Abstract

General

For mining operations, both underground and open cast, there are generally accepted criteria used to arrive at the optimum mining method with which to exploit the ore body economically. Having selected the optimum mining method, mining companies should then make the decision to also select the optimum technology to apply given the various options that are now available.

In the case of a shallow massive ore body where open-pit mining has been selected as the optimum mining method, the use of conventional trucks and shovels has been the popular choice but over the years, as pit become deeper, and stripping ratios increase, growing interest and adoption of in-pit crushing and conveying for both ore and waste has been gaining ground with several mining sites currently now operating, testing the systems or conducting studies at various stages for In-pit Crushing and Conveying (IPCC) in its different configurations (Chadwick, 2010).

Open pit mining general involves the movement of pre-blasted or loose waste ahead of underlying ore out of the pit or to a previously mined part of the pit. This is then followed by the drilling and blasting or loosening of the ore and transportation to the processing plant or stockpiles.

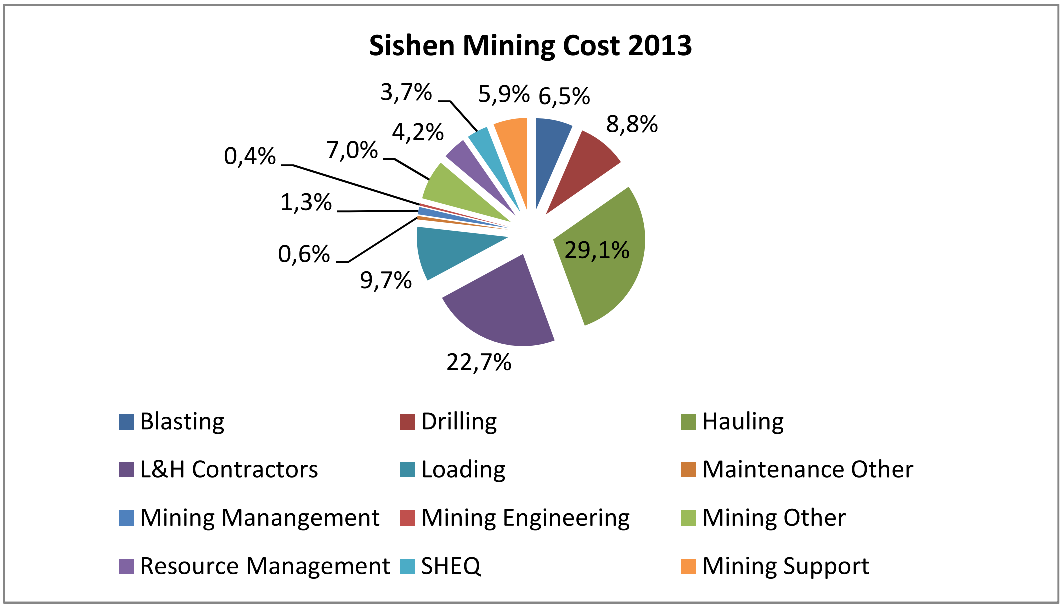
The conventional Truck and Shovel open pit operation involves the use of shovels – electric rope shovels, diesel or electric hydraulic shovels or excavators or front-end loaders to load the blasted, or loose waste and ore material in the pit onto mining trucks which haul the material to crushers or stockpiles if it is ore or to waste dumps in the case of waste.

In a Fully Mobile IPCC (FMIPCC) system, the broken or loose material in the pit is loaded into a crusher or sizer by a shovel, continuous miner or dozer, crushed to a manageable size and transported by conveyor belts to the waste dump where it is deposited in place using spreaders if it is waste or onto stockpiles if it is ore.

A combination of the two systems is where trucks dump material loaded at the face into a semi mobile crusher or sizer located in the pit close to the loading points

before conveying to destination thereby reducing truck haulage distance. In the semi-mobile configuration, the crusher is relocated closer to the loading points to minimise the hauling distance. Other various configurations are also employed depending on the various considerations. Although the Truck and Shovel system is considered as the convention in open pit mining, the IPCC system is not a new concept and has been operational on a number of mines worldwide for quite a number of years (Szalanski, 2010). Loading and hauling receive great attention especially in a high volume open pit mines due to the high cost contribution to the overall operation and therefore, if optimised, good cost savings can be realised (Lamb, 2010).

Figure 1: Sishen Mining Cost Breakdown



In the case of Sishen Loading and Hauling costs constituted 67% of the mining costs including labour mining support services in 2013 (Kumba Iron Ore, 2013). This picture remains unchanged to a large extent. In some cases the hauling cost alone can make up as much as 60% of the mining operating cost (Meredith May, 2012)

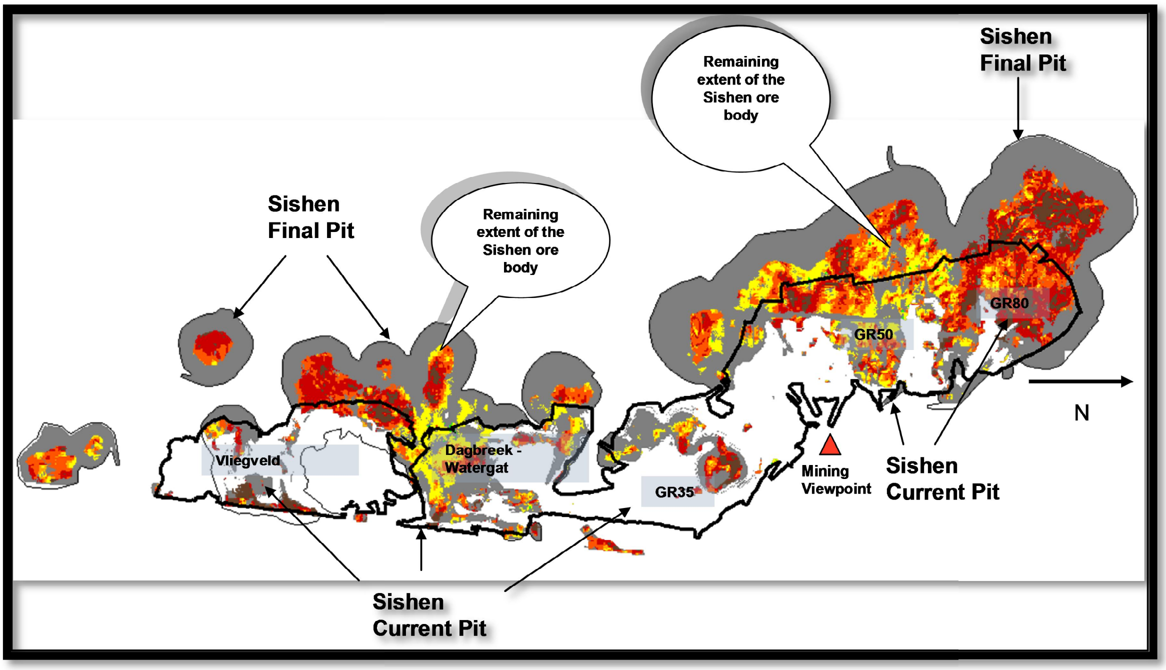
Selection of a materials handling system between Truck and Shovel (T/S) and In-pit Crushing and Conveying (IPCC) has proven to be difficult due to limited understanding of the IPCC system especially its advantages and disadvantages relative to the Truck and Shovel system. The aim of this research was to unpack these two systems in terms of their applicability using studies conducted at Sishen

Mine as well as develop some scorecard that could be used to select one over the other one.

Sishen Case Study

Sishen Mine is an iron ore open pit mine located in the Northern Cape province of South Africa and is part of Kumba Iron Ore Company which is majority owned by Anglo American PLC. The mine has been in operation since 1953 with the current life of mine going up to 2030. It produces 44Mt tonnes of product from a 56Mt run-of-mine ore at a life of mine strip ratio of 4. One of the planned expansion areas is in the north part of the mine known as the GR80 and GR50 areas. Mining in these areas will require pre-stripping of a minimum of 437Mt of calcrete and the underlying 290Mt of clay material over the life of mine to expose the ore in pre-planned time and volume phases.

Figure2: Sishen Pit –Sishen Mine 2014.



Sishen mine is constantly evaluating various technologies in its mining operations aimed at improving its bottom line by way of increasing productivity and efficiency, reducing costs and improving safety, however, the last time that the mine considered evaluating a technology that significantly could have resulted in a totally different operational philosophy was in 2007 when Snowden Mining Consultants were contracted to institute a study to evaluate technology options for mining and moving

55 Mt of the calcrete/clay material per year from the waste pushback area in the GR80/GR50 area of the mine from 2009 till 2030. Snowden completed the Prefeasibility study in early 2008 in which they evaluated a conventional Truck and Shovel operation as well as IPCC. Economic viability of both systems in various configurations was demonstrated with the use of larger trucks and shovels ranked as the most economic option in terms of Net Present Cost (NPC), unit owning and operating cost per mined tonne and, to a less extent, in terms of risk and other considerations. In this case, the Truck and Shovel option was more economic than both IPCC configurations. However the small difference in the cost figures gave rise to interest in further evaluations.

Following the Snowden study, Sishen engaged Sandvik Mining and Construction in 2008, to review the work done by Snowden and provide more detail and practical input to the IPCC system at scoping level. In the review, the IPCC system was shown to be the economic approach for the waste removal from the target area in terms of owning and operating cost. Practicality was also demonstrated and the case for the consideration of the IPCC system was put forward to Sishen.

A further consultant, Sinclair Knight Merz (SKM) of Australia, was engaged, in the later part of 2008, to further evaluate and optimise the IPCC option to further demonstrate practically in detail at a feasible study level and strengthen its case by mitigating perceived risk. This included equipment specifications, mine and equipment layout per period per bench and risk assessment on the IPCC options.

The mine, however, implemented the conventional truck and shovel option using larger equipment. The final decision was to stick with the current set up of Truck and Shovel system and gradually replace the current fleet of 730E Komatsu (190 tonne payload) trucks with the 930E or equivalent (320 tonne payload) and the current XPB 2300 P& H electric rope shovels and CAT 994/Komatsu WA1200 front end loaders with XPC 4100 P&H electric rope shovels, Komatsu PC8000/Liebherr 996 diesel hydraulic shovels and LeTournea L-2350 front end loaders to reduce the number of equipment and manage the operational cost.

This decision was based on issues around initial capital investment, flexibility of the system to suit changing mining plans, ability of current personnel to run the system and general low risk appetite for change. The adopted option has its own challenges such as supporting infrastructure requirements, labour intensity and associated low productivity and high cost, fleet management challenges to achieve required productivity constantly, supplies such as fuel and tyres and safety issues due to traffic density.

A high level recalculation of the costs using current information was done as part of this research. For simplicity, no escalations or discounting were applied on future expenditure. The estimated unit owning and operating costs in 2014 terms for the study area were as follows:-

Fully Mobile IPCC (FMIPCC) option	ZAR 10.38/t,
Semi Mobile IPCC (SMIPCC) option	ZAR 13.12/t,
Truck and Shovel option	ZAR 15.80/t.

The objective of this research is to use lessons from the Sishen case as well as other operations and gather expert views with the aim of establishing criteria that could be applied in a preliminary evaluation that would determine the suitability of either of the materials handling options.

General Approach

The costs were recalculated using as much current information as possible. Other considerations including advantages and disadvantages of either of the systems were examined in more detail, with real life examples examined where possible. This resulted in the establishment of generalized criteria for the selection of mining and transport technology for a large open pit mine with focus on conventional Truck and Shovel systems on one hand and IPCC systems, in their various formats, on the other. These criteria which identify conditions necessary for the successful adoption and implementation of either of the systems could then be used as input into the decision to carry out any further detailed studies of the options. The previous study reports on the Sishen mine case were examined, input parameters to the calculations checked and the general approached analyzed for practicality. The relative costs were also viewed for comparative purposes.

Literature on these two main systems was reviewed including that from conferences. Other large operations running either one or both systems were looked at to gain further insight. Original Equipment suppliers' views on these systems were also looked at through many articles in the public domain. Sishen mine has previously had the IPCC system running in the same part of the mine in a semi mobile configuration, crushing and conveying waste. It was then changed to become a supplementary system for the ore handling system and the in pit crusher has never been relocated. The Truck and Shovel system took over the movement of all the waste and most of the ore at the mine. Lessons from these experiences were incorporated in this study.