A comparative study between shuttle cars and battery haulers

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Synopsis

The purpose of this project was to compare two underground, batch coal haulers – battery haulers and shuttle cars – in order to determine the more viable machine to implement.

The specific standards for battery haulers were investigated and compared to the requirements of shuttle cars in order to identify the unnecessary expenses related to the legal requirements that are attached to the machines.

Costs such as running costs, capital costs, and maintenance costs were researched and compared over a typical life of machine.

Average production rates and breakdown times were obtained and used to determine which machine would be more reliable in achieving the required annual production.

Keywords

coal, bord and pillar, hauling, cost (running, capital, total ownership), productivity, reliability, safety, availability, constraints.

Introduction and mine background

During studies at the University of Pretoria and field research at Exxaro's Arnot coal mine, data was collected that could serve as a guideline for the selection of underground coal hauling machinery and what the present trends are related to these machines.

Arnot Colliery is wholly owned by Exxaro Resources, the largest BEE (Black Economic Empowerment) contributing mining house in South Africa, and is situated in the Witbank Coal fields in the Highveld region. At present the mine is solely an underground operation, exploiting the No. 2 Lower seam with an average calorific value of 23.8 MJ/kg and ash content of 23%. Production is approximately 2.5 Mt/a and is supplied to Eskom's Arnot power station on a cost-plus agreement (Exxaro, 2013).

Arnot employs a mechanized bord and pillar method with continuous coal-cutting miners. At present there are two interlinked shafts, 8 Shaft servicing five sections and 10 Shaft four sections. Currently there are four sections at 8 Shaft that utilize battery haulers, with one using shuttle cars and one planning to change to shuttle cars. At 10 Shaft on the other hand, only shuttle cars are used.

Introduction to bord and pillar coal haulage

In a typical underground mechanized bord and pillar mine section a Continuous Miner (CM) is used to cut the coal from the production face with a rooftogether bolting machine that installs permanent cemented roofbolts. Coal is loaded via the CM's chain conveyor system onto the batch hauling machines, either shuttle cars or battery haulers, which then transport the coal load to an in-section crusher or feeder breaker where the coal is offloaded and crushed to a more tolerable size. From the feeder breaker, coal is transported out of the mine via a series of conveyor belt systems.

Background of the project

Batch hauling systems in an underground coal mine are the most unreliable link in the chain of ore transport. The implications of costs, productivity, reliability, and safety of these machines was scrutinized by the management of Arnot and it was found necessary to investigate these aspects further.

During discussions, different opinions arose related to these machines and it was felt that these criteria need to be fully investigated and documented.

In particular, a critical comparison between battery haulers and shuttle cars was required to determine the more feasible piece of equipment to implement in terms of cost, safety, reliability, and productivity.

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Objectives and methodologies

Objectives	Methodologies
Determine all factors that influence the advantages and disadvantages of battery haulers and shuttle cars	Collect information from different sources i.e. internet, management and operators. Use questionnaires as assistance
Determine safety and health issues of both machines and evaluate them.	Locate and consult articles about the health and safety issues involved with battery haulers and shuttle.
Determine what the industry trend is and what the future outlook is for the use of these machines	Contact manufacturers and request current and future sales profiles
Determine costs such as running, maintenance, capital and others that have a major influence on the use of battery haulers and shuttle cars	Acquire information from suppliers as well as mine employees on the costs involved with the haulers.
Obtain production figures of all the production sections for a certain time period and relate them to the batch haulers from that particular section	Enquire production figures from the surveying department of both 8 Shaft and 10 Shaft
Determine and compare the reliability and availability of the machines	Obtain downtime studies from the engineering department and calculate the relevant figures according to a specific standard
Evaluate and analyse the results	Study, in detail, all the results that were obtained and draw conclusions on findings. Calculate costs, production figures, availabilities and other relevant information

Battery haulers vs. shuttle cars

The major difference between the two systems is that battery haulers are battery powered and shuttle cars are cable powered. This difference in itself entails advantages and disadvantages.

Other factors are the coal load bearing methods, turning mechanisms, and flexibility in terms of use and transport.

Battery haulers are much more flexible as they can travel any route in order to load and offload coal, but this can entail some drawbacks such as increased travelling distance and decreased battery life. This is not the case with shuttle cars since they are confined to travelling a specific route due to the trailing cable that supplies power to the drives. This, however, forces the section to do frequent section moves, where the section equipment is moved closer to the working face.

Figure 1 depicts a typical battery hauler showing the articulation joint. This joint is very useful for cornering and manoeuverability in restricted conditions. The coal loading portion is confined to the rear of the machine and offloading is done with a hydraulic push-off system. This hydraulic mechanism is disadvantageous because it incurs spillages at the feeder breaker and therefore side plates have to be attached to the feeder.

With the shuttle, car on the other hand, offloading can be synchronized with the feeder breaker since both use similar chain conveyor systems for loading and offloading (Figure 2). This reduces spillage and maintains a more constant feed rate to the feeder breaker. Unlike battery haulers, there is no articulation, but steering is via all four wheels, allowing the vehicle to corner easier.

Results and analysis

Current trends

In the current South African coal mining industry Joy's Stamler battery haulers are the front runners in the market and are used at most of the mines that use battery haulers. Joy is also the lead contracting company on the mine, supplying support and operations services to both the battery haulers and the shuttle cars.

According to Stewart (2013) in the past 5 years Joy sold 15 battery haulers and 126 shuttle cars. During that time Joy had a backlog of three battery haulers and almost 100 shuttle cars. This is a clear indication that the industry is moving away from the use of battery haulers and is more prone to buying shuttle cars.

The decrease in the use of battery haulers is resulting in a drop in the skills available for operation and maintenance, as well as increased cost of such skills.

A key aspect to consider is the standardization of the mine fleet in order to ensure better focus and skills for a certain machine, effectively increasing operational life and performance.

Health and safety aspects

Incident studies have shown that shuttle car operators have a reduced field of vision when the machine is loaded. In some cases operators lean out of the cab in order to see clearly, and

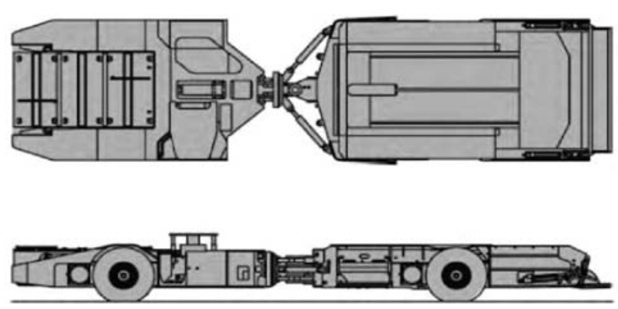

Figure 1—Battery hauler (Joy Global, 2013)

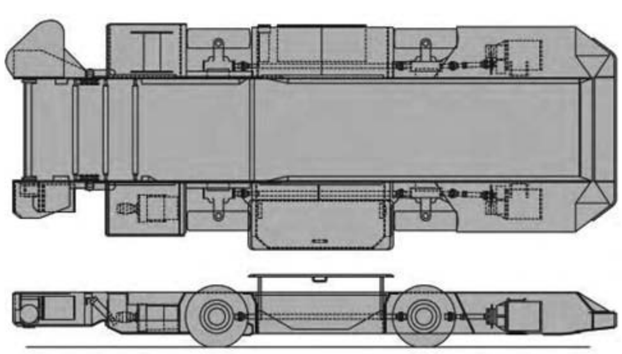

Figure 2—Shuttle car (Joy Global, 2013)

this could result in injuries or fatalities. Another contributor to injuries is the cables that accompany the shuttle cars. These are tripping hazards, and when the haulers are in motion or are cornering these cables can come under tension, and when this tension is released injury, damage, or fatalities may also occur (Bezuidenhout, 2011)

The major safety and environmental concern of the battery haulers is the fact that they are powered by lead-acid type batteries that produce hydrogen gases and might incur leakage of these gases and the acid-based electrolyte. This can lead to environmental contamination and exposure of workers to chemical-related injuries. The gases might also pose an explosion risk and this is of great concern in underground coal mines. (Van der Merwe, 2013)

Costs

Costs are one of the most important factors in the present–mining environment day. Several cost categories have to be considered. These include procurement, operating or life–cycle costs, and the total ownership cost (TOC).

Using the 2014 projected procurement prices that were supplied by Joy Global it was calculated that the difference in initial capital for the two machines was approximately 35%, with battery haulers being the more expensive. This excludes the additional requirement of installing battery bays as well as the ancillary ventilation and safety equipment required for the battery bay.

The cost difference between the major overhauling and replacement bodies is 15% and 6% respectively, with battery haulers again being the more expensive.

Considering that Joy requires these machines to receive a minor overhaul on a 1.0–1.2 million ton period, and a major overhaul every 1.6–1.8 million ROM tons, the life–cycle costs can be calculated using Figure 3. The average total life–cycle cost of the battery hauler per ton hauled is R 5.89 more than that of the shuttle car.

With the projected annual requirement of 190 000 tons per month per machine, the average operating costs would be R3.89 per ton and R2.98 per ton for battery haulers and shuttle cars respectively. Figure 3 shows the life-cycle costs.

The total machine life is approximately 2.4 Mt, which with the 190 000 ton per annum production target equates to approximately 12 years. Using this knowledge, a 10% interest rate, and a 2013/14 electricity cost of 65.51 cents per kilowatt-hour (Eskom, 2013) the TOC was calculated, making the assumption that these machines are operating for 18 hours a day and 26 days per month. Battery haulers have a total of 187 kW of motor power and shuttle cars 219 kW.

Over this 12-year period the battery haulers will cost approximately R3.6 million more to operate moving the same volume of coal.

Productivity

The productivity of the different sections over a six-month period was considered to try to identify whether shuttle car or battery hauler sections have a higher productivity. Several other factors could also contribute to differences in productivity, such as the fact that battery haulers on average carry more tons.

After seam height corrections had been applied, it seen that battery hauler sections produce on average 26 kt/month whereas shuttle car sections produce only an average of 21 kt/month. This is a difference of 5000 t/month per mining section. Also, battery haulers deviate from their monthly targets by about -20% and shuttle cars -30%, clearly indicating that there is a possibility that battery hauler sections are more productive.

Reliability

Downtime data for all the machines was tabulated over a 1-year period to obtain an average engineering availability for the two types of machines (Figure 4).

An average of 96.7% and 96.2% availability is achieved for battery haulers and shuttle cars respectively with a standard deviation of 2% for shuttle cars and 1.3% for battery haulers, indicating that both machines are very close in terms of reliability. Battery haulers had an average of 191 hours per annum downtime and shuttle cars 165 hours.

Figure 5 shows the specific downtimes for the haulers.

- Battery haulers:
  - Average mechanical downtime is 28.65% of the total
  - Electrical downtime is 54.9%
  - Hydraulic downtime totals 16.5%

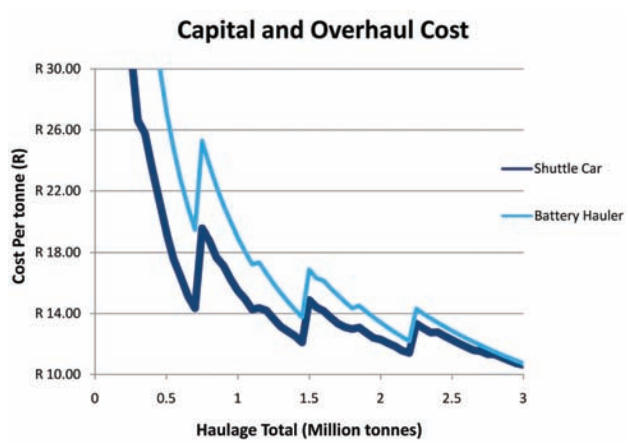

Figure 3—Life-cycle costs

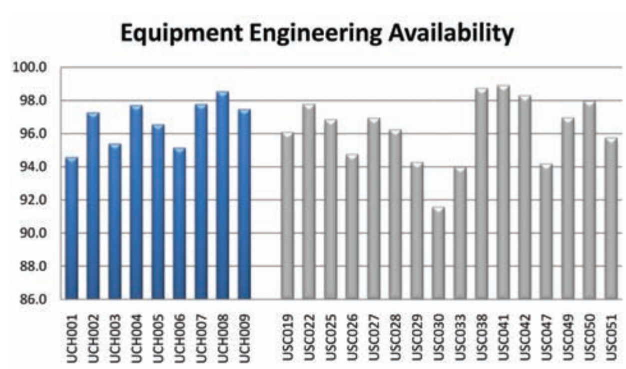

Figure 4—Engineering availability. Blue - battery haulers, grey - shuttle cars

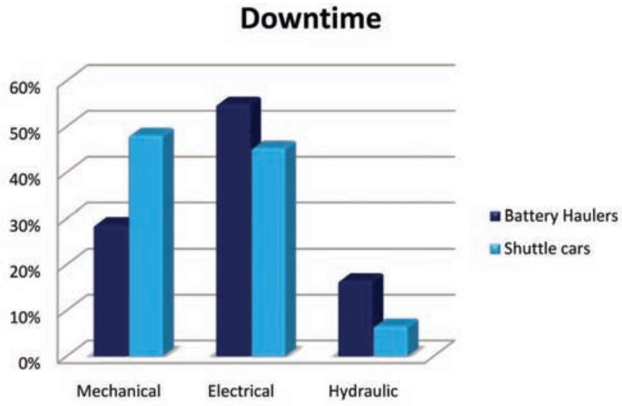

Figure 5—Average downtimes of shuttle cars and battery haulers

- Shuttle cars:
  - Mechanical downtime is 48.1% of the total
  - Electrical downtime is 45.3%
  - Hydraulic downtime is 6.6%.

Despite the belief that battery haulers are simpler in terms of the electrical circuitry, they experience higher relative downtimes due to electrical problems compared to shuttle cars. This may be due mainly to the Lionetics upgrades that are done on the machines to transform the DC current from the batteries into an AC output. This must be done according to SANS 1654. Also, battery haulers suffer more hydraulic breakdowns than shuttle cars and this raises concerns about the efficacy of the articulation joint.

The relative mechanical downtimes of shuttle cars are higher, and this is because some of these machines are nearly 30 years old. However, they still show very high availabilities, similar to those of the battery haulers.

Another factor that needs to be considered is that operators, artisans, and technicians have much more experience with shuttle cars than on battery haulers.

Constraints

Another factor contributing to machine selection is compatibility with other equipment such as feeder breakers and continuous miners. Through calculations and time studies it was found that the average cycle time for battery shuttle is 168 seconds and that of the shuttle cars is 190 seconds. Assuming that battery hauler payload is 18 t and the shuttle car payload 16 t with 21 cycles per hour for battery haulers and 18 cycles per hour for shuttle cars, that battery haulers have a 378 t/h capacity and shuttle cars only 288 t/h.

With a maximum of three haulers in a section the maximum capacity in a section is 1134 t/h for battery haulers and 864 t/h for shuttle cars. Comparing these figures to the capacities of the feeder breaker (770 t/h) and the CM (840 t/h) shows that there will be some waiting time at the CM for both machines, but because of the increased flexibility of the battery haulers they will thus be underutilized. This clearly shows that shuttle cars are more than capable of transporting the required tons if they are maintained properly and that battery haulers will not be used to their full capacity. (Figure 6).

Conclusions

Table I is a representation, according to level of significance, of which machine has superior performance in terms of the various criteria.

- In terms of safety and environmental concerns the shuttle car is a much better option
- Shuttle cars incur fewer costs in both running and procuring
- Battery haulers offer better productivity
- Both machines are very reliable
- Shuttle cars are more adaptable and compatible with the other equipment in the transport chain
- Battery haulers are prone to be much more flexible
- The coal mining industry seems to shy away from the use of battery haulers.

Recommendations

According to the results obtained from this study, it is recommended that the mine moves to the use of shuttle cars in order to reduce annual running costs, and also to reduce the funding required for battery bays, battery bay personnel, and refurbishing of batteries. In doing this the mine will also standardize the fleet and simplify ordering of spares and equipment.

However, use of battery haulers should not necessarily be completely eliminated. In some cases, such as poor in-section and low seam conditions, battery hauler are the preferred choice because of the better flexibility and manoeverability. Thus further study into the effects that bad section and seam conditions have on the haulers is required.

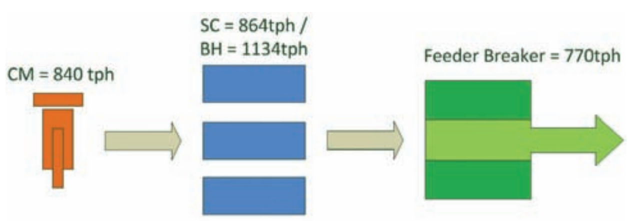

Figure 6—Evaluation of capacities

Table I

Conclusive comparison

Criteria	Weighting	Shuttle car	Product	Battery hauler	Product
Safety	10	8	80	6	60
Cost	9	8	72	6	54
Productivity	8	7	56	8	64
Reliabilty	7	9	63	9	63
Constraints	4	9	36	7	28
Flexibility	3	5	15	9	27
Trend	2	9	18	3	6
Total		340		302	

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