost benefit analysis

Locality and background

Figure 1 illustrates the locations of all the Anglo Coal mines and New Denmark Colliery is at the bottom right of that map. New Denmark Colliery is located approximately 30 km from Standerton, 130 km from Witbank and 170 km from Johannesburg. New Denmark was established in 1984 and is the deepest underground colliery mining the no. 4 seam. It is contracted to supply Eskom, specifically Tutuka power station, with coal[1].

The mine has two production shafts namely Central and Okhozini shafts. There are seven continuous miner (CM) sections and one Longwall section. The author was specifically placed at Okhozini shaft which has two chain road production sections, two multi road production sections and one longwall section. Okhozini shaft has 15 LHDs in total, nine of them belong to the out bye service, two belong to the longwall section and the remaining four belong to the four CM sections available[1].

The author's project was more focused on the chain road production sections mainly because these sections develop the quickest. This means that these sections are the furthest from the shaft; that should therefore give us

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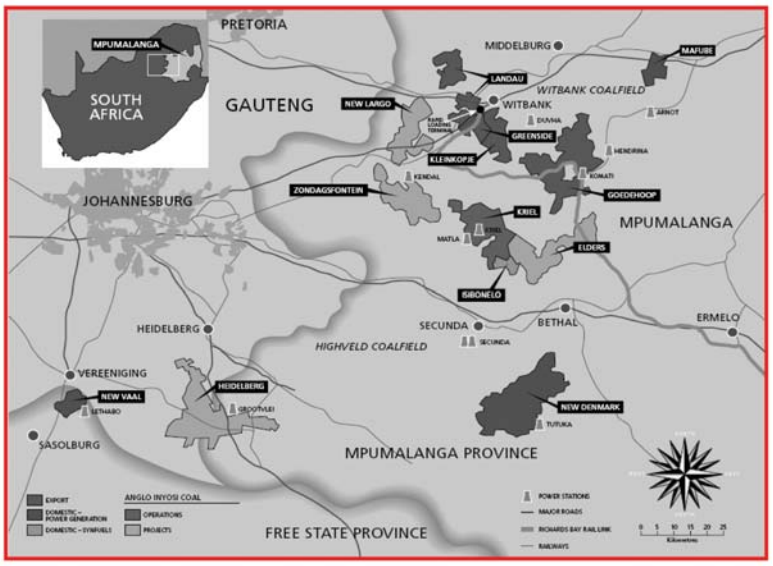

Figure 1—Simplified map showing New Denmark Colliery location[1]

more reliable results for LHD utilization. The chain road production sections have 48 skilled employees and 13 LHD drivers for both maintenance and rotation shifts[2].

The following are the LHDs that the author has been working with at the CM sections[3]:

- ED7 702
- ED7 703
- ED7 704
- ED7 706.

Project objectives

The project objectives were to:

- Determine what the LHDs are doing
- Determine what the LHDs should be doing
- Identify the problem areas
- Convert the actual practices to best practices
- Identify and optimize opportunities.

Project methodology

The following is what the author had to do in order to satisfy the defined objectives.

Do a literature search

The author researched on other mines with a similar problem; this gave the author a few ideas on what to specifically look at and how to approach such a problem.

The author managed to gather information in the following ways:

- The author used a machine checklist to see if the machine is doing everything that it should be doing.
- The author drew up a machine use sheet in order to record what an LHD does and how long it takes to complete a specific task in an 8 hour shift.
- The author also interviewed operators and their supervisors to determine the best practice work and the challenges they face.

The following mining data was also used:

- The author collected the historical key performance indicators (KPIs) in order to compare the budgeted availability with the actual availability.
- The author looked at the life of the machine review and the machine hour metre in order to calculate the actual utilization of the machine.
- The author also looked at the machine costs in order to get the rand per direct operating hour (R/DOH) of the machine.

Observations, measurements and data collection

The following data assisted the author in gathering the results, drawing conclusions and making recommendations.

Measured and collected LHD data

Table I illustrates the measured and collected data for all four LHD machines. This data is very important for the analysis of project results. The following points give a brief description of each column in Table I:

- Actual availability: column two gives the actual availability of each LHD machine; the average availability for all four machines is calculated to be 86%.
- Purchase dates: column three shows the dates that each LHD was bought.
- Hours on the hour meter: column four shows the hours on the hour meter of each LHD. The hour meters for ED7 703 and ED7 706 were not working.
- Maintenance costs: column five shows the maintenance cost of each LHD (total cost and unit cost). The author averaged the unit cost for the first three LHDs (ED7 702, 703, 704) to get the average rand per direct operating hour (R/DOH). The fourth LHD was excluded because its cost is close to negligible as compared to other machines therefore including that cost will lead to a problem of underestimating the operating cost. The

Table I

LHDs observations, measurements and data collection[3]

LHD type	Actual availability (%)	Purchase dates	Hours on the hour meter	Maintenance costs	
				Total cost (R)	Cost per unit (R/h)
ED7 702	85.56	2006/01/10	4771	206 611	30.82
ED7 703	80.68	2006/09/20	Not working	123 012	19.38
ED7 704	90.23	2008/02/28	3276	143 204	20.31
ED7 706	92.66	2008/06/29	Not working	19 469	2.68

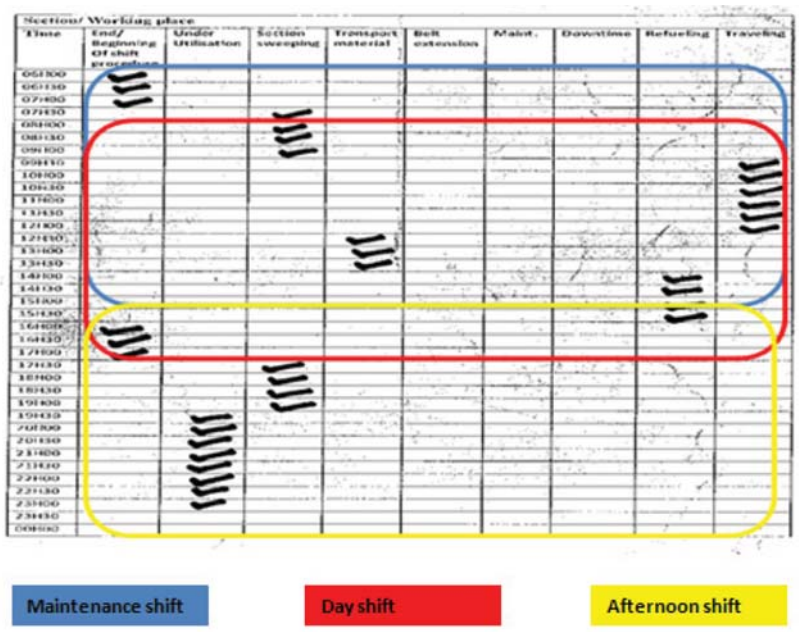

Figure 2—Daily machine use sheet

rand per direct operating hour averages to R23.50. This amount is for the maintenance cost excluding fuel. Note that the maintenance costs for each LHD were collected from the planning department not calculated.

Planned hours per year

There are 4690 planned hours for each LHD per year; these hours were calculated in the following manner[3]:

= 7 planned hours/shift × 670 shift/year
= 4 690 h/year

ED7 LHD capacities

The following are the LHD capacities which are of great importance in this project:

- Fuel consumption—the fuel consumption ranges between 23 ℓ/h and 46 ℓ/h, that is, 23 ℓ/ h when LHD is idling, 34.3 ℓ/h when it is doing average work and 46 ℓ/h when LHD is doing heavy work at full power[4].
- Payload—EIMCO ED7 LHD flameproof has 7000 kg payload[4].
- Fuel tank—The ED7 LHD has a 140 litre fuel tank[4].

LHD petrol price

The LHD petrol price amounts to R5.60 per litre (2009)[5].

Analysis and evaluation of research/investigation results

The author drew up a daily machine use sheet which was used when going down with the shift on a daily basis. Figure 2 illustrates the daily machine use sheet. The author worked closely with an LHD driver so as to tick off what the LHD is doing and how long it took to complete the task. The top of the sheet shows all the possible tasks of an LHD and on the side going down is the corresponding time of each task shown by the black ticks.

The portion circled in blue in Figure 2 symbolizes the maintenance shift which goes down at 6 a.m. and knocks off at 3 p.m., in red is the day shift which goes down at 9 a.m. and knocks off at 5 p.m. and in yellow is the afternoon shift which goes down at 3 p.m. and knocks off at 12 a.m. The author did not get the opportunity to work with the night shift due to supervision and transport related issues.

The first overlapping area between shifts in Figure 2 shows that the day shift goes down while the maintenance shift is still on duty. The maintenance shift should be done with sweeping the floor and pulling the belt before the day shift starts with production. The second overlapping area also shows that the afternoon shift goes down while the day shift is still on duty. The time when both shifts are underground is

used to communicate what was done on the previous shift and what still needs to be done so that the other shift can take over from there[5].

There is another overlap between the night shift that goes down at 11 p.m. and the afternoon shift that will still be on duty at that time as they knock off 12 a.m. This overlap is not shown on the daily machine use sheet as the author did not get an opportunity to work night shifts.

The graph in Figure 3 indicates the deduced results from all the daily machine use sheets that the author filled up in a space of six weeks. The graph has all the tasks on the x-axis and the corresponding minutes per shift on the y-axis, knowing that there are 540 minutes per shift. The graph in Figure 4 compares the actual results with the idealized results which the author got from interviewing operators and their supervisors.

The circled bars in Figure 4 symbolize the problem areas based on the discrepancy between the two bars in terms of time. This means that the LHDs take much more time than planned either loading material, travelling underground (going for refuelling), travelling to Central shaft or when they are not doing anything (idling).

Figure 5 shows an underground layout plan of New Denmark Colliery. The plan basically shows how far the sections are relative to the diesel shop and the two shafts (Okhozini and Central). The blue bold arrows indicate the route an LHD takes when it leaves the chain road production section to go to the diesel shop either for refuelling or to collect material transported by rails from Central shaft. The arrows also show that the LHD travels from the Chain road production section to Central shaft either for its monthly maintenance or to collect material now and then. This is not economical because the LHDs have to travel a distance of about 9 km from the section to the shaft. Figure 5 therefore gives a better understanding of why the author identified the problem areas mentioned above.

From the results shown above, the author saw that the biggest opportunities are to:

- Reduce the non-productive time (idling time).
- Reduce travelling time to central shaft and loading material.
- Reduce tramming time underground.

Conclusions

Conclusions from the analysis and investigation of results (daily machine use sheets and interviews)

The author concluded from the results shown that if the time for actual practice work would be brought down and equalized with the time for best practice work, there would be an opportunity of saving up to 50 minutes per shift. This amount of time seems short but it can definitely make a difference if used wisely. The 50 minutes is a summation of the time taken to do the following tasks:

- Loading material = 10 minutes
- Tramming underground = 10 minutes
- Travelling to Central shaft = 10 minutes
- Idling = 20 minutes
- Total = 50 minutes

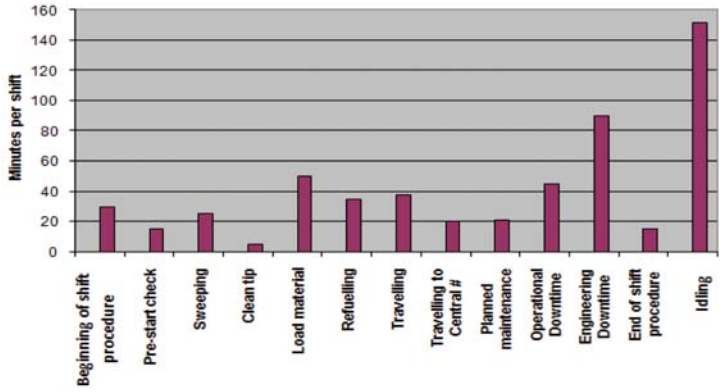

Figure 3—Actual daily machine use sheet results

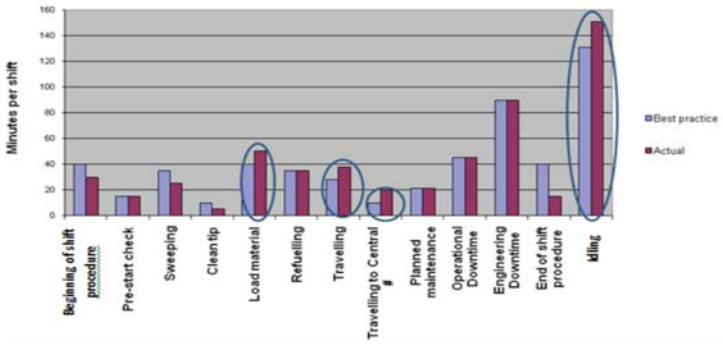

Figure 4—Actual versus the best practice results

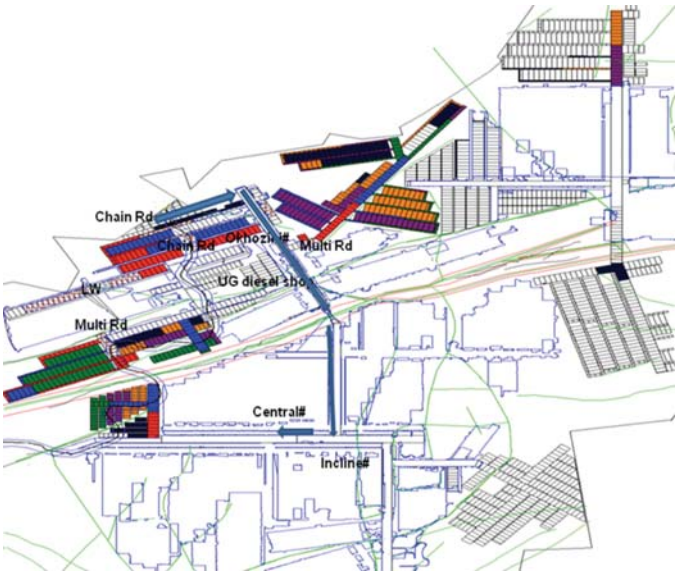

Figure 5—General plan of the underground layout[1]

Conclusions from the observations, measurements and collected data

Budget availability

The target engineering availability is 85%. This 85% is standard for all diesel equipment at the mine[3].

Actual availability

The actual availability for each LHD used in the CM sections has been included in the collected data (Table I). The average actual availability for all four LHDs is 86% which is more than the 85% for budget availability[3]. These results show that the LHDs have met their target in terms of availability therefore the author's project was more focused on LHD utilization.

Actual utilization

To calculate the actual utilization, the author needs to know the life of the machine, the planned possible hours and the hours on the hour-meter. These parameters were used in the following way to give the actual utilization:

Life of the machine

The author calculated the life of the machine to date (January 2010) by using the purchase dates which have been included in the collected data (Table I) for each LHD.

The following represents the life of each LHD:

- ED7 702 = 4 years
- ED7 703 = 3 years and 4 months = 3.33 years
- ED7 704 = 1 year and 11 months = 1.92 years
- ED7 706 = 1 year and 4 months = 1.33 years[3].

Possible hours

There are 4 690 planned hours in one year for each LHD. This figure was used to calculate the possible hour for each LHD knowing the life of the machine and the actual availability using the following equation:

Life of the machine (years) × Availability (%) × Planned hours in 1 year (hours/year)[5].

The equation gave the following results:

- ED7 702 = 16134 hours
- ED7 703 = 13431 hours
- ED7 704 = 7744 hours
- ED7 706 = 5364 hours

The calculations have been included in the appendices (Appendix A).

Actual utilization

Finally the author had enough parameters to calculate the actual utilization. The following equation was used[5]:

Hours on the hour meter / possible hours × 100%.

The equation gave the following results:

- ED7 702 = 30%
- ED7 703 (hour meter not working)
- ED7 704 = 42%
- ED7 706 (hour meter not working)

The calculations for these results are included in the appendices (Appendix B). The actual utilization during the course of the project was surprisingly 72%.

As seen from the calculations above, the actual availability is 86% but the actual utilization ranges between 30% and 42%.The author concluded that the machines had low utilization due to the fact that they spend most of their time idling and when in use, they waste their total working time doing easy jobs like tramming and spend a little bit of time on hard jobs like sweeping. If the operator starts using the machine effectively by operating the LHDs equally for both easy and hard jobs, there will be an opportunity of increasing the machine's utilization.

The actual utilization during the course of the project is high (72%) due to the fact that the LHD operators knew the content of the author's project, so they always made sure that the machine was working more often and effectively than usual during the investigation. When looking at the key performance indicators (KPIs) from the beginning of the year, one can see the usual trend of how the machines are normally used.

Recommendations

The author's recommendations were to optimize on the opportunities listed in the results, that is, to improve machine utilization and reduce its travelling time.

Machine utilization

Machine utilization can be improved by:

- Making sure that the hour meters on the LHDs are working so as to easily report the machine's operating hours at the control room. In that way, one can easily control the utilization of the machine.
- Eliminating the 'no operator downtime'. This is the time an LHD is idling because of the shortage of operators.
- By issuing more LHD licences because there are only 10 LHD drivers with licences for both chain road production sections when excluding the three drivers for the maintenance shift[3]. The situation is very concerning as this means that each section has five drivers in total for the day shift, afternoon shift and night shift[2]. From the author's perspective, a minimum number of six drivers should be available for each section so that there can be two drivers for each shift. This might be a solution for eliminating the 'no operator downtime' problem.

Travelling time

The machine's travelling time can be reduced by:

- Using tractors to travel to Central shaft instead of LHDs for material loading because LHDs are not meant for such long distances (9 km). This will allow LHDs to focus on their primary duties like sweeping a section. According to one of the operators, the LHDs were used for travelling to Central shaft because the tractors are always on breakdown. This is due to the fact that mechanics take a long time to respond to breakdowns[6]. A solution to this issue is to make sure that there is at least one mechanic at the park bay waiting for such breakdowns to avoid delays.
- Reduce travelling time for refuelling by bringing the mobile fuel tank closer to the section. The idea of bringing a mobile fuel tank closer to the section is not as easy as it sounds because there are a lot of factors to be considered, that is why the author looked at the cost implications (cost benefit analysis) for this recommendation.

Cost benefit analysis

The author compiled a cost benefit analysis for moving the mobile fuel tank closer to the section. Table II shows the items required and the costs per unit for each item, the explanation for this cost benefit analysis including the assumptions made are discussed in the next section.

Cost benefits analysis explanation

The author first confirmed that there is sufficient ventilation to the return airways in order carry out the idea[7]. Table II lists all the items needed in one column, the costs per unit and the cost per month in the other columns. Note that these are owning and operating costs excluding costs of depreciation. The following sub-headings explain how the author calculated the costs per month for each item assuming the tank is moved closer to the section every 2 months.

Mobile fuel tank

Each 5 000 litres tank costs R15 000, the useful economic life is assumed to be 2 years because the tank gets worn every time it is moved closer to the section[8].

Therefore cost per month = R1 500/ 24
= R625

The amount above is a rough estimate as the author did not consider the time value of money in the two-year period.

Hand-held fire extinguishers

According to the Anglo Coal standards, four fire extinguishers will be required which will sum to an amount of R1 400. The company will need to replace (refill) them every year[8].

Therefore cost per month = R1 400/ 12
= R117

Flameproof lights (cable installations included)

The flameproof lights will cost about R3 600 including cable installations[8]. The useful economic life for these lights is a year.

Therefore cost per month = R3 600/12
= R300

Concrete

The 12 m^3 of concrete has to be bought every time a mobile fuel tank moves closer to the section for preparation of a new split as the section advances. The mobile fuel tank will be moved every two months therefore the concrete has to be bought six times in one year. Each m^3 of concrete amounts to R935, that is, R11 220 for 12 m^3 of concrete[8].

Therefore cost per month = R11 220/2
= R5 610

Stone dust

A 3 m^3 of stone dust will be needed as the mobile fuel tank is moved every two months. This will amount to about R3 000 in total[8].

Therefore cost per month = R3 000/2
= R1 500

Table II

Cost benefit analysis

Item	Owning and operating cost	
	Cost per unit	Cost per month
5000 litre mobile fuel tank	R 15 000	R 625
4 hand-held fire extinguishers	R 1 400	R 117
Flameproof lights (cable installations incl.)	R 3 600	R 300
12 m^3 concrete	R 11 220	R 5 610
3 m^3 stone dust	R 3 000	R 1 500
LHD operating cost (inch fuel)	R 283.5 / hour	R 142
Concrete formal operating cost	R 216.5/ hour R 325 / trip	R 163
LHD tramming costs to refuel	R 152 per hour R 228 per trip	R 1 368
Total		**R 9 825**

LHD operating cost

An LHD will be required for cleaning the split and moving things around every time the mobile fuel tank is moved. The amount per direct operating hour excluding fuel is R23.50 (maintenance) as mentioned earlier. Since the author knows the fuel consumption at full power (46 ℓ/h) and the petrol price (R5.60/litre), the total LHD operating cost including fuel can be calculated.

Therefore fuel cost
= R5.60/litre × 46 litres/h
= R260/h

Therefore the total LHD operating cost
= R23.50 + R260
= R 283.50/h

Therefore cost per month = R283.5/2
= R142

Concrete truck operating cost

A concrete truck will be needed to deliver the concrete every two months. Assuming the amount per direct operating hour for the concrete truck is the same as the LHD and that the concrete truck will be doing average work at a fuel burn rate of 34.3 ℓ/h, the total operating cost can be calculated[5].

Therefore fuel cost = R5.60 × 34.5ℓ/h
= R193/h

Therefore the total concrete truck operating cost
= R23.50 + R193
= R 216.50/h

The concrete truck will be working for 1 h 30 min, therefore the total amount will be R325/ trip.

Therefore cost per month = R325/2
= R163

LHD tramming cost to refuel

An LHD is also needed for towing the mobile fuel tank to the park bay for refuelling. Knowing that an LHD has a 140 litre fuel tank and there are 18 production days in a month, the LHD will need to refuel every third day of the month, that is, 6 times a month[5].

Assuming that the LHD will be idling at a fuel burn rate of 23 ℓ/h, the total operating cost can be calculated in the following way:

Therefore fuel cost = R5.60/litre × 23 litres/h
= R129/h

Therefore the total LHD operating cost
= R23.50 + R129
= R 152/h

The LHD will be working for 1 h 30 min, therefore the total amount will be R228/ trip

Therefore cost per month = R228×6 trips
= R1 368

The total cost for the month to move the mobile fuel tank closer to the section amounts to R9 825.

Benefits

The idea of bringing the mobile fuel tank closer to the section will benefit the mine both quantitatively and qualitatively.

Quantitative benefit

The company will have an opportunity of saving up to 15 hours per month of travelling time for refuelling.

Qualitative benefit

The author cannot specify what can be done with the 15 hours but it is a fact that 15 hours is a lot of time and it can really make a difference in production if used wisely.

In order to obtain that 15 hours per month, R9 825 has to be paid per month. Therefore the company has an opportunity cost of R655 per hour, meaning that this is the amount that needs to be paid per hour to save 15 hours per month of travelling time for refuelling. Is this worth it?

The author did further research so as to optimize saving both time and money. It was found that to hire a contractor's LHD costs R578 per hour including diesel[8].

The cost benefit analysis showed us that the mine can hire an LHD from contractors for less than the amount needed to implement the idea of bringing the mobile fuel tank closer to the section. Therefore in the author's opinion, it would be economical to make use of the idling time on the LHDs for more important duties as well as using tractors for long trips in order to reduce travelling. In that way, both the availability and the utilization of the machine will be optimized.

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- LHD operators and shiftbosses at the chain road production sections for their assistance and for working with me during shifts.

Appendices

Appendix A: Calculations for machine possible hours per year

Equation: Life of the machine × Availability × Planned hours in 1 year

- ED7 702 = 4 years × 86% × 4 690 h/year
  = 16 134 hours
- ED7 703 = 3.33 years × 86% × 4 690 h/year
  = 13 431 hours
- ED7 704 = 1.92 years × 86% × 4 690 h/year
  = 7 744 hours
- ED7 706 = 1.33 years × 86% × 4 690 h/year
  = 5 364 hours

Appendix B: Calculation for actual utilization

Equation: Hours on the hour meter / possible hours × 100%

- ED7 702 = 4771 h/ 16 134 h × 100%
  = 30 %
- ED7 703 (hour meter not working)
- ED7 704 = 3 276 h/ 7 744 h × 100%
  = 42 %
- ED7 706 = (hour meter not working)

References

1. New Denmark Colliery. Company's internal data source, 14 December 2009.
2. New Denmark Colliery. Training Department internal data source, 14 December 2009.
3. New Denmark Colliery. Planning Department internal data source, 17 December 2009.
4. EIMCO. Operator's Manual: Machine Description; VA Alpine Mining and Tunnelling PTY Limited, 2005, p. 9.
5. Steyn, K. Shaft Manager; Personal Communication; New Denmark Colliery, 14 December 2009–13 January 2010.
6. Mahlangu, S. LHD operator; Personal Communication; New Denmark Colliery, 4 January 2010.
7. Venter, F. Ventilation officer; Personal Communication; New Denmark Colliery, 4 January 2010.
8. New Denmark Colliery. Stores internal data source, 5 January 2010. ◆