Feasibility study of replacing bottom dump trucks with rear dump trucks at Kleinkopje colliery

by T. Tamenti*

Synopsis

The purpose of the project was to conduct a feasibility study to determine if the current operating bottom dump trucks that haul coal should be replaced with rear dump trucks. The engineering availability of the bottom dump trucks was lower than targeted while the operating costs are the highest of all coal haulers within the Anglo Coal opencasts. To determine if it is feasible to replace the current bottom dump trucks with rear dump trucks, a production profile simulation was conducted to determine the number of rear dump trucks that would be required to meet the annual coal hauling requirements. The total capital and operating costs of these rear dump trucks were also determined using a total cost of ownership model. These were compared with the current costs of the bottom dump trucks to determine if it is financially feasible to replace the bottom dump trucks with rear dump trucks.

Having considered the capital outlay that would be required to replace the bottom dump trucks with rear dump trucks as well as their respective operating costs, it was concluded that the current bottom dump trucks should be replaced with rear dump trucks. Other factors were considered in coming to this conclusion.

Introduction

Mine background and general information

Kleinkopje Colliery is a multi-product opencast mine situated 10 km south-west of Witbank in the Mpumalanga Province. Mining commenced in 1979, although there had been underground mining in the Kleinkopje area in the 19th century[1]. Five main seams that are numbered in order of deposition from No.1 seam to No. 5 seam are present at Kleinkopje Colliery, this being typical of the Witbank Coalfield[1]. The coal-seams are separated by sediments of shale, sandstone and siltstone. The coal reserves of the mine are predominantly found in the No. 1, 2 and 4 seams[1]. There are limited reserves in the No. 2 Lower and No. 5 seam. Select and non select horizons are mined using selective mining and then delivered to a processing plant, as shown in Figure 1. Mining is currently being carried out in four pits: 2A North (No. 2 and 4 seams), 2A South (No. 1, 2 and 4 seams), 5 West (No. 1, 2 and 4 seams) and 3A North (No. 2 and 4 seams) with plans for mining a new pit called the Z Pit from 2006. According to the current plans, Kleinkopje Colliery will be mined until the end of 2025.

Along with Goedehoop, Bank, Greenside and Landau Collieries, Kleinkopje Colliery is one of Anglo Coal's South African coal export mines[2]. It produces low volatile steam coal derived from the non select coal for the export market; and double stage washed sized low ash metallurgical coal derived from the select coal for consumption by the local steel industry[1]. Middlings from the double stage wash are then added to the steam coal. The low volatile steam coal and low ash metallurgical coal are transported to the rapid loading terminal (RLT) for dispatch to the export and domestic markets by overland conveyors[1].

Some of the challenges facing mining at Kleinkopje are spontaneous combustion, appreciable amounts of it in pit water; steep ramps and bad quality run of mine coal as a result of burnt coal and cladding that is employed to prevent the burning of the *in situ* coal. The in-pit floor is full of undulations and is also relatively confined and the distances trucks have to travel from the loading area to the tipping area are relatively long (greater than 10 km in certain instances). Five draglines are currently being used at Kleinkopje Colliery for overburden removal.

Blasted coal is transported by trucks from the loading area inside the pit to the tipping area. There are currently three tips being utilized (Tip A. Tip B and Tip C), with Tips A and B having a coal handling capacity of 1 500

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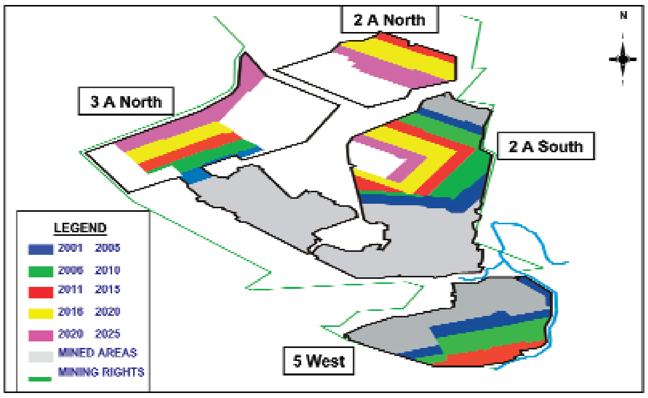

Figure 1—Kleinkopje Colliery mining areas with pits 3A North, 2A South, 2A North and 5 West shown

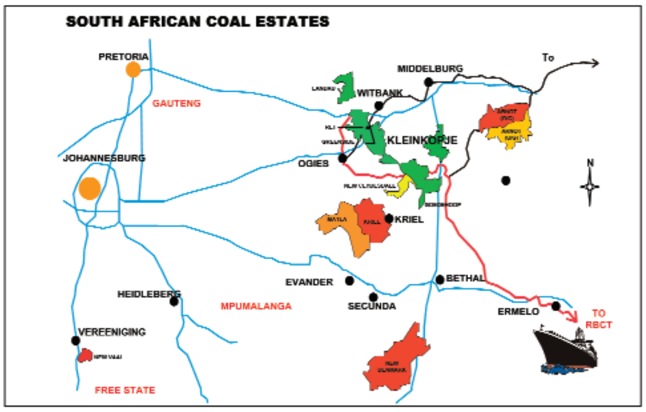

Figure 2—Map showing the location of Kleinkopje Colliery 10 km south of Witbank (source: Kleinkopje Visitors' Presentation)

tons per hour (t/h) and Tip C with a handling capacity of 1 000 t/h. Tips A and B are suited only for bottom dump trucks whereas both rear dump trucks and bottom dump trucks can off load coal at Tip C (see Figures 3 and 4). Tip C is the most recent of the three tips as it was commissioned only in 2002, whereas the other two tips have been operational since the inception of the mine.

Project background

Kleinkopje Colliery currently uses eight tractor-trailer type bottom dump trucks for its coal hauling operation. Five of these trucks are Euclid-Hitachi CH 130 and three are Euclid-Hitachi CH 135, with each truck further identified by its own unique number, as shown in Table I. The trucks are usually referred to using the truck number (such as 10, 11, 12, 13, etc.), which is displayed on the front of each truck as shown in Figure 5. The truck numbers are used interchangeably with truck codes, which are essentially the truck numbers with a pre-fix of OCH 2 or OCH 3. All CH 130 trucks have a prefix of OCH2 whereas CH 135 trucks have OCH 3 used as a prefix.

CH 130 and CH 135 denote that the trucks are bottom dump coal haulers with a maximum payload of 130 and 135 metric tonnes respectively. The abbreviation of OCH used as part of the code for the trucks indicates that the trucks are Open pit coal haulers. The coal haulers are loaded by a P&H 1900 rope shovel, CAT 992D and CAT 992G front end wheel loaders with bucket sizes of 14 m^3, 12.5 m^3 and 18 m^3 respectively. The engineering availability of the respective loaders are 82%, 75% and 85%. On average they take 8, 12 and 7 passes respectively to fill the bottom dump trucks. The loaders are shown in Figure 5 to Figure 7.

As a result of frequent mechanical breakdown of the coal hauling fleet, the total fleet's engineering availability is decreasing. On the other hand, the rands per direct operating hours (R/DOH) and rands per ton (R/ton) of coal hauled are progressively increasing[3]. Kleinkopje Colliery coal haulers' key performance indicators (KPI) for 2005 are summarized below.

Euclid-Hitachi CH 130 fleet:

- Actual engineering availability : 70%
- Target engineering availability : 88%
- R/ton : 4.67
- R/DOH : 689.41

Euclid-Hitachi CH 135 fleet:

- Actual engineering availability : 79%
- Target engineering availability : 88%
- R/ton : 4.94
- R/DOH : 864.16

The difference between the target and actual engineering availabilities for the CH 130 and CH 135 fleets respectively is 18% and 9%. The financial implications of these differences

Figure 3—Tips A and B (left) with bottom dump truck dumping coal into Tip A

Figure 4—Rear dump truck reversing towards (left) and dumping coal into Tip C (right)

Table I

CH 130 and CH 135 trucks with unique truck identification numbers

Truck number and (code)	Truck type
10 (OCH 210)	CH 130
11 (OCH 211)	CH 130
12 (OCH 212)	CH 130
13 (OCH 213)	CH 130
14 (OCH 214)	CH 130
15 (OCH 315)	CH 135
16 (OCH 316)	CH 135
17 (OCH 317)	CH 135

Figure 5—PH 1900 rope shovel loading a CH 130 bottom dump truck

Figure 6—CAT 992D front end loader loading a CH 135 bottom dump truck

Figure 7—CAT 992G front end loader preparing to load coal

have been established. Key performance indicators (KPIs) of coal-hauling trucks in other mines were obtained and used to assess whether the coal-hauling truck fleet at Kleinkopje Colliery is relatively similar to those of other mines. Isibonelo Colliery, New Vaal Colliery, Landau Colliery and Kriel Colliery are the mines whose coal hauling trucks' key performance indicators were obtained and compared with those of the current fleet at Kleinkopje Colliery.

All the Anglo Coal opencast mines with the exception of Kleinkopje Colliery are currently using only rear dump trucks for coal-hauling purposes. It was thus deemed necessary to investigate the advantages and disadvantages of the currently used bottom dump trucks over the rear dump trucks that all the other mines are using.

Problem statement

The purpose of this project is to carry out a feasibility study concerning the replacement of existing bottom dump trucks with new rear dump trucks.

Objectives

This project is set to meet the following key goals:

- Identify major problems with the current fleet.
- Determine the operating costs of the current fleet.
- Evaluate if these costs are excessive or not.
- Consider the operational advantages and disadvantages of both the rear and bottom dump trucks.
- Shortlist possible rear dump trucks that might replace the bottom dump trucks and conduct a production simulation of each to determine the number of trucks needed.
- Calculate the capital and operating costs of the new fleet using a total cost of ownership model and compare the results with those of the current bottom dump trucks.
- Identify new loading machinery if needs be and their capital costs.
- Based on the above information, determine which type of rear dump truck is most suitable to replace the current fleet of bottom dump trucks. This is to be done if it is deemed necessary to replace the mine's existing bottom dump trucks.

Scope of the study

A time study was done to determine the loading cycle time of each loader. From this the number of passes required by each loader to fill the bottom dump trucks could be determined. The travelling time of each hauler from the loading area to the tipping area, however, was not determined. The time was not determined as it was acknowledged as a supposition that there were records of travelling times.

The operating costs of the existing bottom dump trucks were obtained and compared with those of rear dump trucks serving at other Anglo Coal collieries. The causes of the operating costs were, however, not extensively looked into. The same can be said about the trucks' engineering availability, which once obtained, were not analysed to determine the root of the values gathered.

Research methodology

The majority of the information concerning the bottom dump trucks was obtained from the Kleinkopje Colliery Cognos Upfront System. This is a computer database system that has records of all data that have been recorded by the engineering data capturers. From this system all the key performance indicators (KPIs) for the existing bottom dump trucks and all other equipment at Kleinkopje Colliery can be obtained. KPIs of other machines and equipment that operate in other Anglo Coal collieries can also be obtained. The availability of this information was utilized to compare the KPIs of the Kleinkopje Colliery coal haulers with those of Isibonelo Colliery, New Vaal Colliery, Landau Colliery and Kriel Colliery coal haulers.

A literature study was conducted to identify the advantages and disadvantages of both the rear and bottom dump trucks. Technical information relating to the different truck types was obtained from off-highway truck manufacturers to compare the performance of the different trucks. This information would then used to select the most likely or suitable rear dump trucks to replace the current bottom dump trucks; if the feasibility study reveals there is a need for such a decision to be made.

Readings of the loader cycle times were taken to determine how long it takes the current fleet of trucks to be loaded. This required measurements to be taken in the pit over a period of three days. The numerous and often variable cycle times of the trucks were not measured, however, as these could be obtained from the mine's database.

The profiles of the haul roads in the pit were obtained from the survey department and these were used by the truck manufacturers to carry out a production simulation using computer software packages. From this the number of trucks that would be required to achieve the targeted annual coal hauling production would be obtained. Having obtained this number it would be possible to determine the total cost of ownership for the possible new trucks. This total cost of ownership was calculated for a period of ten years.

Results from literature study

When conducting investigations and analysis of results the following assumption was made:

- Labour costs will remain constant for the duration of the project life.

Current fleet service life

The Euclid Hitachi CH 130 and CH 135 bottom dump trucks, like any other truck in a mining operation, have a limited number of hours for which they can operate. The CH 130 trucks have limited service hours of 80 000 hours; whereas the CH 135 trucks have longer limited service hours of 100 000 hours. These replacement hours are determined by the manufacturer and indicate the total number of hours each truck can travel (both empty and laden) before it has to be replaced with another truck. The alternative to replacing the truck would be to rebuild the truck by installing new truck components such as the engine and transmission[4].

Table II shows the total number of hours each CH 130 truck has managed to operate from the year of purchase (YOP) until the time the hours were taken in the first week of January 2006.

It is worth noting that the average total machine hours of the CH 130 fleet is 77 038 hours. These trucks were all, with the exception of number 11, purchased in 1991—meaning that they have been operating at Kleinkopje Colliery for approximately 14 years. Truck number 12 has completed the most number of hours, with truck number 14 having completed the least. These figures highlight the fact that from a truck replacement hours point of view, the trucks have to be replaced soon as they are on the verge of achieving their allotted maximum total hours. The replacement would, however, have to be a planned and staged event to prevent major disruption to the coal-hauling operation. Table III depicts a different scenario to the one above. The total fleet average hours of the CH 135 fleet is currently 23 834 hours; with all the trucks having been purchased in 2002. The replacement hours of the CH 135 trucks is 100 000 hours and, as a result, the current fleet has an average number of 76 166 hours left. From this it is unnecessary to replace the CH 135 fleet based purely on the hours the trucks have completed.

Truck availability

The engineering availability of machinery is an important aspect in any operation. The reason for this is that whenever a piece of equipment or machinery has broken down and needs maintenance, it becomes unavailable for the function it is meant to be performing. The same is true for the bottom dump trucks that are serving at Kleinkopje Colliery.

The engineering availability of the current fleet is below the planned engineering availability of 88%. Currently the average engineering availability of the CH 130 and CH 135 is 70% and 79% respectively. This is relatively far off the targeted engineering availability of 88%. What is also concerning is that the engineering availability has been decreasing over a period of 12 months. Figures 8 and 9 indicate the engineering availability over a period of 12 months, with the gradual decline indicated by the black trend line. These two figures were compiled with the information displayed in Tables IV and V. In addition to the engineering availability, the tables show the total number of failures the fleet experiences, the total tons hauled per fleet, as well as the total mean time to failure (MTTF) and mean time to repair (MTTR) per month. MTTF and MTTR are indicated as totals in the two tables. The average values can be obtained by dividing the totals by the number of trucks of each fleet. These tables are summaries of values that were obtained for each individual coal hauler. Details of the KPIs for each coal hauler can be found in Appendix A. MTTF refers to the total number of hours a truck operates before it experiences any mechanical problems that need to be fixed. These could include anything from flat tyres to replacing a damaged oil sump. MTTR refers to the total number of hours it takes to fix any mechanical problems the truck may have experienced. The total coal hauled by the coal haulers is also indicated.

The total number of tons hauled in 2005 by the CH 135 and CH 130 amount to 6 527 373, which is less than the targeted amount of 9 845 883 tons by 3 318 510 tons. A total of 7 797 874 tons was actually hauled during 2005, meaning that the current CH 135 and CH 130 trucks were not able to haul 1 270 501 tons (7 797 874 – 6 527 373 = 1 270 501). The coal that was not hauled by the coal-hauling trucks was transported by rear dump trucks that are borrowed from other operations such as the prestrip or top soil removal fleets, whenever these trucks are available. There have been instances when the coal haulers that are operating are insufficient in number as a result of mechanical breakdowns suffered by most coal haulers. This situation is

Table II

Current total hours of all CH 130 trucks

No.	YOP	Total hours
10	1990	76 518
11	1991	78 264
12	1991	79 979
13	1991	75 945
14	1991	74 485
Average	1991	77 038

Table III

Current total hours of all 135 trucks

No.	YOP	Total hours
15	2002	25 870
16	2002	23 470
17	2002	22 163
Average	2002	23 834

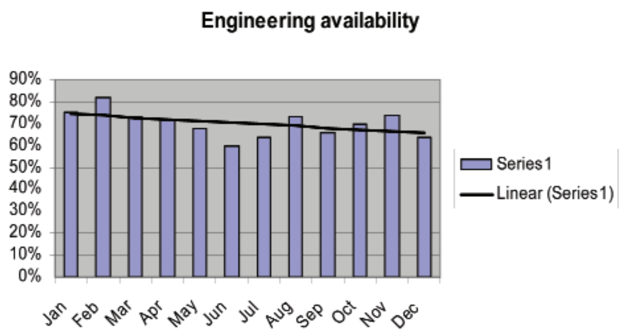

Figure 8—CH 130 fleet engineering availability

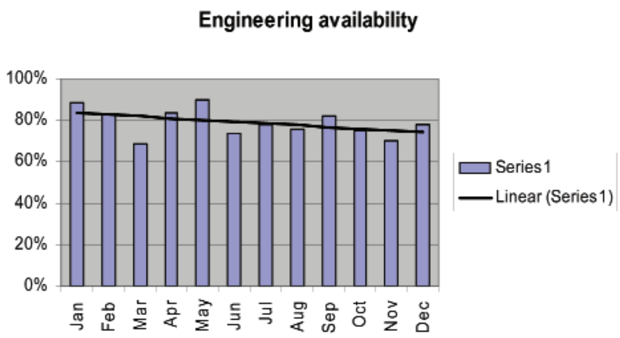

Figure 9—CH 135 fleet engineering availability

Table IV

Engineering availability and other key performance indicators of the CH 130 fleet

CH 130 fleet							
	Jan	Feb	Mar	Apr	May	Jun	
Failures	95	70	73	82	87	91	
Tons	348 722	333 110	304 265	348 240	293 790	261 762	
MTTF	156	214	175	157	153	108	
MTTR	19	13	23	26	27	57	
Eng avail	75%	82%	73%	72%	68%	60%	
	Jul	Aug	Sep	Oct	Nov	Dec	Total
Failures	105	95	89	103	125	38	1053
Tons	347 595	369 058	360 390	397 830	449 457	-	3 814 219
MTTF	114	137	136	123	104	133	1710
MTTR	64	23	42	27	15	37	372.9
Eng avail	64%	72%	66%	70%	74%	64%	70%

Table V

Engineering availability and other key performance indicators of the CH 135 fleet

CH 135 fleet							
	Jan	Feb	Mar	Apr	May	Jun	
Failures	48	51	44	60	39	54	
Tons	260 918	200 610	191 560	262 545	239 390	191 821	
MTTF	109	78	121	75	144	71	
MTTR	9	16	68	14	13	23	
Eng avail	89%	83%	69%	84%	90%	74%	
	Jul	Aug	Sep	Oct	Nov	Dec	Total
Failures	63	57	64	31	58	36	605
Tons	242 915	279 417	299 915	277 230	266 833	-	2 713 154
MTTF	70	78	77	152	67	64	1106
MTTR	22	34	16	56	46	18	335
Eng avail	78%	76%	81%	75%	70%	75%	79%

unsatisfactory as it means that coal is left exposed at the face with loading shovels being underutilized, hence leading the targeted coal to be hauled not being realized.

The weighted average availability of both the CH 130 and CH 135 is 73% instead of 88%; a combined deficit of 15%. A weighted average availability is used as opposed to evaluating the trucks individually so that the performance of the whole fleet can be assessed. The newer CH 135 trucks as expected have a higher engineering availability, but because there are only 3 of them as opposed to 5 CH 130 trucks, the weighted engineering availability of the fleet as a whole is relatively low. This actual weighted average availability is determined as:

$$[(0.79 * 3) + (0.70 * 5)]/8 = 73\%$$

The consequence of having such deficiencies between the target and actual engineering availabilities is lost coal hauling time, which can never be regained once lost. In a single year there are 24 * 365 = 8 760 hours of which 312 are lost due to 13 public holidays. Kleinkopje Colliery operates throughout the year (except on public holidays) with a 7-day 3-shift roster. There are also hours that are lost (when it is not possible to work) due to factors such as rain, mist, poor visibility, transfer of personnel between shifts, unavailability of operators and unavailability of loaders, among many. The hours that are lost on an annual basis vary every single year. Excluding all the lost hours annually, the coal-hauling fleet is scheduled for approximately 5 400 hours. If the planned engineering availability of 88% is applied to this value then it means that annually the trucks should be able to haul coal for 5 400 * 0.88 = 4 752 hours. It can thus be said that the trucks are scheduled to haul coal for a total of 4 752 hours annually to meet the production demands. When the combined engineering availability of the two fleets is factored into the 5 400 hours workable annually, it then means that the trucks haul coal for only approximately 5400 * 0.73 = 3 942 hours. As a result of the target engineering availability of the trucks not being met, there are approximately 4 752 – 3 942 = 810 hours that are lost annually per truck. This translates to an average of 810/12 = 68 hours lost per month by each truck. Multiplying these hours by the total fleet of 8 trucks means that in total there are 544 hours that are lost monthly. On average each truck manages to carry 1.5 loads per hour. Incidentally, the use of engineering availability is relatively high for both trucks. The CH 130 and CH 135 fleets averaged 94% and 95% respectively in 2005.

Appendix B contains the coal hauler statistics for each truck for the month indicated. These statistics were compiled by Mr. Ken McLaren (Kleinkopje Colliery pit superintendent and mentor). Included are the trucks (numbered 10 to 17), time and the number of coal loads transported by each truck. Due to operational unavailability trucks may not be able to carry loads within an hour or a number of hours. This is indicated by the colour green in any hour(s). Operational availability means that a truck may be available mechanically but not operationally due to lack of access into working areas, rain, mist, dust, full and blocked tips, preshift inspections, to mention a few. Blocks that are coloured red with the letter 'm' indicate that a truck was unavailable mechanically. This method of differentiation highlights the difference between the operational and mechanical unavailability at a given time of a month. The original compiled data showed only green blocks for both the mechanical and operational unavailability. During the project research in December 2005 mechanical breakdown records for the relevant months were analysed and used to indicate which hours of a day were unworked due to mechanical or operational unavailability of the trucks. The duration of each operational or mechanical unavailability is a rounded off value. This means that if a truck was mechanically unavailable for 45 minutes, then the unavailability is indicated as an hour. On the other hand, if it was unavailable for 10 minutes then it would be shown to have been available for the whole hour.

It must be noted that the sole reason for compiling the tables mentioned above is to visually show the extent of unavailability of the coal hauling trucks at Kleinkopje Colliery. Visual inspection of the hours that are lost on average may prove to be easier to understand and more enlightening than reading values that are quoted in percentages.

Operating costs

The rand per direct operating hours and rand per ton of the CH 130 are currently R/DOH 689.41 and R/ton 4.67 respectively. Taking the increase in the rand per ton of the CH 130 fleet in the last 12 months, a projection can be done using this increase to determine the likely cost per ton of coal hauled in 2006. The value calculated using this method is R/ton 5.79.

The respective costs for the CH 135 fleet are R/DOH 864.26 and R/ton 4.94. Using a similar projection method as above, the possible cost per ton of coal hauled (if the current increment rate is maintained) is R/ton 5.23. Figures 10–13 indicate the trend in increasing costs for the past 12 months for both bottom dump truck fleets.

When the costs stated above are compared to those of Euclid-Hitachi R170 trucks operating at Isibonelo, Kriel, Landau and New Vaal collieries (see Table VI); it is observed that all the costs of the current bottom dump fleet is the highest of all the fleets considered in the comparison. The large discrepancy between the costs of the coal haulers at Kleinkopje Colliery and those at other mines can possibly be attributed to the age of the current bottom dump trucks. Having stated this, however, it is surprising to note that although the CH 135 fleet was commissioned only in 2002, its costs are higher than those of the CH 130 fleet at Kleinkopje Colliery.

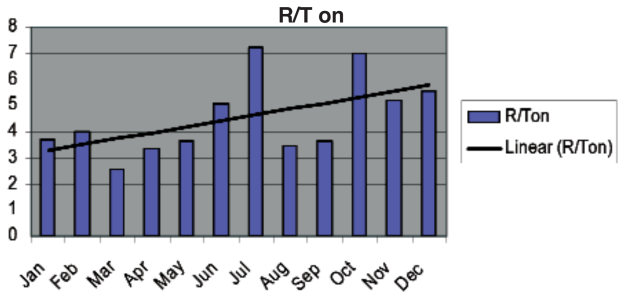

Figure 10—CH 130 fleet rand per ton costs

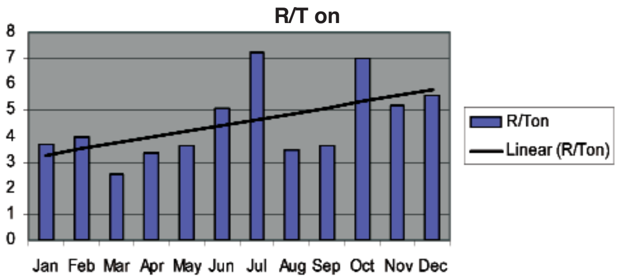

Figure 11—CH 135 fleet rand per ton costs

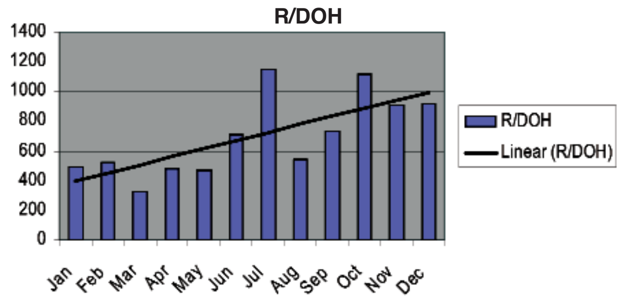

Figure 12—CH 130 fleet (R/DOH) costs

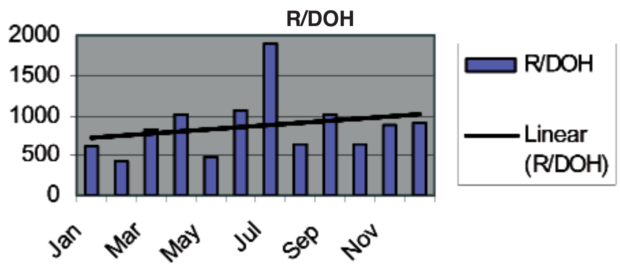

Figure 13—CH 135 fleet (R/DOH)

Table VI

KPI for coal haulers at four other Anglo Coal collieries

KPI 2005	Isibonelo Colliery	Kriel Colliery	Landau Colliery	New Vaal Colliery	Kleinkopje Colliery	
					CH 130	CH 135
Fleet size	4	5	6	20	5	3
R/ton	1.19	1.52	2.2	1.86	4.67	4.94
R/DOH	220	575	639	450	689.41	864.26

The weighted R/ton cost of the 8 coal haulers at Kleinkopje Colliery is [(4.67 * 5) + (4.94 * 3)]/8 = 4.77 while the weighted R/DOH cost is [(689.41 * 5) + (864.26 * 3)]/8 = 755. This means that the R/ton cost of the Kleinkopje Colliery coal haulers is 54% more than the second highest of all Anglo Coal open cast mines (Landau Colliery). The weighted average R/DOH cost is 15% greater than the costs of the coal haulers at Landau Colliery.

Advantages and disadvantages

For a specific operation, bottom and rear dump trucks each have characteristic advantages and disadvantages. This section aims to highlight the difference between the two types of trucks and then briefly consider which of the two types of trucks would be most suitable for the current conditions at Kleinkopje Colliery.

Bottom dump trucks

From the book *Surface Mining* by Seeley Mudd (1968) it is recommended to use bottom dump trucks when:

- ➤ The material hauled is free flowing
- ➤ The haul is relatively level, allowing high travel speeds
- ➤ Dumping is unrestricted into drive-over hopper, or the load is to be spread in windrows
- ➤ Long grades do not exceed 6%. (This is recommended as a general rule for optimum performance but is by no means a measure of the actual grade-ability of bottom dump semitrailers.)[5]

From the list above it is advantageous to continue using the current bottom dump trucks because the coal hauled is relatively free flowing and tipping is done on a drive-over tip. When considering the operation the latter is an advantage because the three tips that are currently in operation at Kleinkopje Colliery are all suitable for the bottom dump trucks. Haul roads are also relatively flat, allowing for high travel speeds.

However, the current bottom dump trucks are unsuitable for Kleinkopje Colliery conditions for the following reasons.

- ➤ The pit ramps are not relatively flat, with certain sections of the ramps having grades in excess of 8%. The pit ramps on the mine are planned to be no more than 6% so as to make them suitable for the current bottom dump trucks. This has not been achieved because of ramp construction difficulties, in addition to the multi-seam mining that has to be undertaken at the mine. The steep gradients that the current bottom dump trucks have to negotiate have been pinpointed as the main reason for gearbox failure[4]. The fleet of coal haulers is not designed for gradients in excess of 6%, and as a result the transmission is forced to select gear ratios numerous times to negotiate the sudden change in road grades.
- ➤ The bottom dump trucks are operationally inflexible because they cannot be used for hauling topsoil or overburden material once they are not needed for hauling coal. This can happen, for instance, when the crushers at the tips are not working and as a result the trucks cannot offload coal onto the tip. If the rear dump trucks that are dedicated to hauling the prestrip or topsoil material are being maintained or have broken down, the respective operations may have to stop or be slowed down as a result of a small number or total lack of trucks. It was mentioned in the previous section that whenever there is a shortage of bottom dump trucks operating in the pit as a result of mechanical breakdowns or any other reasons, rear dump trucks from either the topsoil or prestrip are called upon to haul coal from the working faces to the tip, if they are available for this. This means that the rear dump truck is more operationally flexible and versatile than the bottom dump truck, which can be used only for coal hauling.
- ➤ The hydraulic cylinders that open the clamshell gates of the trailer are susceptible to damage. Operators of the loading machines are trained by the mine to load coal onto the sloping front end of the trailer, so that the weight of the coal will not impose high impact forces on the cylinders that open the gates. Observations on the loading and hauling cycle have, however, indicated that this practice is not followed strictly by the loading equipment operators. Direct loading onto the floor area that overlies the gate cylinders leads to the gates malfunctioning and needing maintenance on a regular basis as the gates cannot open or close in the required amount of time. A secondary problem is that because some areas of the mine such as Pit 2A South experience spontaneous combustion, the coal loaded onto the trucks is sometimes transported while burning or relatively hot. This affects the cylinders of the gates because they were not designed to operate in such high temperature conditions[4].
- ➤ As the bottom dump truck is a tractor-trailer type arrangement that is connected by a pivotal hitch point, the truck does not act or handle as a single solid unit. This makes it difficult to manoeuvre the trucks,

especially when having to spot into a loading position. The trucks often have to turn acutely inside the loading faces so that they can reverse into their loading positions. Once they have turned, the drivers have to reverse the trucks accurately until they park beneath the raised bucket of the loading machine. This takes some time to achieve because the truck is not a unit but a system of two components (the trailer and the tractor/horse).

The four factors listed above are the main factors that limit the use of current bottom dump trucks at Kleinkopje Colliery. The trailer of a bottom dump truck is transported on 4 more tyres at the rear, meaning that bottom dump trucks need 4 tyres than rear dump truck. As a result tyre expenditure for bottom dump trucks is likely to be higher than for the same rear dump truck. This, however, cannot be substantiated as the tyre expenditure costs that were obtained are totals and not tyre costs for the current coal haulers only.

Rear dump trucks

The largest drawback of trying to use rear dump trucks at the mine would be their unsuitability for tips A and B. Tip C, which was constructed and commissioned in 2002, can be tipped into by both bottom and rear dump trucks. The rear dump trucks reverse against a constructed low wall and then stop to tip into the tipping area once the wall is touched by the rear tyres of the truck, as shown in Figure 4. The same cannot be said about Tips A and B, which would have to be modified to make them suitable for rear dump trucks. An attempt to obtain capital costs that would be required to convert the current tips A and B to suit rear dump trucks was unsuccessful.

Below are the advantages that stand to be gained by utilizing rear dump trucks for the coal hauling operation:

- ➤ Owing to their rigid, singular body that is shorter than the bottom dump trucks', the rear dump trucks are more manoeuvrable. This has been evidenced at Kleinkopje when these trucks are moved into a loading position under the bucket of a loader, where there is limited space inside the pit between the pit highwall and the spoils. This would reduce the spotting at the loader component of the cycle time as less time is required to manoeuvre the truck under the bucket of the loading machine. Secondly, rear dump trucks tend to be slightly easier to negotiate on wet inclined haul roads as they have smaller inter-axle spacing. Bottom dump trucks are more cumbersome to negotiate on wet inclined haul roads because the tractor and trailer can behave as two independent structures. Such an instance can arise when a truck operator rapidly retards a truck on a wet, inclined and curving haul road. While the truck is retarding in a straight line, the trailer might veer out of control to the side where it can potentially collide with an oncoming truck or other structures.
- ➤ The other main advantage a rear dump truck would render to the mine is versatility. These trucks can be used for not only the coal hauling operation, but also for hauling other material such as top soil when the need arises. This cannot be achieved with the current bottom dump trucks on the mine. Rear dump trucks are more versatile as they can be deployed to carry out such a task in instances where the three primary coal loaders break down simultaneously. This would ensure that the trucks are utilized (while the loaders are being mechanically attended to), albeit for an operation for which they are not purchased.
- ➤ Rear dump trucks have a smaller turning circle because they do not tow a trailer that adds length to the total dimension of the tractor/horse. The effect is that the trucks do not have to take turns going into a curve that turns more than 160° at the top of ramps that lead into the pit, for instance. This will potentially reduce travelling time from the pit to the tip, especially in instances where there is only one loader operating for a given period of time. This, however, is unlikely to happen frequently enough in a year to the extent that would result in more tonnages being hauled as a result of decreased hauling time.
- ➤ As they are not modified units these trucks can theoretically handle the gradients that are prevalent at the mine. This will lead to a reduced number of transmission problems that arise from trucks having to negotiate gradients for which they were not designed.
- ➤ The hydraulic cylinders that raise the bucket of the truck are less susceptible to damage when the truck is being loaded because of a more rigid design.

New fleet consideration

Having examined the state of the current coal-hauling fleet, the subsequent step was to consider the possibility of using rear dump trucks. This involved assessing the advantages and disadvantages of both types of trucks, as mentioned in the preceding section. The relatively high operating costs, low engineering availabilities and age of the current trucks warranted the consideration of new trucks for the coal hauling operation. If the trucks are to be replaced, it would be to the advantage of the mine to consider if the trucks should be replaced with a similar type of truck or totally changed to rear dump trucks.

Figure 14 is a schematic diagram of the process that was followed to evaluate the selection of a rear dump truck that would most optimally replace the current bottom dump trucks that are operating at Kleinkopje Colliery. Different rear dump trucks from different manufactures were considered when conducting the study. The study is limited, however, as only 2 trucks were considered due to time constraints. Preferably numerous trucks should be analysed.

A TCO model is a total cost of ownership model, which is a financial tool that provides an assessor with information of how much cost a company or a mine will have to incur for a single or number of machinery, equipment, etc. that it purchases and operates. TCO is mathematically defined as:

$$TCO = A + NPV \Sigma \ (Ti + Oi + Mi + RCn - Sn)^6$$

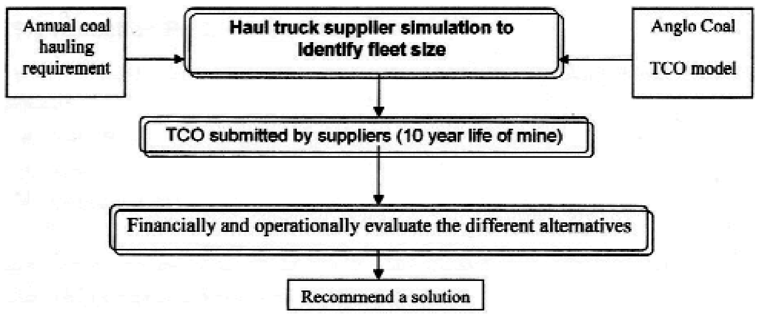

Figure 14—The process followed to consider the possible new rear dump truck replacement fleet[6]

where:
- *A* = Acquisition cost
- *NPV* = Net Present Value at a weighted average cost of capital (WACC)
- *Ti* = Training cost in year i
- *Oi* = Operating cost in year i
- *Mi* = Maintenance cost in year i
- *Sn* = Salvage value in year n
- *Rcn* = Recapitalisation value in year n[6]

If a decision is taken to purchase rear dump trucks, then the option with the lowest TCO would be taken with the objective of minimizing the costs as much as possible. This would, however, need to be compared with the operational efficiency and suitability of the trucks to be chosen to do service at Kleinkopje Colliery. In so doing one would be solving the problem using a holistic approach that is the best compromise between the financial and operational aspects. It would not make much logical sense to opt for a solution that is the cheapest but least operationally feasible. The converse is true: adopting the best operationally efficient solution with astronomical capital and running costs would be financially inept.

Production profile simulation

A production-based computer simulation was conducted with three rear dump truck manufacturing companies:
- Euclid Hitachi
- Komatsu
- Caterpillar(CAT)

These suppliers would normally be chosen from a list of numerous suppliers using the Anglo Coal South Africa's (ACSA) supplier service scorecard, an example of which is shown in Figure 15. For the purpose of the project, however, the suppliers were chosen by the author rather conveniently as there was not adequate time to evaluate all the manufacturers and their various truck options.

The scorecards rate the different suppliers based on the following skills and aspects (as numbered in the scorecards):

1. Safety
2. Safety
3. Technical
4. Training
5. Past performance
6. Spares
7. Infrastructure
8. Professionalism
9. General

As a result of time constraints, though, the results from Komatsu could not be assessed timeously.

The simulation required the respective manufacturing companies to determine the number of new trucks that would be required to meet the annual production demands of the mine. This was achieved by entering the total amount of coal (including roof coal) that would have to be hauled from the loading area to the tipping areas into simulation software packages by the respective companies. The packages that were used respectively by Komatsu and Caterpillar are called Talpac and Caterpillar Inc. Fleet Production and Cost Program (FPC); while it is unknown which package was used by Hitachi. Haul road profiles, loading equipment and their KPIs were included in the simulation as well. The software packages would then match the job conditions with the performance capabilities of the trucks to give an indication of how many trucks would be needed to meet the annual hauling demands from the various pits of the mine.

To ensure that the simulation that is to be done is representative, two assumptions were made:
- Coal from the Z-pit, which is in close proximity to pit 5 West, would be added to the coal that is to be hauled from the Z-pit.
- Similarly, the coal from pit 3A East, which is to be mined only from the year 2013, would be added to the coal that is to be hauled from pit 3A North.

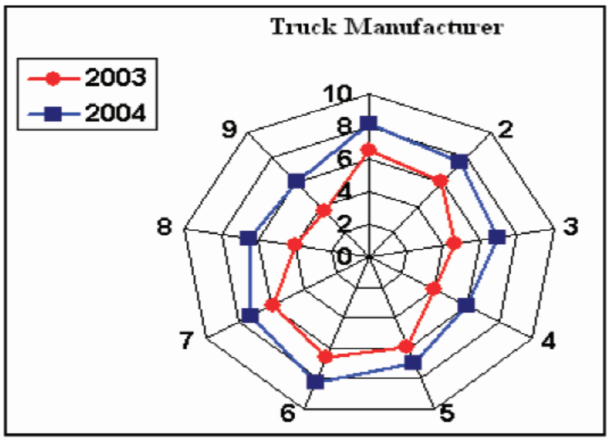

Figure 15—An example of an ACSA supplier service scorecard[6]

These assumptions are made on the basis that there are currently no haul roads that access these pits as mining has not started there yet (the earlier of the two to be mined is in 2006). As a result of the lack of access routes, there were no haul route profiles available that could be used in the respective manufacturers' simulation software. It was believed that omitting the coal in the two areas from the simulation would give results that are less representative of the actual situation than if the coal is assumed to be hauled from pit 5 West and the Z-pit

Table VII shows the total provisional annual tonnages that have to be hauled from each pit for the next ten years. These values were obtained from the planning department at Kleinkopje Colliery and were used in the production simulation as they appear in the table.

Haul road profiles and distances were obtained from the survey office and supplied to the manufacturers. Along with the coal tonnages that have to be hauled from each pit annually, the haulage profiles were used as inputs into the production simulation software. The simulation also required other inputs (as can be evidenced in Appendix C and D) such as:

- The type and number of shovels and their swing times, operational and engineering availabilities, passes and capacities
- Truck fuel consumption rates and working costs
- System efficiencies, theoretical and projected productivities
- Possible operating and available hauling hours per annum
- Hauling restrictions (e.g. speed limits, stop signs, yielding areas, etc.).

Table VIII shows the distances that are travelled by the coal haulers from the different ramps to the tips. It must be noted, however, that the hauling distances from the ramps to the tip will not remain constant during the 10-year period for which the simulation was done. Depending on whether mining of the respective pits is occurring towards or away from the tips, the hauling distances will either decrease or increase. This, however, was ignored as it would mean that different simulations would have to be done, leading to a solution that is potentially difficult for the author to draw workable conclusions from with the amount of time available.

An example of the fleet production simulation results from the FPC is available in Appendix E.

With the given number of trucks determined from the production simulation, it would be possible to calculate the total capital costs of the whole fleet that would have to be purchased by the mine to fulfil its coal-hauling requirements. A total cost of ownership was also determined and provided by the manufacturers for each fleet of trucks. The costs were determined using the total cost of ownership (TCO) model, which were developed by Anglo Coal South Africa (ACSA) and supplied to the manufacturers. Appendices C and D are copies of the final TCO results as supplied by the respective manufactures.

Trucks considered

Production simulation results and total costs of ownership were obtained for two trucks, namely:

- CAT777F
- Euclid Hitachi EH 3000.

Table VII

Target coal hauling requirements for a ten year period

	PITS						
Year	**2A North**	**2A South**	**3A North**	**3A East**	**5 West**	**Z Pit**	**TOTAL**
2006	1 367 762	2 431 578	2 151 406	0	1 236 890	718 041	7 905 677
2007	1 441 839	2 563 270	1 752 616	0	1 499 314	569 651	7 826 690
2008	1 740 499	3 094 221	1 950 009	0	1 090 081	1 071 147	8 945 957
2009	1 656 800	2 945 421	2 064 196	0	1 259 149	971 508	8 897 074
2010	1 651 509	2 936 015	2 243 700	0	1 896 665	384 667	9 112 556
2011	1 683 067	2 992 118	2 325 278	0	1 628 707	422 315	9 051 485
2012	1 597 809	2 840 550	2 465 345	0	1 965 183	301 940	9 170 827
2013	1 467 147	2 608 260	2 692 573	68 553	2 142 463	253 981	9 232 977
2014	1 512 357	2 688 636	2 538 273	132 952	2 453 904	0	9 326 122
2015	1 568 781	2 788 945	1 583 253	813 406	2 583 968	0	9 338 353

Table VIII

Hauling distances from the ramps to the tipping area

	2A North			**2A South**					**3A North**		**5 West**			
Ramp number	19	20	21	6	7	8	9	10	11	12	14	15	16	17
Distance (km)	9.4	9.8	8.3	5.3	4.2	3.9	2.8	2.7	4.8	4.1	4.9	4.6	5.0	5.3

Table IX contains the specifications of both trucks. The trucks were selected as they have payloads that are smaller (CAT 777F) and larger (EH 3000) than the current Kleinkopje coal haulers. Both trucks would thus provide management with the option of either employing smaller or larger trucks should the feasibility study indicate that the current bottom dump trucks need to be replaced with rear dump trucks.

Truck dimensions and other specifications for both trucks can be found in Appendix F. The following subsection compares the two rear dump trucks to establish any similarities and differences. The advantages and disadvantages of the two trucks as would be inherent if they operated at the mine are determined.

Euclid Hitachi EH 3000

This rear dump truck has the largest payload of the two considered (147 tons as opposed to 91 tons). Its replacement hours are currently claimed by the manufacturer to be 100 000 hours, the same as the current CH 135 operating at the mine. On other ACSA mines the EH 3000 has proved to be very productive with a relatively high degree of reliability and low operating costs. In fact, the operating costs of the EH 3000 operating at Kleinkopje Colliery is the best in ACSA[7].The EH 3000 fleet at Kleinkopje averaged 86% while the Hitachi R 170 (R 170 is the earlier version of the EH 3000) fleet at New Vaal Colliery averaged 89%[7]. The engineering availability of the EH 3000 fleet at Isibonelo Colliery is 93%, whilst the engineering availabilities of the R 170 fleets at Kriel and Landau collieries are 94% and 83% respectively[3].

The EH 3000 can be loaded by the P& H 1900 that is being currently used at the mine to load coal onto the bottom dump trucks, but cannot be loaded by the two front end loaders (CAT 9920 and CAT 992D). This truck would require the purchase of another loading machine, such as the CAT 994F. This would require additional capital expenditure of R 20 451 464 for the loader alone. The EH 3000 would be loaded with only two loaders, meaning that if one of the loaders breaks down or undergoing routine maintenance, one loader would be required to load 6 or 7 trucks. Having both loaders on routine maintenance is also possible, leaving the trucks with no dedicated coal loader operating.

The availability of EH 3000 and CAT 994 tyres is a worldwide problem currently, as there is a shortage of its tyres. The shortage of these large tyres is 'expected to last for several years—possibly until 2010—according to retailers and mining executives'[8]. The duration of the tyres can be increased by adopting strategies such as wrapping chains (that can cost $76 000 for two tyres) around the tyres, rotating them and improving the quality and frequency of road maintenance to reduce rock cuts[8]. Assmang for instance is faced with a 'shortage of tyres for the Cat 789 trucks and Cat 994 front end loaders'[9]. If this shortage persists or worsens, there may be trucks and a loader that have no tyres and become operationally non-functional.

The electrical drive system that is used in the truck is not supposed to come into contact with excessive amounts of water, and for this reason the tyres cannot get submerged in a pool of water. This is a large disadvantage because the mine is experiencing problems with in-pit water, with the pumping requirements needed to pump dry the in-pit floor not being achieved on a regular basis. The truck model that precedes the EH 3000, the R170, has relatively low running costs at other Anglo Coal collieries, as was pointed out previously. The TCO results indicate that this truck has the more expensive working costs, NPV and total cost of ownership per ton hauled. The other disadvantage is that because of its height, the truck cannot haul coal from pit 5 West because of overhead power lines, and from pit 3A North because of an overhead road to Tweefontein.

Table VIX

Specifications of the CAT 777F and EH 3000 rear dump trucks

Specifications	CAT 777F	EH 3000
Nominal payload (ton)	96	157
Target payload (ton)	91	147
Fuel tank capacity (ℓ)	1137	2839
Fuel consumption (ℓ/h)	65	100
Machine life hours	85 000	100 000
Gross machine weight (kg)	163 293	278 964
Gross power (kW)	746	1 343
Top speed (km/h)	60.4	54.7
Standard tyres	27.00R49	36.00R51(E4)
Front weight distribution	33	33
Rear weight distribution	67	67
Engine model	35088 EUI	K1800E
Number of cylinders	8	16

Figure 16—The CAT 777F (left) and the Euclid Hitachi EH 3000 (pictures not to scale)

CAT 777F

Having a capacity of 91 tons means that this truck is the smaller of the two by a relatively large margin. At 85 000, it also has lowest replacement hours of the two trucks considered. This means that it would have to be replaced 15 000 hours before the EH 3000 has to be replaced, given that they start operating at the same time and that they cover the same number of working hours per annum or any period of time. These replacement hours are 5 000 longer than those of the CH 130 and 15 000 short of those of the CH 135.

Being a smaller truck of the two, the 777F is the more manoeuvrable truck. The mechanical drive system that is utilized in the 777F does not have problems when it comes to interacting with excessive amounts of water. The hubs of the truck can be submerged in a pool of water without any damage to the drive system of the truck being adversely affected. This would suit the mine conditions, wherein the pit can have pools of water as a result of rain water that has not been pumped out of the pit.

The 777F can haul coal from all four pits of the mine because its height is well short of the power lines that traverse through 5 West and the overhead bridge that goes through pit 3 A North. The P & H 1900 rope shovel can load the 777F, and unlike the EH 3000 it can also be loaded by the current front end loaders (992G and 992D). The truck has had worldwide success in terms of sales around the world and also the high levels of engineering availability the truck is averaging[6].

The truck uses smaller tyres that are currently not in short supply like those of the EH 3000 and CAT 994F.

Simulation/TCO results and analysis

Below are the numbers of trucks needed to meet the required annual production.

As would be expected, the 777F (which has a target payload capacity that is 38% smaller than the EH 3000) requires more trucks than the latter to haul an equal amount of coal per annum. The following are the capital costs of each truck at the time of project completion:

1. CAT777F R 7 097 000
2. Euclid-Hitachi EH 3000 R 12 000 000

Table XI summarizes the TCO results obtained for both trucks.

If the current fleet were to be replaced, the total capital cost that the mining company would have to incur for 8, 9 and 10 CAT 777F trucks would be R56 776 000, R63 873 000 and R70 970 000 respectively. The acquisition of 6 and 7 EH 3000 trucks would require total capital of R72 000 000 and R84 000 000 respectively. As the current operating 992G and 992D front end loaders cannot load the EH 3000, a new loader would be required, increasing the capital costs. For the purpose of the simulation done with the EH3000 truck the CAT 994F front end loader, with a capital cost of R20 451 464, that was chosen. This would increase the capital costs to R92 451,464 for 6 EH 3000s and R104 451 464 for 7 trucks. It is acknowledged that there is a multitude of loaders available in the market and that the production profile simulation could have been conducted with some of them. Given the time constraints during vacation work, however, this could not be achieved.

The second acknowledgement is that some of the simulation and TCO results obtained seem to be a departure from what is expected. For instance, if one considers the operating costs of the EH 3000 and compares them with those of the trucks operating at other Anglo Coal mines, one can immediately realize that they are appreciably higher. The highest operating costs of EH 3000 trucks are those of the Landau Colliery fleet at R2.20 per ton and R639 per DOH (see Table VI). The operating costs of EH 3000 operating at Kleinkopje Colliery in the prestrip fleet are R1.51 per ton and R515 per DOH[7]. These are lower than the costs obtained from the TCO model. It is thus possible that the values obtained from the TCO model will be different from those that would be realized if the mine used any of the new rear dump trucks. This aside, the average operating costs of both trucks are less than the average operating costs (R4.77 per ton and R754.98 per DOH) of the current operating bottom dump trucks. Comparing these costs with those of the CAT 777F

Table X

Production simulation results for CAT 777F and EH 3000

Trucks required	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CAT 777F	7	8	8	9	19	9	9	10	10	9
EH 3000	6	6	7	7	7	7	7	7	7	7

Table XI

Summary of the TCO results

	CAT 777F	EH 3000
Capital cost (R/truck)	7 097 000.00	12 000 000.00
Capital cost (R/truck h)	83.00	120.00
Working costs (R/ton)	2.64	3.02
Working costs (R/truck h)	582.00	695.11
NPV R	206 194 534.00	283 615 671.00
TCO (R/ton)	2.32	3.19

(which is generally a cheaper option than the EH 3000) indicates that savings of R2.13 per ton and R172.98 per DOH would be realized.

While there would be savings realized on the operating costs, the capital expenditure that would be required for either rear dump truck is rather excessive. The total capital expenditure that would be required for having each truck operating at the mine is shown in Table XII.

These costs exclude the capital expenditure that would be needed to modify Tip A and Tip B to enable the rear dump trucks to tip into them. As was mentioned in one of the preceding sections, the costs that would be involved could not be obtained. The current fleet of bottom dump trucks does not require the acquisition of a new loader. Replacing all the CH 130 (as they are about to reach their replacement hours and have an average engineering availability of 70%) with CH 135 would require a capital outlay of R40 000 000 (R8 000 000 per CH 135 truck). These would be the only capital costs that would be required as the tips would not require modifications for these trucks.

The exorbitant capital expenditure required for either the CAT 777F or EH 3000 should be considered in conjunction with capital expenditure requirements of other machines on the mine. The following are machines that the mine has/is considering to replace:

- *Pre strip*—replace 3 x 630EH dumpers with 2 x EH 3000 dumpers @ RI1.1M per machine - excluding financials.
- *PC fleet*—replace PC 1000 with a EX 1900 class backhoe @ R11.2M - excluding financials.
- *Coaling*—replace a CAT 992D with a CAT 994 F class machine @ R20.5M _ excluding financials.
- *Coaling*—replace a CH 135 coal hauler with a EH 3000 dumper @ R11.1 M excluding fmancials.[7]

Ignoring the last two replacement applications (as they are subject of this feasibility study), the total capital that would be required for the first two applications (should they be approved) amount to R33 000 000. Using the EH 3000 purchase price used in the TCO model this value would increase marginally to R35 200 000. As any mining company should try and minimize both capital and operating as much as possible in order to realize maximum profits, the capital requirements of the rear dump trucks negate their purchase. Replacing the 5 CH 130 trucks with 5 CH 135 trucks is the least expensive of all options. Purchasing 5 CH 135 would require a total capital of R40 000 000 as opposed to R70 970 000 and R84 000 000 for 10 CAT 777F and 7 EH 3000 rear dump trucks respectively. This excludes the capital costs of acquiring at least an additional loader for the bigger capacity EH 3000.

Conclusions

The engineering availabilities of the bottom dump trucks are relatively low compared to the targeted engineering availability, the consequence of which being that certain rear dump trucks that are allocated to other sections (overburden, etc.) occasionally have to be called upon to transport coal when the bottom dump trucks have broken down in multiple numbers. The five CH 130 trucks have an average engineering availability of 70%, while the three CH 135 trucks are averaging 79%. The total fleet average equates to 73%, which is lower than the target engineering availability of 88%. The reasons as to why the bottom dump trucks operating at the mine have low engineering availabilities were not exactly established. As a result of the lower engineering availabilities, the fleet of 8 trucks is currently losing 544 hours monthly, which equates to approximately 6 528 hours per annum.

The operating costs of the trucks were determined to be high; in fact they are the highest of all ACSA coal haulers. The average R/DOH and R/ton costs for the whole fleet of 8 trucks are 754.98 and 4.77. Comparing these costs to those in other Anglo Coal mines indicates that these costs are rather excessive. As with the engineering availability, it was not determined why these costs are greater than those in other mines.

The current grades of certain sections of the haul road are equal to 8%, which is greater than the maximum grade suitable for bottom dump trucks (6%). Rear dump trucks are better able to negotiate grades in excess of 8% and would be better suited to operate on the mine haul roads than the bottom dump trucks. Employment of rear dump trucks would require the modification of Tip A and B as these are currently suitable only for the bottom dump trucks. Tip C is the only one of the three that is suitable for both types of trucks.

A production profile simulation that was conducted with a CAT 777F and a EH 3000 indicated that the former would require a maximum of 10 trucks while the latter would require 7 to meet the production hauling requirements of the mine over a 10-year period. Using the ACSA total cost of ownership model, probable operating costs of the two trucks were determined and are shown in Table XIII.

The capital costs required for the 10 CAT 777F is R70.97 million while the 7 EH 3000 would require R84 million. The latter would also require the purchase of a new loader, increasing the total capital costs the mine would have to incur if it were to purchase this or other similar truck (in terms of payload capacity). Both these costs exclude the costs that would be incurred for converting tips A and B to make them more suitable for rear dump truck. An approximate figure of these costs could not be obtained or determined during the feasibility study period.

The following are the recommendations made after conducting the feasibility study.

- Ideally an evaluation of the decreasing engineering availability as well as the increasing operating costs ought to be done, as no clear reasons for their respective decreases and increases could be established by the author during the study.

Table XII

Total capital expenditure required for loaders and CAT 777F and EH 3000

	CAT 777F	EH 3000
Number of trucks (max.)	10	7
Capital cost (R)	70 097 000.00	84 000 000.00
Additional loader CAPEX	-	20 451 464.00
Total CAPEX (R)	70 097 000.00	104 451 464.00

N.B.: CAPEX = capital expenditure

Table XIII

Summary of the TCO results

	CAT 777F	EH 3000
Capital cost (R/truck)	7 097 000.00	12 000 000.00
Capital cost (R/truck h)	83.00	120.00
Working costs (R/ton)	2.64	3.02
Working costs (R/truck h)	582.00	695.11
NPV R	206 194 534.00	283 615 671.00
TCO (R/ton)	2.32	3.19

➤ A re-evaluation of the TCO results and simulation ought to be done as there may be errors in the results obtained. This is indicated by the relatively high TCO results for the EH 3000 as an example, whereas in reality these figures are quiet low in currently operating mines

➤ If the aforementioned study of the engineering availabilities and operating costs proves that the they can be improved significantly, then the current CH 130 fleet of trucks can be replaced with 5 CH 135. This would require only a capital injection of R40 000 000. The horses of the old CH 130 can be alternatively used as lowbeds, resulting in a capital investment saving of R5 600 000,[7] per horse. The extra amount of money saved by purchasing these trucks as opposed to rear dump trucks can be used, for instance, to upgrade the bucket of the CAT 992D to a larger volume. Alternatively, a CATT 992G can be purchased. The author acknowledges, however, that it is possibly impossible to increase the engineering availabilities of the fleet as well as decrease their operating costs.

➤ Should the recommended study yield no improvements in the costs and engineering availabilities (which is very likely), the bottom dump trucks that are currently employed at Kleinkopje Colliery should be replaced with rear dump trucks. This would require substantial capital injection, as explained previously.

➤ Of the two rear dump trucks considered for replacing the bottom dump trucks, the CAT 777F (or similar sized truck) proved to be the better suited replacement truck when financial and operational factors were considered.

➤ The loading machines operating at the mine fill the trucks in more than 6 passes. A study should be conducted to determine whether the loaders can be fitted with larger buckets to ensure that they can load the trucks in the recommended 4–6 passes. This would decrease the loading time and the overall cycle time of the trucks by some margin. This would theoretically enable the trucks to do more loads in a day. Alternatively, newer and bigger loaders should be considered.

➤ The gradients of the ramps should be decreased as much as possible to suit the truck performance specifications.

➤ The water that collects at the pit should be pumped more efficiently to ensure that there is minimal water that accumulates on the mine. The purchase of rear dump trucks will not leave the tyres that they use less vulnerable to damage as a result of water and rocks that are hidden within it.

➤ Proper loading procedures should be inculcated into the loader operators to ensure that they follow the correct loading procedures. This would probably lead to reduced damage of the cylinders that open and close the clamshell gates of the bottom dump trucks. Spontaneous combustion should be better controlled as it will lead to the reduction of transportation of burning or burnt coal.

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