UNIVERSITY OF WITWATERSRAND

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

MASTER OF SCIENCE IN ENGINEERING

By Advanced Coursework and a Project

EVALUATION OF TWO DIFFERENT MECHANIZED EARTH MOVING TECHNOLOGIES- TRUCK AND SHOVEL AND IPCC FOR HANDLING MATERIAL FROM A LARGE OPEN PIT MINE USING REQUESITE DESIGN AND OPERATIONAL CONDITIONS, EFFICIENCY, COST, SKILLS AND SAFETY AS CRITERIA USING SISHEN IRON ORE MINE AS A CASE STUDY.

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DECLARATION: “I declare that I am familiar with the school of Mining Engineering’s policy on plagiarism, that the work contained in this project is my own unaided work, that it is written in my own words, and that all sources of material contained within this report have been suitably acknowledged.”

Signed : ___________________________________ Date: 13 November 2015

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Contents

List of Tables

List of Figures

Appendices

Chapter 1: Abstract

1.1 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).

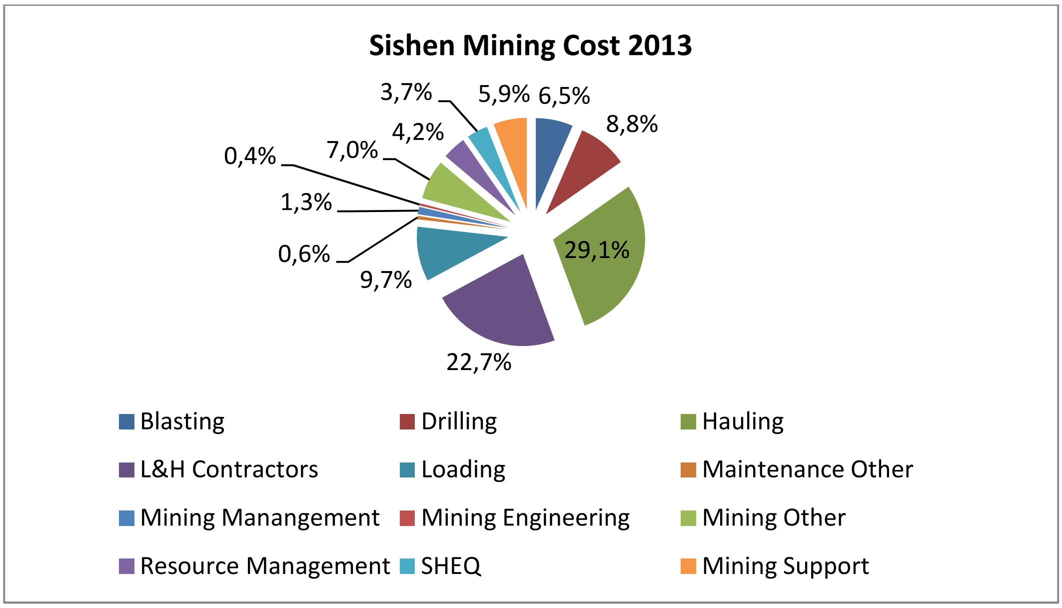
Open pit mining general involves the movement of pre-blasted or loose waste ahead of underlying ore out of the pit or to a previously mined part of the pit. This is then followed by the drilling and blasting or loosening of the ore and transportation to the processing plant or stockpiles.

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



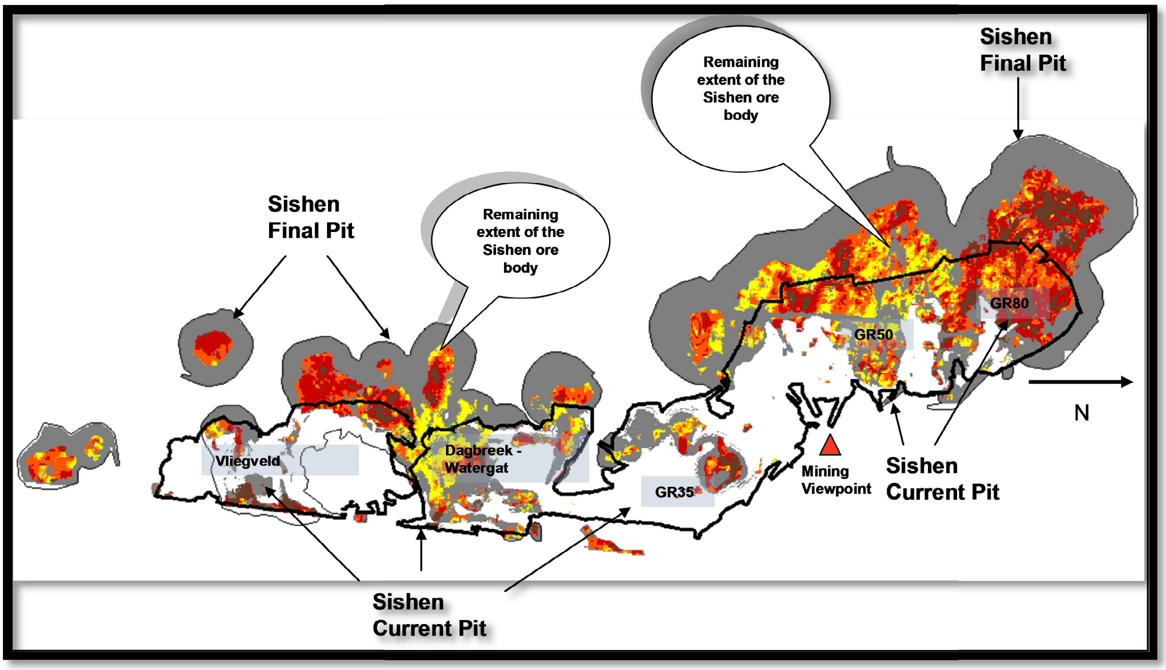
In the case of Sishen Loading and Hauling costs constituted 67% of the mining costs including labour mining support services in 2013 (Kumba Iron Ore, 2013). This picture remains unchanged to a large extent. In some cases the hauling cost alone can make up as much as 60% of the mining operating cost (Meredith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

1.2 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.

1.3 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.

Chapter 2: Literature Review

There are a number of papers and presentations that discuss various aspects of the truck and shovel as well as the in-pit crushing and conveying technical system as it applies to large open pit mines as well as experiences from across the world.

A presentation at an Anglo American IPCC workshop in 2013 highlighted the following (Morriss, 2013):-

- The Truck and Shovel set up still remains the default or baseline for large open pit mines that are considering a system to move ore or waste from the face to the ore crushers or waste dump.
- Long truck cycle distances, cycle times, difficult dump locations, increasing pit depth, remote mine site locations, increasing labour and camp costs, fuel price volatility compared to electrical energy, safety and environmental concerns are driving mining companies to look at alternatives to the Truck and Shovel system and IPCC is one such viable option.
- The IPCC system requires a different approach to mine planning, design and operational philosophy than the conventional Truck and Shovel system.
- Material properties, including variability, have a bearing on crusher selection, throughput, maintenance and cost. This is more critical when the IPCC system is applied on waste.
- The perception of risk, unfamiliarity and the failure of some of the earlier IPCC systems have led to decision makers requiring more detailed studies on IPCC systems than the proven truck and shovel system.
- The viability of the IPCC system has been demonstrated in a number studies carried out, ranging from desktop to feasibility level.
- There are a number of IPCC systems currently operational in various configurations around the world.

In the paper by David Tutton and Willibald Streck titled '***The Application of In-pit crushing and conveying in large, hard rock open pit mines***' (2009), the significance of hauling costs at above 48% of the operating costs in large open pit mines, is highlighted together with the fact that almost half of this cost is incurred on the in-pit ramps. The suitability of IPCC in high tonnage deep mines is discussed including having to deal with other necessary mining activities such as pit wall control, drilling and blasting and the development of pit accesses. The concept of phase value was also brought up as one of the disadvantages of the IPCC system. The conclusion was that it may be worthwhile to consider a hybrid of the truck and shovel and IPCC systems to address most of the concerns raised.

In another paper titled '***The use of in-pit crushing and conveying methods to significantly reduce transportation costs by truck***' by Detlev L. Schroder, Coal Trans -June 2003, the author elevates the compressive strength of the material to be moved as the key determinant factor in selecting a mining system and cost efficiency in the case of a transportation system.

The configuration of the mining faces as well as the presence/absence of geological structures determines whether to go fully mobile or semi mobile.

- Long straight mining faces, few geological structures – fully mobile
- Deep and wide in all directions, many geological structures – semi mobile.

In this paper, careful analysis is advised before deciding on a system. A hybrid option is recommended in some cases rather than an 'either or' approach.

Philip Morriss, in his paper '***Key Production Drivers in In-pit Crushing and Conveying Studies'*** highlights the following challenges when considering IPCC systems such as:

- Mine planning/ scheduling e.g. high vertical rate of advance and pit geometry that do not support the operation of IPCC systems
- Achievable operating hours and instantaneous production rates due to linkages of the system components in series.
- Risk perceptions

A completely different planning approach to that of Truck and Shovel operating is required when considering IPCC system (Turnbull, 2013). Engaging expertise in the design if IPCC systems in critical (Armesy, 2010).

In the article appearing in the International Mining magazine in May 2012 titled '***The Road to IPCC***' Paul Moore discusses a number of IPCC systems in various mining sites around the world including the following:

- Hawson iron ore project, Australia, realized a 14% cost improvement with IPCC compared to truck/shovel option.
- Penasquito mine, Mexico, used hybrid truck/shovel and IPCC system to solve their distant waste dump problem.
- Hancock Coal, Australia, use dozers to push down the top 12 metres of a 30 metre bench to enable the shovels to feed sizer for the IPCC system.
- Pumpkin Hollow, Nevada copper, switchback design in the mine ramps to minimize haul road/ conveyor interaction along the pit walls.

He raises the issue of the cyclic nature of the mineral markets with respect to the length of a payback period, low risk, short term flexibility, early payback truck and shovel system compared to a longer term, optimised, investment in a low cost IPCC operation to ride the cycles.

Rio Tinto Coal Australia installed an IPCC system at Clermont mine in 2009 which enabled mining of areas where the ore is deeper with high stripping ratios. These areas would have been uneconomic to mine using a conventional truck and shovel approach (Chadwick, 2010)

The Truck and Shovel option still remains the preferred option. To improve the safety and efficiency of the system, developments are directed at to simulations and optimisation, dispatch systems and automation. Ercelebi and Bascetin in their paper titled '***Optimisation of shovel-truck system for surface mine'*** (2009), demonstrated that efficient truck allocation and dispatching can be achieved using queuing theory and linear programming in a truck and shovel operation.

Sishen mine instituted studies in 2007 and 2008 to evaluate the potential of applying In-pit crushing and conveying as an alternative to the conventional truck and shovel operation for accelerated movement of overburden from a particular part of the mine known as the GR80/GR50. The scope of work for this study, conducted by Snowden reviewed by Sandvik and Sinclair Knight and Merz, included a practical implementation or operational plan, complete with designs, equipment lists and budget quotes and supporting infrastructure such as energy, risk assessment and mitigation as well as cost. The study confirmed the practical viability of implementing the IPCC system at Sishen mine but there were conflicting estimates on the cost with the Truck and Shovel being shown to be more economically more viable than IPCC in one study and the opposite being indicated in the other report. The costs were however within 30% percent of each other with the accuracy of the studies being cited at ±25%.

Some of the sites mentioned in the studies as running IPCC systems in various configurations and combinations include:

- Goonyella Riverside mine- Australia
- Suncor Voyager mine- Canada
- Yimin mine- China
- Escondida mine- Chile
- Clermont mine- Australia

Sishen mine uses a computerised truck dispatch system provided by Modular Mining systems to allocate and dispatch its huge fleet of trucks quite efficiently. The dispatch system is also critical in ensuring that the required blend, from multiple ore loading faces, is achieved. The truck and shovel system also makes short term planning much easier due to its flexibility and adaptability to changes in economic and operating conditions. Furthermore some of the longer ramps are equipped with trolley lines upon which the diesel-electric trucks can engage on the upward haul when loaded thereby utilising electric power. Higher speeds can be achieved thus improving truck productivity with low diesel consumption. This trolley system is being considered in the area under study and as one option that could strengthen the case for a Truck and Shovel system.

Sishen mine once operated a Semi mobile In-pit Crushing and Conveying system to handle waste from the same area. This was later converted to an ore handling system with the crusher fixed in one position in the pit. Reasons quoted from Sishen personnel are that it was converted once it was felt that there was sufficient ore exposed and additional waste stripping could be handled adequately by trucks and shovels. Others say dump relocations was a problem as they could not locate one dump large enough to prevent frequent relocations of the spreaders and associated conveyors. Whatever the case, it would appear that the system was not operated efficiently enough and questions were raised on the economics of crushing waste. The gyratory crusher was never relocated from its original installed position.

Figure 3: Sishen Semi mobile crusher being moved to a position (Morriss, 2013)

From the papers above, the workshop, as well as discussions with various knowledgeable colleagues, it can be concluded that the decision to select between a conventional truck and shovel and in-pit crushing and conveying for moving material from inside an open pit, is not an easy one. In some cases, a hybrid of the two systems may be the answer. General criteria to evaluate the potential of each of the system as the optimum solution for a given project would go a long way in assisting on whether to take the studies from a preliminary assessment stage to conceptual or pre-feasibility level. This is the objective of this research project.

Chapter 3: Systems Design

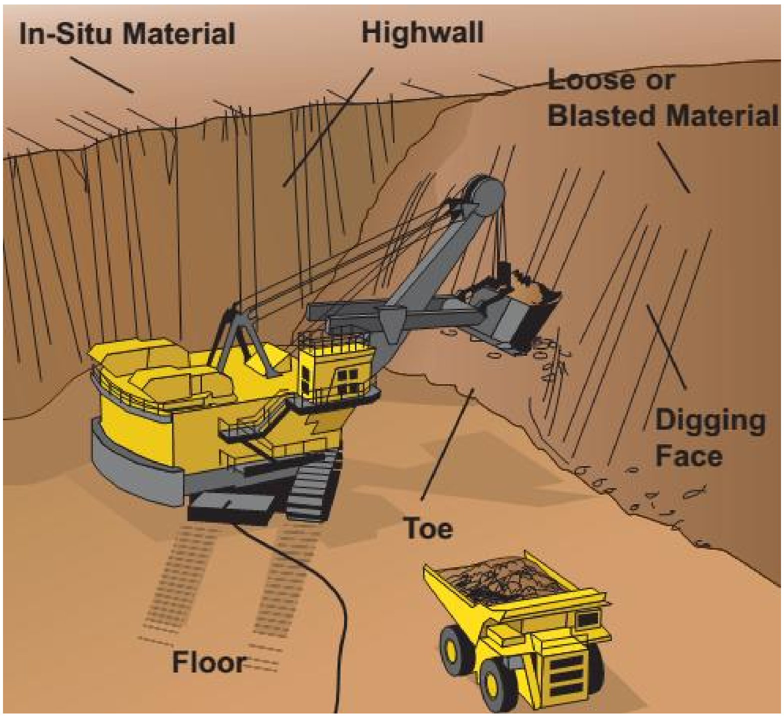
3.1 Truck and Shovel System

The truck and shovel system is whereby shovels loaders or excavators are used to load broken or loose ore or waste from a bench in the pit onto trucks which then transport the material out of the pit to the crusher or stockpile if it is ore or to the waste dump in the case of waste or overburden.

Truck & Shovel System Description

The system design process follows the pit optimisation, pit design and scheduling processes (mine planning) which define the material to be mined, the layout of the pit and the type and volumes of material to be mined at any given time over the life of the mine or project.

Figure 4: Truck and Shovel Operation



Source: Peak Performance Practices (P&H, 2006)

Shovel Selection

For a large open pit mine, the shovel size is selected on the basis of the bench height, volume required to be moved, the required selectivity of mining, material type, the truck options that may be used, given the site operating conditions, and cost implications (Burt and Caccetta, 2013). This involves analysis of a number of options. Shovel types include the following:-

Electric Rope Shovels

Examples of the larger class range include:

- P&H 2800XPC – nominal bucket size 36.6m^3, payload 59 tonnes
- CAT 7395 (BE 395) - bucket size 19.1 - 49.7m^3, payload 63.5 tonnes
- P&H 4100XPC – bucket size 30.6 - 62.7m^3, payload 109 tonnes
- CAT 7495 (BE 495) - bucket size 30.6 - 62.7m^3, payload 109 tonnes

Hydraulic Shovels or Excavators – (Diesel or Electric)

Examples of the large Hydraulic shovels with backhoe or face shovel configurations are:-

- Liebherr R996 - bucket size 29 - 34m^3 –payload 61 tonnes
- Terex RH 340 - nominal bucket size 34m^3 –payload 61 tonnes
- Liebherr R9800 - nominal bucket size 42m^3 –payload 76 tonnes
- Komatsu PC8000 - bucket size 45m^3 –payload 80 tonnes
- Terex RH 400 – nominal bucket size 47.2m^3 –payload 85 tonnes
- CAT 6090 - bucket size 37 - 52m^3 –payload 90 tonnes

Front End Loaders (Diesel)

Examples of the larger machines include:-

- Komatsu WA1200 – payload 36 tonnes
- CAT 994 – payload 34.5 tonne
- LeTourneau L-2350 – payload 72 tonnes

Truck Matching

Having settled on the shovel, a suitably sized truck must then be selected to match the shovel. As a rule of thumb, the truck size has to be such that it can be fully loaded with 3-4 passes by the shovel factoring in the bucket fill factor.

Maximum Shovel Productivity Calculation

The maximum production rate of the shovel depends on the following loading factors

- Truck spotting time –T_s (minutes)
- Time for first pass – T_{p1}
- Time for each of subsequent passes - T_{ave}
- Number of loading passes- N_p
- Bucket volume –-B_v (m^3)
- Bucket fill factor -B_f (%)
- Material density – D_m (t/m^3)
- Average effective working time per hour – T_e (minutes/hour)

The bucket is sized taking the material density into consideration such that the rated payload of the shovel is not exceeded.

Using typical numbers from Sishen mine

Shovel type - P&H 4100 XPC – installed bucket size: $45m^3$

Truck type - Komatsu 960E – Rated payload (P_l): 327 tonnes

- T_s = 1 minute
- T_{p1} = 1 minute
- T_{ave} = 0.7 minute
- N_p = 3
- B_v = 45 m^3
- B_f = 88 %
- D_m = 2.62 t/m^3
- T_e = 50 mins/hour

Total Loading Time per Truck (T_l) $= T_s + T_{p1} + T_{ave} (N_p - 1)$

$= 1 + 1 + 0.7(3-1)$

$= 3.4$minutes

Potential Number of Truck Loads per Hour (N_l) $= T_e / T_l$

$= 55/3.4$

$= 16.2$

Truck Payload (P_l) $= B_v \times B_f \times D_m \times N_p$

$= 45m^3 \times 88\% \times 2.62\ t/m^3 \times 3$

= 311 tonnes

Potential Shovel Productivity (P_{ts}) $= N_l \times P_l$

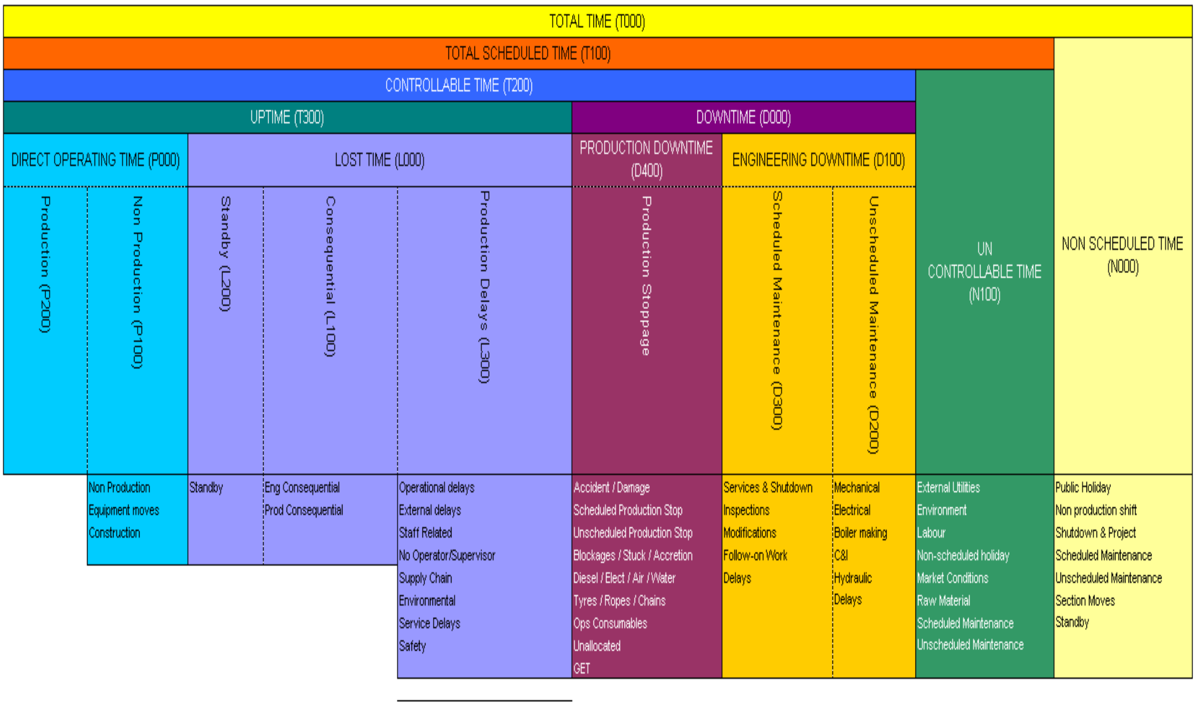
= 16.2 x 311 tonnes

= 5 030 tonnes per hour

Shovel Fleet Determination

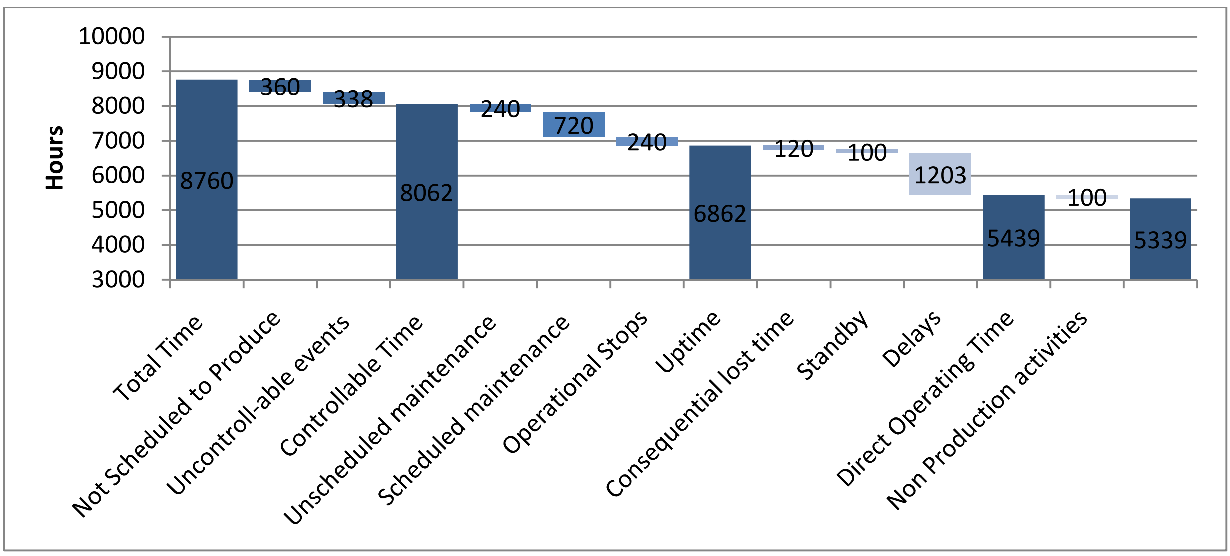
The size of the shovel fleet can be determined by considering the tonnes scheduled for that type of shovel, the spatial distribution of those tonnes per given period and the achievable direct operating times of the shovels per period under consideration. The tonnage information is provided by the mining schedule and the direct operating hours can be calculated using the mine’s time usage model. Other factors such as operator skill can also be applied. A typical time usage model, as applied by Anglo American, is shown below:

Figure 5: Anglo American Availability Model



The potential production for each shovel is calculated by multiplying the potential productivity by the direct operating time for the period. The baseline number of shovels required can then be calculated by dividing the scheduled tonnes for the period by the potential production per shovel. Spatial distribution and blending requirements are also considered so as to minimize shovel moves.

Figure 6: Shovel Operating Hours- Sishen Mine



From the Sishen time usage model shown above the direct operating hours (DOH) for the shovel are 5339 hours per annum. The potential maximum shovel production per annum, $P_{s,}$ is given by:-

$$P_s = P_{ts} \text{ x DOH}$$

$$= 5\ 030 \text{ tph x } 5\ 339 \text{ hrs}$$

$$= 26.9 \text{ Mt per annum}$$

Truck Selection and Fleet Sizing

The selection of the truck size is based on the requirement to limit the number of shovel passes to fill the truck to three or four so at to minimise the loading time while loading the truck to as close to its rated payload as possible. The other consideration is that the TKPH rating of the truck tyres should not be exceeded. The operational conditions may be such that for certain size of trucks, the tyres that would meet the TKPH rating are not available in the market. The truck type should also be able to provide enough rim pull at acceptable speeds given the grade and rolling resistances encountered at the operation.

The size of the truck fleet can then be determined by considering each shovel location and defining the profile of the route from the shovel to the dump location either at the crusher or ore stockpile or to the waste dump. Each segment of the route is defined in terms of its length, grade and rolling resistance as these will determine that time it will take for a truck to traverse the segment based on achievable speeds. The popular simulation packages take gear changes into consideration to model the truck speeds on flat and inclined segments of the route. The total time taken by a truck to travel from and back to the shovel loading point is then determined and this becomes the total cycle time (T_t) if combined with the loading and dumping times. Number of loads (N_t) that a truck can potentially make per hour can be calculated dividing the average working time per hour (T_e) by the total truck cycle time

i.e. $N_t = T_e / T_t$

Typical Sishen numbers in the area of study are:-

T_e = 55 minutes

T_t = 44 minutes

N_t = 55/44 = 1.25 Loads

Truck payload (Komatsu 960E) P_l = 311 tonnes

Productivity per truck $P_{tt} = N_t \times P_l$ = 1.25 x 311 tonnes

= 389 tph

Again applying the time usage model will indicate the potential direct operating hours for the truck. If these operating hours for the truck are greater than those calculated for the shovel then the shovel hours are then applied, if less, then the truck direct operating hours will be applied. The truck production (P_a) for the period is then determined by multiplying the truck productivity (P_t) by the direct operating hours (DOH).

In the case of Sishen the truck shovel system direct operating hours are budgeted at 5 339 hours per annum.

P_a = P_{tt} x DOH

= 389 tph x 5 339 hrs

= 2.08 Mt per annum (for each truck)

To determine the number of trucks (N_{tt}) required per shovel, the tonnes scheduled for the shovel (V_{bt}) in the period are divided by the potential tonnes that a truck can achieve in that system.

In the case of Sishen, the budgeted tonnes (V_{bt}) for the P&H 4100 XPC are 26 million tonnes per annum in the overburden. The calculated number of trucks required to achieve the production would be the following:

Ntt = V_{bt} / P_a

= 26.9 Mtpa / 2.08 Mtpa

= 12.9 trucks

The truck and shovel system productivity (P_{st}) can thus be estimated by multiplying the number of trucks (N_{tt}) by the truck productivity (P_{tt})

P_{st} = N_{tt} x P_{tt}

= 12.9 trucks x 389 tph per truck

= 5 057 tph

This is used as a guide; the actual production that can be achieved by the system can be modelled taking into consideration queuing theory principles. Since the trucks move independently in the cycle, their arrival at the shovel and at the dumping area depicts some random behaviour and the probability that a truck will always be present at the shovel to be loaded approximates a Poisson distribution. This is the approach taken by the more popular simulation packages currently in the market such as Talpac and FPC.

Probability Model Example

Given the following:-

Loading & Truck transfer Time = L&T

Haul, Dump and Return Time = HDR

Then Cycle Ratio R = L&T /HDR

Taking the Sishen case for one loading point and applying probability distribution tables

L&T = 3.4 minutes

HDR = 40.6 minutes

R = 3.4 /40.6 = 0.08 ~0.1

From the probability tables for R = 0.1, the probability factors are given in the table below for the given number of trucks in the system and multiplied by the potential system productivity to obtain the possible productivity. The potential system productivity for the Sishen case is 5 057 tph.

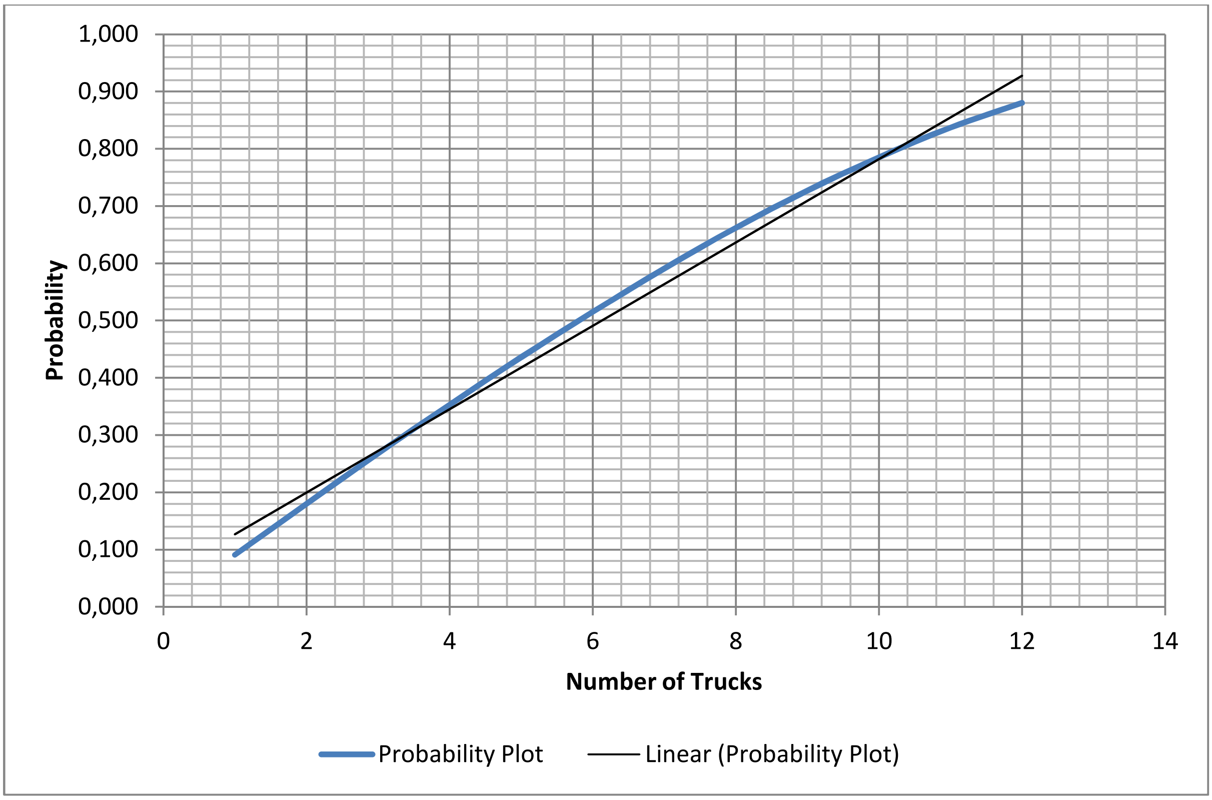
Table 1: Truck probability factors and potential productivity

Number of Trucks	Probability Factor	Productivity (tph)
4	0.353	1 785
6	0.515	2 604
8	0.662	3 348
10	0.785	3 970
12	0.880	4 450
13	0.915	4 627
14	0.930	4 703

As can be seen from the table, the system struggles to achieve productivity close to the required rate. This is due to the long haul, dump and return time relative to the loading and truck spotting time.

The probability distribution for this scenario is shown in the graph below.

Figure 7: Probability that trucks will be available at the shovel for loading



To determine what the system can deliver in a given period, the time usage model is applied to derive the direct operating hours of the system. The direct operating hours of the truck fleet linked to a shovel cannot exceed that of the shovel. It is highly unlikely that the unplanned downtimes on the shovel and the trucks will coincide. The number of trucks in the system will fluctuate due to the unplanned truck downtimes. During periods of low truck availability, the system will deliver less production than the potential capacity. It is therefore necessary to set the target which is less than what the system can deliver on average so that, at other times, it is delivering more than the target to compensate for the times when it would be under performing. The level of unplanned down times can be used to set the catch-up capacity, factoring in the diminishing returns of adding more trucks, or de-rate the system production.

Taking the Sishen example:-

Direct operating hours for both the shovel and trucks = 5 335 hours per annum.

System Productivity Potential = 5 057 tph

System Production Potential = 26.8 Mtpa

Number of trucks in the system = 12.9 ~13

Assuming the unplanned truck breakdowns to be random and that this constitutes 4% of the scheduled hours, the probability that a truck will experience an unplanned breakdown at any given moment can be modelled using a binomial distribution.

Binomial Probability Distribution Function = $X \sim B(n,p)$

Probability for k successes = $P(X=k) = \dfrac{n!\ p^k\ (1-p)^{n-k}}{k!(n-k)!}$

Table below shows the probability values various n and k value where k is the number of trucks on unplanned maintenance, n is the total number of trucks in the system and 0.04 (4%) is the probability of success where "success" in this case is having a truck on unplanned downtime.

Table 2: Probability that the given number of trucks will be on breakdown at the same time

n	k												
	1	2	3	4	5	6	7	8	9	10	11	12	13
5	17%	1%	0%	0%	0%	-	-	-	-	-	-	-	-
6	20%	2%	0%	0%	0%	0%	-	-	-	-	-	-	-
7	22%	3%	0%	0%	0%	0%	0%	-	-	-	-	-	-
8	24%	4%	0%	0%	0%	0%	0%	0%	-	-	-	-	-
9	26%	4%	0%	0%	0%	0%	0%	0%	0%	-	-	-	-
10	28%	5%	1%	0%	0%	0%	0%	0%	0%	0%	-	-	-
11	29%	6%	1%	0%	0%	0%	0%	0%	0%	0%	0%	-	-
12	31%	7%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-
13	32%	8%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	33%	9%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15	34%	10%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16	35%	11%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
17	35%	12%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
18	36%	13%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	36%	14%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	37%	15%	4%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%

As can be seen, the probability that there will be one or more trucks on unplanned breakdown increases with the number of trucks in the system. For the Sishen system with 13 trucks, the table value indicate that during 32% of the time they will be one truck on unplanned downtime, two trucks down 8% of the time and three trucks down 1% of the time over and above the planned maintenance. The time usage model can therefore be adjusted accordingly.

Haulage Simulation

Sishen Fleet

The proposed fleet for the area of study at Sishen consists of the following:-

Electric Rope Shovel for the calcrete

- P&H 4100XPC

Hydraulic Shovel for the clay

- Komatsu PC 8000

Truck Fleet

- Komatsu 960E

A simulation was run for the target area, material and designed haulage profiles for the GR80 area of Sishen mine for the years 2014 till 2027 using Talpac software. The mine profile does not change much from 2014 to 2016 and from 2027 to 2030. The results for 2016 are shown in table 3 to table 5 below. The rest of the results are contained in Appendix 1

Table 3: Sishen Truck and Shovel Talpac Simulation Run

Production Summary - Full Simulation			
Haulage System: GR80_2016_Rev		Haul Cycle: [PRJ] Haul Cycle_GR80_2016	
Material: [PRJ] Oher Waste GR80		Roster: [PRJ] GR80_5339_OpHrs	
Loader		**[PRJ] P&H 4100 XPC (AC)-Cost_GR80**	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,08	
Average Payload	tonne	101,66	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 893,85	
Production per Loader Operating Shift	tonne	55 500	Max. prod. based on 100% avail.
Production per Year	tonne	31 468 732	Avg. production factored by avail.
Wait Time per Operating Hour	min	3,35	
Truck		**[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost**	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,88	
Production per Operating Hour	tonne	453,37	
Production per Loader Operating Shift	tonne	4 269	
Production per Year	tonne	2 420 672	
Queue Time at Loader	min/ Cycle	3,12	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	23,94	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	31,05	
Fleet Size		13	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	31 468 732	

Table 4: Sishen Haul Road Profile

Full Simulation Results

Material: [PRJ] Oher Waste GR80 — Haulage System: GR80_2016_Rev

Roster: [PRJ] GR80_5339_OpHrs — Haul Cycle: [PRJ] Haul Cycle_GR80_2016

Type	Segment Title	Distance	Grade	Rolling Resist.	Curve Angle	Load	Segment Time	Cycle Time	Max Vel.	Final Vel.	Velocity Limit.	Average Velocity	Elevation Change	Fuel Usage	% Duty Cycle
		metres	%	%	degrees	%	min	%	km/h	km/h		km/h	metres	litre/OpHr	%
[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost															
Queue	Queue at Loader	Auto	Mins				3,12	10,06						12,5	
Spot	Spot at Loader	1	Mins				0,75	2,42						12,5	
Load	Loading	Auto	Mins				1,43	4,61						12,5	
1	Haul Segment	2859	0,0	3,0	0,0	Full	4,54	14,63	46,4	0,0	Final Sp.	37,8	0,0	103,7	80,9
2	Haul Segment	2439	8,0	3,0	0,0	Full	11,72	37,74	12,7	0,0	Final Sp.	12,5	195,1	123,6	97,9
Spot	Spot Time at Dump	1	Mins				0,80	2,58						12,5	
Dump	Dumping	1	Mins				1,00	3,22						12,5	
3	Haul Segment (rev.)	2439	-8,0	3,0	0,0	Empty	3,58	11,53	48,0	0,0	Final Sp.	40,9	-195,1	12,5	0,3
4	Haul Segment (rev.)	2859	0,0	3,0	0,0	Empty	4,10	13,22	48,0	0,0	Final Sp.	41,8	0,0	59,4	42,0
	Total	10 596					31,05	100,00				20,5	0		

Table 5: Sishen Talpac Optimisation Run

Run No.	Fleet Size	Fleet Production Per Year tonne	Production Change %	Loader on Per Oper. Hour tonne	Truck Avg. Cycle Time min	Truck Production Per Oper. Hour tonne	Truck Avg. Load Queue Time min
1	1,00	2 684 147,32	0,00	502,72	27,93	502,72	0,00
2	2,00	5 341 881,21	99,02	1 000,49	28,08	500,25	0,15
3	3,00	7 918 431,53	195,01	1 483,06	28,26	494,35	0,32
4	4,00	10 511 869,65	291,63	1 968,79	28,43	492,20	0,51
5	5,00	13 116 118,65	388,65	2 456,55	28,63	491,31	0,70
6	6,00	15 598 905,57	481,15	2 921,55	28,81	486,93	0,89
7	7,00	18 095 601,42	574,17	3 389,17	29,03	484,17	1,11
8	8,00	20 498 381,95	663,68	3 839,19	29,26	479,90	1,34
9	9,00	22 921 123,63	753,94	4 292,95	29,49	476,99	1,56
10	10,00	25 157 088,34	837,25	4 711,73	29,80	471,17	1,87
11	11,00	27 397 575,48	920,72	5 131,35	30,14	466,49	2,22
12	12,00	29 530 436,32	1 000,18	5 530,82	30,53	460,90	2,61
13	13,00	31 399 664,19	1 069,82	5 880,91	31,12	452,38	3,19
14	14,00	32 892 405,14	1 125,43	6 160,49	32,00	440,04	4,08
15	15,00	33 618 785,71	1 152,49	6 296,54	33,67	419,77	5,74
16	16,00	33 817 389,33	1 159,89	6 333,73	35,74	395,86	7,82
17	17,00	34 009 466,38	1 167,05	6 369,71	37,90	374,69	9,97
18	18,00	34 156 445,99	1 172,53	6 397,24	39,99	355,40	12,06
19	19,00	34 320 827,12	1 178,65	6 428,02	42,11	338,32	14,19

The truck production rate per hour in table 5 shows diminishing returns in terms of productivity as more trucks are added to the system. The area was divided into two loading areas with each area being serviced by either the hydraulic shovel or the electric rope shovel. Each area has an independent haulage route to the dumping area to minimise traffic. The results for each route showing the optimum fleet and the related optimum production as well as the installed fleet and the actual production are given in the table below.

Table 6: Sishen Simulated Annual Productivity

Year	Optimum Fleet	Installed Fleet	Opt Production Mtpa	Act Production Mtpa
2014	13	13	31.5	31.5
2015	13	13	31.5	31.5
2016	13	13	31.5	31.5
2017	14	14	32.2	32.3
2018	13	14	30.8	32,4
2019	15	15	31.8	31.8
2020	17	17	31.7	31.7
2021	16	17	30.5	31,9
2022	17	17	31.1	31.1
2023	17	17	31.7	31.7
2024	19	19	31.5	31.5
2025	18	18	30.7	30.7
2026	20	20	30.6	30.6
2027	21	21	30.6	30.6
2028	21	21	30.6	30.6
2029	21	21	30.6	30.6
2030	21	21	30.6	30.6
Average		**17,1**		**32,15**

Trolley Assist System

At Sishen there are some ramps that have trolley lines installed on them and are currently used by the ore truck fleet of Komatsu 730E trucks. Using the external electrical power enables the trucks to increase speed on the ramps from 10kph up to 22 kph thereby reducing truck cycle times. The other added benefit is on reduced fuel consumption from 258 litres per hour on the ramp to 25 litres per hour. Maintenance costs are also reduced as a consequence.
The truck manufacturer is being engaged to consider making the ultra-class trucks also trolley assist compatible.

Planned Performance

The current schedule is to move 55Mt of clay and calcrete material per annum from the GR80/50 area of Sishen mine until the end of the life of mine in 2030. The simulation indicates a potential to achieve 64Mt per annum on average from the two loading points.

Fleet Management System

Sishen runs a truck dispatch system provided by Modular Mining Services. This system automatically dispatches trucks to shovels using linear and dynamic algorithms so as to minimise queuing at the shovels and, for ore, to satisfy the continuous blending requirements of the mine. It also captures all the loading and hauling events which can be used for drawing reports. There are other fleet management systems in the market that can also serve the same purpose such as the Caterpillar's MineStar system.

Mining Support Equipment

The fleet would need to be supported by secondary equipment to be effective. The following are allocated based on the site philosophy:-

Two loading point track dozers for floor maintenance and toe ripping

One dumping point track dozers for dumping area and tipping berm maintenance

One additional track dozer for road construction and maintenance

Two rubber wheel dozers for road maintenance

Two water trucks for dust suppression on the haul roads

One diesel bowser for refuelling hydraulic shovel and secondary equipment

Two road graders for road maintenance

Operational and Maintenance Personnel

Sishen has permanently employed truck and shovel operators as well as the maintenance crew. It is a 24 hour operation with two 12 hour shifts per day and seven days per week. The operational crew is organised into four shift crews each working a total of 96 shifts per year including one training shift per month. To cater for absenteeism, illness and leave, a staff over-complement factor of 1.2 or 20% is also applied. Applying some mine standard maintenance ratios, the required number of maintenance personnel can also be calculated. The average fleet size and manning level are shown below in the tables 7 and 8 respectively.

Table 7: Truck and Shovel Fleet

Equipment	Fleet Size
Eletric Rope Shovel (P&H 4100 XPC class)	1
Hydraulic Shovel (Komatsu PC8000 class)	1
Ultra class Truck (Komatsu 960E class)	34
Grader (CAT 16M class)	2
Wheel Dozer (Komatsu WD600 class)	2
Diesel Bowser (CAT 740 ADT class)	1
Water Truck (Komatsu HD785 class)	2
Cable Handler (Komatsu WA600 class)	1
Track Dozer (CAT D10 class)	4

Table 8: Truck and Shovel Manning Level

Personnel	Ratios	Manning Level
Operation Supervisors	2,0	4
Operators Primary Equip	4,8	173
Operators Support Equip	4,8	58
Maintenance Supervisors	2,0	2
Maintenance Operators	1,0	48
Artisans- Primary Equipment	2,0	72
Artisans- Support Equipment	1,0	12
Total		**368**

Owning and Operating Cost

In the cost calculations inputs were derived from internal company models compiled using information from equipment suppliers as well as from the company's experience. The costs are first expressed per annum and the unit cost determined by dividing by the annual production. The costs are stated in 2014 terms with no escalation or discounting on future costs applied.

Table 9: Truck and Shovel System Capital Cost

Equipment	2014		
	Foreign Content ZAR	Local Content ZAR	Total ZAR m
Electric Rope Shovel (P&H 4100 XPC class)	291 858 950	36 286 349	328,15
Hydraulic Shovel (Komatsu PC8000 class)	185 763 139	6 003 485	191,77
Ultra class Trucks (Komatsu 960E class)	69 633 664	6 757 472	76,39
Grader (CAT 16M class)	8 920 838	3 305 183	12,23
Wheel Dozer (Komatsu WD600 class)	8 499 839	1 006 476	9,51
Diesel Bowser (CAT 740 ADT class)	5 806 181	5 051 431	10,86
Water Truck (Komatsu HD785 class)	12 871 323	4 555 546	17,43
Cable Handler (Komatsu WA600 class)	6 907 211	1 901 038	8,81
Track Dozer (CAT D10 class)	12 066 505	3 832 940	15,90

Truck Owning Cost

- Service Life 60 000 Hours
- Annual Hours 5 335 Hours/ year
- Service Life in years 11years
- Annual Production 64.3 Mtpa

Table 10: Truck Annual Capital Cost

Year	Optimum Fleet	Installed Fleet	Opt Production Mtpa	Act Production Mtpa	Capex ZAR m	Annual Capex ZAR m/year
2014	13	13	31.5	31.5	993,08	88,30
2015	13	13	31.5	31.5	993,08	88,30
2016	13	13	31.5	31.5	993,08	88,30
2017	14	14	32.2	32.3	1 069,48	95,09
2018	13	14	30.8	32,4	1 069,48	95,09
2019	15	15	31.8	31.8	1 145,87	101,89
2020	17	17	31.7	31.7	1 298,65	115,47
2021	16	17	30.5	31,9	1 298,65	115,47
2022	17	17	31.1	31.1	1 298,65	115,47
2023	17	17	31.7	31.7	1 298,65	115,47
2024	19	19	31.5	31.5	1 451,43	129,06
2025	18	18	30.7	30.7	1 375,04	122,26
2026	20	20	30.6	30.6	1 527,82	135,85
2027	21	21	30.6	30.6	1 604,21	142,64
2028	21	21	30.6	30.6	1 604,21	142,64
2029	21	21	30.6	30.6	1 604,21	142,64
2030	21	21	30.6	30.6	1 604,21	142,64
Average		**17,1**		**32,15**		**116,27**
Total Cost ZARm/yr						232,54
Production Mtpa						64,30
Unit Owning Cost ZAR/t						**3,62**

Table 11: Loading and Support Equipment Owning Cost

Equipment	Fleet Size	Service Life Hours	Operating Hours Hrs/yr	Service Life Years	Capex ZAR m	Annual Capex ZAR m/year
Eletric Rope Shovel (P&H 4100 XPC class)	1	100 000	5 339	18,7	328,15	17,52
Hydraulic Shovel (Komatsu PC8000 class)	1	60 000	5 339	11,2	191,77	17,06
Grader (CAT 16M class)	2	50 000	4 000	12,5	24,45	1,96
Wheel Dozer (Komatsu WD600 class)	2	50 000	4 000	12,5	19,01	1,52
Diesel Bowser (CAT 740 ADT class)	1	35 000	4 000	8,8	10,86	1,24
Water Truck (Komatsu HD785 class)	2	45 000	4 000	11,3	34,85	3,10
Cable Handler (Komatsu WA600 class)	1	50 000	2 000	25,0	8,81	0,35
Track Dozer (CAT D10 class)	4	35 000	4 000	8,8	63,60	7,27
Total Cost ZARm/yr						**50,02**
Production Mtpa						**64,30**
Unit Owning Cost ZAR/t						**0,78**

Total Owning Cost is therefore ZAR 4.39/t.

Table 12: Operating Cost Excluding Labour

Equipment	Fleet Size	Unit Op Cost ZAR/hr	Op Hours Hrs/yr	Op Cost ZAR m/yr
Eletric Rope Shovel (P&H 4100 XPC class)	1	3 546	5 339	18,93
Hydraulic Shovel (Komatsu PC8000 class)	1	4 005	5 339	21,38
Komatsu 960E	34	2 972	5 339	539,46
Grader (CAT 16M class)	2	591	4 000	4,73
Wheel Dozer (Komatsu WD600 class)	2	735	4 000	5,88
Diesel Bowser (CAT 740 ADT class)	1	535	4 000	2,14
Water Truck (Komatsu HD785 class)	2	751	4 000	6,01
Cable Handler (Komatsu WA600 class)	1	556	2 000	1,11
Track Dozer (CAT D10 class)	4	1 230	4 000	19,69
Total Cost ZARm/yr				**619,32**
Production Mtpa				**64,30**
Unit Operating Cost ZAR/t				**9,63**

The labour cost based on the manning level as well cost of employment to company is shown below.

Table 13: Truck and Shovel Labour Cost

Support Equipment	12			
Primary Equipment	36			
Personnel	**Ratios**	**Manning Level**	**CTC ZAR/ Annum**	**Total CTC ZAR m/ Annum**
Operation Supervisors	2,0	4	491 448	1,97
Operators Primary Equip	4,8	173	280 201	48,42
Operators Support Equip	4,8	58	222 352	12,81
Maintenance Supervisors	2,0	2	491 448	0,98
Maintenance Operators	1,0	48	222 352	10,67
Artisans- Primary Equipment	2,0	72	470 564	33,88
Artisans- Support Equipment	1,0	12	470 564	5,65
Total Cost ZARm/yr		368		**114,38**
Production Mtpa				**64,30**
Unit Labour Cost ZAR/t				**1,78**

This brings to the unit Owning and Operating cost of the Truck and Shovel option to ZAR 15.80/t.

3.2 In-pit Crushing and Conveying

In-pit crushing and conveying is whereby broken material is fed through a fully mobile or semi mobile crusher located within the pit and the crushed material is then transported by conveyors from the crusher to its destination which could be the plant, stockpile or waste dump. For a stockpile, a stacker is then used to place the material for subsequent reclamation. For a waste dump, spreaders are normally used to place the material according to the dump design.
Conveyor capacities depend on belt width and speed. The material has to be crushed down to a size less than 25% of the belt width for efficient conveying.

The choice between a fully mobile and a semi mobile system is influenced by the properties of the material being mined as well as pit design constraints. Currently the available crushers that can be configured into a fully mobile system are the sizers, double roll crusher which can crush material with strength of up to 100MPa. There is a newer crusher, the Hybrid double Roll crusher which can handle up to 200MPa currently on trial. The material has to be consistent in terms of strength and fragmentation as well to achieve design throughput of up to 12 000 tph depending on the rock strength. For rock strength higher than 200MPa, gyratory crushers become the crusher of choice as they can handle material up to 250 MPa. Gyratory crushers have, however big height, up to 8 m making it currently impossible to install them in a fully mobile configuration. They are the crusher of choice in the semi mobile configuration with throughputs up to 12 000 tph.
The other consideration is the pit layout. The fully mobile system can be prone to blasting damage if the pit deployment is such that it would be difficult to keep the components out of the way during blasting such as in smaller conical pits.

Fully Mobile IPCC System

In a fully mobile configuration the material is dumped directly into a mobile crusher by the shovel at the loading face. From the crusher, the material is then transported by a mobile transfer conveyor onto a series of mobile or track shift able conveyors across the pit and on the ramps via belt wagons, and out of the pit on to the stacker or spreader and then dump or stockpile. The conveyors have either crawler systems which make them self- propelled or they would be on tracks and can be easily shifted by specially equipped dozers. Bridge conveyor sections provide access points on haul roads through which other mine vehicles can pass.

Figure 8: Fully mobile IPCC system (Morriss, 2013)

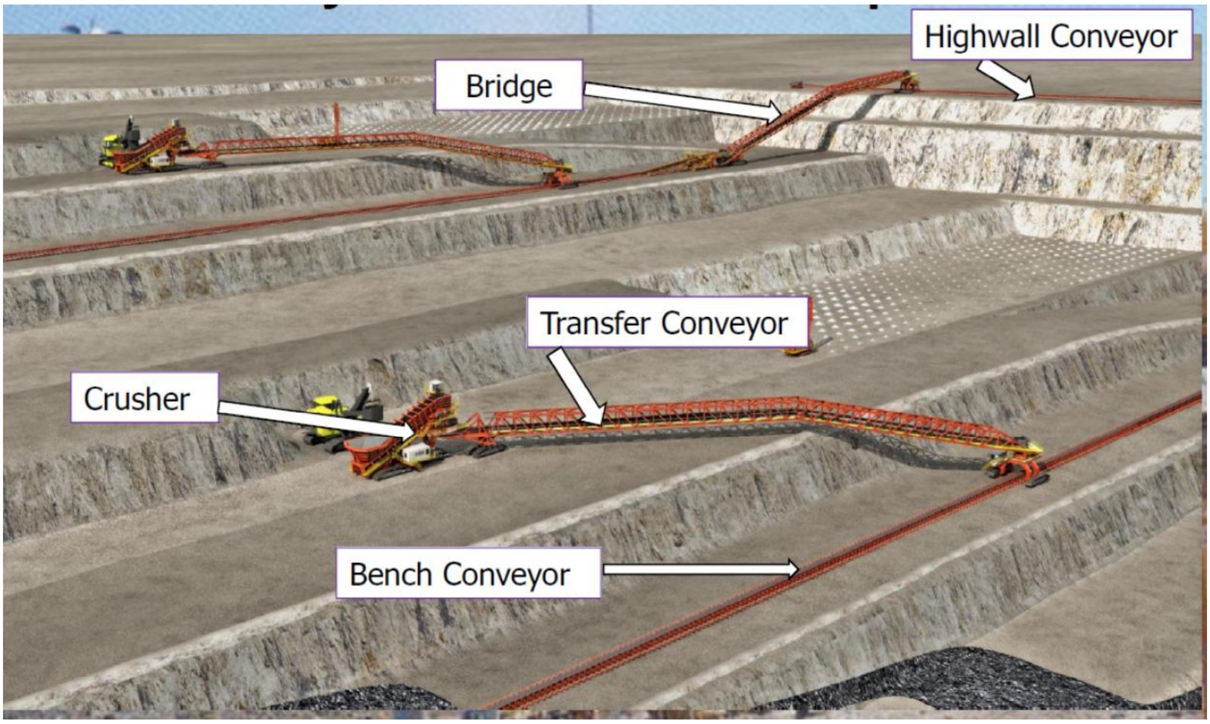
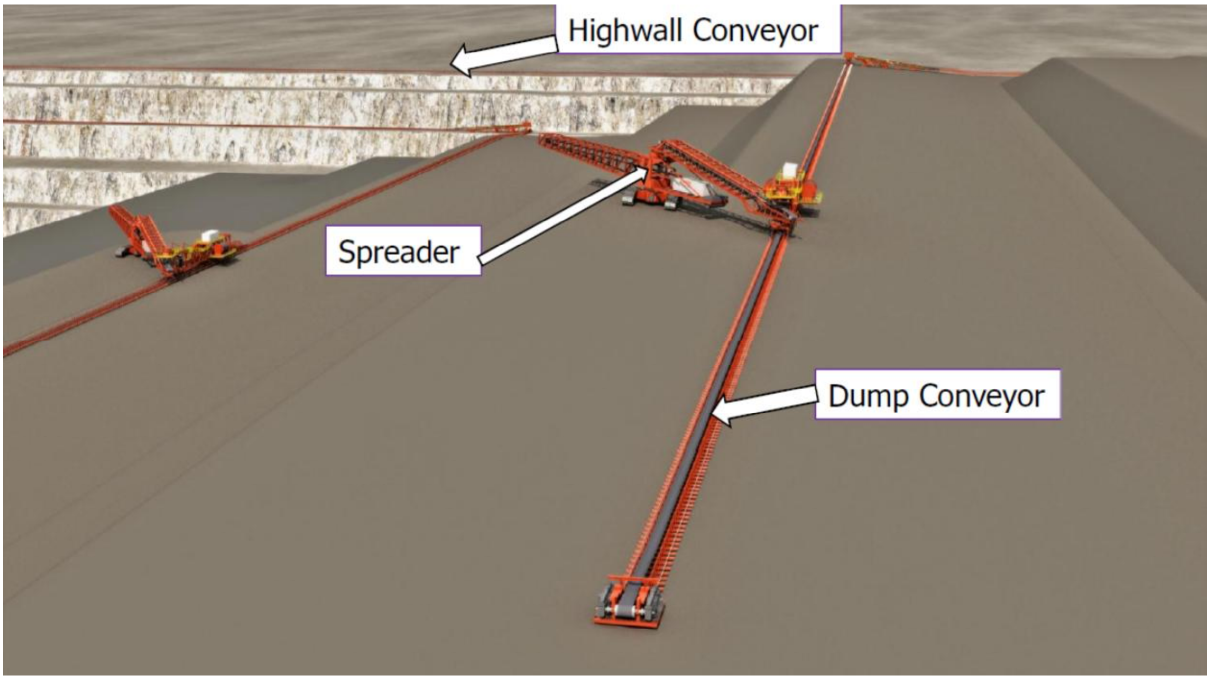


Figure 9: Spreaders on the waste dump (Morriss, 2013)

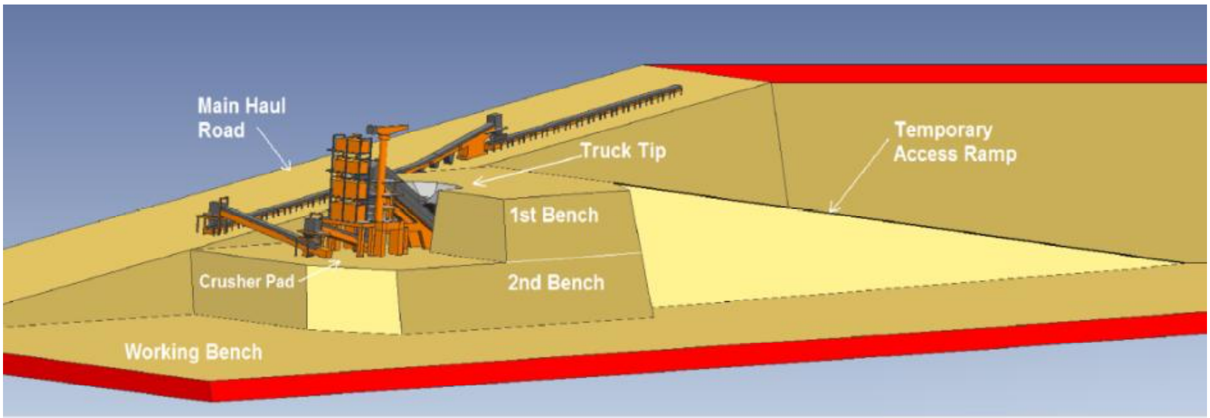


A smaller truck fleet is usually required to establish the initial benches as well as handle the overflow from the IPCC system.

Semi Mobile IPCC System

For a semi mobile configuration, the material is loaded onto trucks which transport and dump it into the semi mobile crusher within the pit. A series of conveyors then transport the material out of the pit. The crusher is moved to different positions within the pit based on the pit deployment. The position of the crusher location is carefully chosen so as to limit the frequency of the relocations while keeping it as close as possible to the loading areas to minimise truck cycle times. Relocations are usually done once or twice a year. Another variation, called semi fixed, is whereby the crusher stays longer in the same position for up to three to five years and the installation is therefore more solid.

Figure 10: Semi mobile IPCC system (Morriss, 2013)



The access route to the crusher can be either through temporary ramps such as in figure 5 or through the existing ramps. The crusher may have a surge bin before or after crusher feeding.

In both cases the out of pit conveyors can be on dedicated conveyor ramps or tunnels which can be made steeper or the truck haulage ramps. The proposed layout for the Sishen case is to have the out of pit conveyors on dedicated ramps with separate routes for each sizer with the two systems tying in at the waste dump incline conveyor.

Availability of electrical power supply, including the necessary reticulation facilities, is a main consideration when looking at the viability of IPCC systems.

Another consideration and challenge is the ability to achieve direct operating hours for the system due to the fact that the system is directly coupled and a problem with one component affects the whole system from the crusher to the spreader. Relocations have to be managed properly as well as a lot of time may be lost in the process. Both the fully mobile and semi mobile IPCC options were considered for Sishen.

The proposed IPCC equipment has been determined using the final operating position at the last level of the over burden at a depth of 200m and using a grade of 10% for the inclines.

Sishen Proposed IPCC System

Table14: Proposed Sishen IPCC Equipment List for Fully Mobile System

Component	Quantity	Throughput per unit (tph)
Sizer	2	6 000
Belt Wagon	2	6 000
Link Conveyor	2	6 000
1200m Face Conveyor –Track shift able	2	6 000
Bench Link Conveyor – Track shift able	2	6 000
Bridge Conveyors	2	6 000
2000m Bench Incline Conveyor - re-locatable	2	6 000
2000m Overland Conveyors	2	6 000
1000m Waste Dump Incline Conveyor - Fixed	1	12 000
2000m Waste Dump Flat – Track shift able	1	12 000
Spreader	2	12 000

The equipment to load the fully mobile sizers including the support equipment is as listed in the table 15 below.

Table 15: FMIPCC Loading Fleet

Equipment Type	Fleet Size	Operating Hours Hrs/yr
P&H 4100 XPC	1	5560
Komatsu PC8000	1	5560
Grader 16M	1	2000
Komatsu WD600 Wheel Dozer	1	2000
CAT 740 ADT Diesel Bowser	1	2000
Komatsu HD785 Water Truck	1	2000
CAT D10 Dozer	2	2000

Table 16: Proposed Sishen IPCC Equipment List for Semi Mobile System

Component	Quantity	Throughput per each (tph)
Sizer	2	6 000
1200m Face Conveyor –Track shift able	2	6 000
Bench Link Conveyor – Track shift able	2	6 000
Bridge Conveyors	2	6 000
2000m Bench Incline Conveyor - re-locatable	2	6 000
2000m Overland Conveyors	2	6 000
1000m Waste Dump Incline Conveyor - Fixed	1	12 000
2000m Waste Dump Flat – Track shift able	1	12 000
Spreader including spare	2	12 000

The equipment to load the semi mobile sizers is determined below.

Truck Payload (tonnes)	327
Truck Average Speed (kph)	15,00
Truck Loading Time (Hrs)	0,08
Truck Dumping Time (Hrs)	0,05
Truck Travel Distance (km)	1,00
Truck Travel Time (Hrs)	0,13
Total Cycle Time (Hrs)	0,27

Shovel Capacity (cubic metres)	45
Bucket Fill Factor	88%
Number of Passes	3
Material Density (tonnes per cubic metre)	2,62
Average Truck Payload (tonne)	311
Truck Loads per Hour	3,75
Truck Capacity (tph)	1 167
Required Capacity (tph)	5 030
Required Truck Fleet per shovel	4,31
Shovel Number	2
Total Truck Fleet Size	9

The semi mobile sizer loading fleet is as listed in table 17 below.

Table 17: SMIPCC Loading Fleet

Equipment Type	Fleet Size	Operating Hours Hrs/yr
P&H 4100 XPC	1	5335
Komatsu PC8000	1	5335
Komatsu 960E Trucks	9	5335
Grader 16M	1	4000
Komatsu WD600 Wheel Dozer	1	4000
CAT 740 ADT Diesel Bowser	1	4000
Komatsu HD785 Water Truck	1	4000
CAT D10 Dozer	2	4000

Both the FMIPCC and the SMIPCC require additional support equipment to assist in the relocations and preparation of areas during installations. The proposed list is shown in table 18 below.

Table18: Proposed Sishen Ancillary Equipment

Equipment Type	Quantity
Transporter	1
Crane 120t/150t	1
Excavator 2 Tonne	1
Bobcat	1
IT Loader	1
Maintenance Truck	2
Conveyor Side Lifting Truck	1
Rock Breaker	1
Track Dozer (D10 Class)	3
Truck & Lowbed	1
Pipe Layer Dozer	1
Belt realer	1
Cable realer	1

The IPCC operations would also be a 24 hour operation with two 12 hour shifts. Four crews would be required to allow for off days with an additional 20% staff over compliment on the operators allowed for leave, sickness and absenteeism. The manning levels for the two IPCC configurations are shown in tables 19 and 20 below.

Table 19: FMIPCC Manning Level

FMIPCC Component	Manning Level
IPCC System	
Supervisor	4,0
Control Room Operator	4,8
Crusher Station Attendant	4,8
Spreader Attendant	4,8
Belt Attendant	4,8
Mechanical Artisan	4,0
Electrical Artisan	4,0
Assistants	4,8
Ancillary Equipment Operators	
Transporter	-
Crane 120t/150t	4,0
Excavator 2 Tonne	4,0
Bobcat	4,0
IT Loader	-
Maintenance Truck	4,0
Conveyor Side Lifting Truck	4,0
Rock Breaker	-
Track Dozer (D10 Class)	12,0
Truck & Lowbed	-
Pipe Layer Dozer	-
Belt realer	4,0
Cable realer	-
Loading System	
Operators Primary Equip	9,6
Operators Support Equip	28,8
Maintenance Operators	8,0
Artisans- Primary Equipment	4,0
Artisans- Support Equipment	6,0
Total	**128**

Table 20: SMIPCC Manning Level

SMIPCC Component	Manning Levels
IPCC System	
Supervisor	4,0
Control Room Operator	4,8
Crusher Station Attendant	4,8
Spreader Attendant	4,8
Belt Attendant	4,8
Leave Relief	4,8
Mechanical Artisan	4,0
Electrical Artisan	4,0
Assistants	4,8
Sub Total	

Ancillary Equipment Operators	
Transporter	-
Crane 120t/150t	4,0
Excavator 2 Tonne	4,0
Bobcat	4,0
IT Loader	-
Maintenance Truck	4,0
Conveyor Side Lifting Truck	4,0
Rock Breaker	-
Track Dozer (D10 Class)	12,0
Truck & Lowbed	-
Pipe Layer Dozer	-
Belt realer	4,0
Cable realer	-
Loading System	
Operators Primary Equip	53
Operators Support Equip	29
Maintenance Operators	17
Artisans- Primary Equipment	22
Artisans- Support Equipment	6
Total	**203**

IPCC System Cost

The build up of the cost for the IPCC systems follows the same principle as the Truck and Shovel option. First the production rate is estimated using efficiency factors and the operating hours determined using the time usage model. The capital cost is derived from information from suppliers and reduced to an annual cost based on the life of the equipment and then to a unit cost based on the estimated annual production. The maintenance cost of each component is determined using available industry norms and also reduced to a unit cost per tonne. The labour cost is then included using the manning level for the system and the cost of labour to company.

FMIPCC System Cost

Table 21: FMIPCC Time Usage Model

FMIPCC	Average													
Design Operating Hours	**Shovel**	**FM Crusher**	**Belt Wagon**	**Link Conveyor**	**Face Conveyor**	**Bench Link Conveyor**	**Bridge Conveyor**	**Bench Incline Conveyor**	**Overland Conveyor**	**Waste Dump Incline**	**Waste Dump Flat Conveyor**	**50/50 Radial Spreader**	**Spreader Spare**	**IPCC SYSTEM**
Calendar Hours	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**
Weather losses	120	120	120	120	120	120	120	120	120	120	120	120	120	120
FM Crusher Relocation		0												0
In pit Conveyor Relocations			72	72	72	72	72	72	72					72
Dump Conveyor Relocations										72	72			72
Spreader Relocations														0
Relocation new level			72	72	72	72	72	72	72					72
Scheduled Hours	**8 640**	**8 640**	**8 496**	**8 496**	**8 496**	**8 496**	**8 496**	**8 496**	**8 496**	**8 568**	**8 568**	**8 640**	**8 640**	**8 424**
Daily Service	361	180	180	180	180	180	180	180	180	180	180	0	180	361
Weekly Maintenance	411	617	309	309	309	309	309	309	309	309	309	0	617	617
Other Maintenance Shutdown	120	240	240	0	0	0	0	0	0	0	0	0	0	240
Scheduled Maintenance	801	1 037	729	489	489	489	489	489	489	489	489	0	797	1 218
Available Hours														
Scheduled Availability	90,7%	88,0%	91,4%	94,2%	94,2%	94,2%	94,2%	94,2%	94,2%	94,3%	94,3%	100,0%	90,8%	85,5%
Breakdowns as % of Scheduled Hrs	6,0%	3,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	0,0%	2,0%	8,6%
Breakdowns	518	259	170	170	170	170	170	170	170	171	171	0	173	622
BUDGET Overall Availability	84,7%	85,0%	89,4%	92,2%	92,2%	92,2%	92,2%	92,2%	92,2%	92,3%	92,3%	100,0%	88,8%	78,2%
Available Hours	**7321**	**7344**	**7597**	**7837**	**7837**	**7837**	**7837**	**7837**	**7837**	**7908**	**7908**	**8640**	**7670**	**6584**
Design Operating Hours	**Shovel**	**FM Crusher**	**Belt Wagon**	**Link Conveyor**	**Face Conveyor**	**Bench Link Conveyor**	**Bridge Conveyor**	**Bench Incline Conveyor**	**Overland Conveyor**	**Waste Dump Incline**	**Waste Dump Flat Conveyor**	**50/50 Radial Spreader**	**Spreader Spare**	**IPCC SYSTEM**
Utilization														
Shift Duration (hrs)	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00
Shift duration (mins)	720	720	720	720	720	720	720	720	720	720	720	720	720	720
No of shifts/day	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Shift startup + meeting	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Travel to /from pit	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Travel from pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operator changeout	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment Inspection	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Meal break	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Blasting delays	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20
Fuel/Lubrication	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Manoeuvre	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Manoeuvre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fatigue + Safety Meeting Delays	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Not required	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Effective Operation/Shift	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608
Equipment Utilization	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**
	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Shift startup + meeting	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Travel to /from pit	0	0	0	0	0	0	1	0	0	1	0	1	1	1
Travel from pit	0	0	0	0	0	0	1	0	0	1	0	1	1	1
Operator changeout	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment Inspection	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meal break	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Blasting delays	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fuel/Lubrication	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manoeuvre														
Manoeuvre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fatigue + Safety Meeting Delays	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Not required	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SMU Factors (Engine to OpHrs)														
Shift startup + meeting	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
Travel to /from pit	ON	ON	ON	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
Travel from pit	ON	ON	ON	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
Operator changeout	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Equipment Inspection	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Meal break	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Blasting delays	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Fuel/Lubrication	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Manoeuvre	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Manoeuvre	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Fatigue + Safety Meeting Delays	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Not required	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
SMU Factor	**1,09**	**1,09**	**1,09**	**1,09**	**1,09**	**1,09**	**1,08**	**1,09**	**1,09**	**1,08**	**1,09**	**1,08**	**1,08**	**1,06**
Effective Operating Hours	**Shovel**	**FM Crusher**	**Belt Wagon**	**Link Conveyor**	**Face Conveyor**	**Bench Link Conveyor**	**Bridge Conveyor**	**Bench Incline Conveyor**	**Overland Conveyor**	**Waste Dump Incline**	**Waste Dump Flat Conveyor**	**50/50 Radial Spreader**	**Spreader Spare**	**IPCC SYSTEM**
Annual Hours	8 640	8 640	8 496	8 496	8 496	8 496	8 496	8 496	8 496	8 568	8 568	8 640	8 640	8 424
Equipment Availability	84,7%	85,0%	89,4%	92,2%	92,2%	92,2%	92,2%	92,2%	92,2%	92,3%	92,3%	100,0%	88,8%	78,2%
Possible Mine Operating Hours	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Equipment Utilization	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%
Factor for start up years	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Effective Operating Hours	**6 182**	**6 201**	**6 415**	**6 618**	**6 618**	**6 618**	**6 618**	**6 618**	**6 618**	**6 678**	**6 678**	**7 296**	**6 477**	**5 560**
SMU (Engine) Hrs / year	**6 711**	**6 732**	**6 964**	**7 184**	**7 184**	**7 184**	**7 130**	**7 184**	**7 184**	**7 194**	**7 249**	**7 860**	**6 978**	**5 898**

Adopted from Morriss, 2013

The effective operating hours are 5 560 hours per year.The nominal capacity of the system with the two sizers is 12 000 tph and at 85% efficiency the expected production rate is 10 200 tph. The annual capacity of the system is thus determined at 10 200 tph x 5560 hrs giving an estimated annual capacity of 56.71 Mtpa.

Table 22: FMIPCC Owning Cost

Equipment Replacement Schedule	Qty	Life Hrs Hrs	Op Hrs Hrs/yr	Service Life Yrs	Capital Cost ZAR m	Annual Capital ZAR m/yr
Sizer	2	100000	5560	18	394,53	21,94
Belt Wagon	2	100000	5560	18	244,72	13,61
Link Conveyor	2	100000	5560	18	61,95	3,44
1200m Face conveyor	2	100000	5560	18	122,50	6,81
Bench Link Conveyor	2	100000	5560	18	61,39	3,41
Bridge Conveyors	2	100000	5560	18	61,67	3,43
Bench Incline Conveyor 500m	2	100000	5560	18	25,63	1,42
Overland Conveyor 1000m	2	100000	5560	18	129,82	7,22
Waste Dump Incline Conveyor	1	100000	5560	18	23,09	1,28
Waste Dump Flat Conveyor 1200m	1	100000	5560	18	82,09	4,56
Spreader	2	100000	5560	18	260,20	14,47
Transporter	1	50000	1000	50	49,76	1,00
Crane 120t/150t	1	25000	1000	25	14,54	0,58
Excavator 2 Tonne	1	10000	2000	5	0,50	0,10
Bobcat	1	10000	2000	5	0,44	0,09
IT Loader	1	20000	2000	10	4,42	0,44
Maintenance Truck	2	15000	2400	6	3,66	0,59
Conveyor Side Lifting Truck	1	15000	2000	8	3,11	0,41
Rock Breaker	1	24000	4000	6	3,55	0,59
Track Dozer (D10 Class)	3	35000	4000	9	43,50	4,97
Truck & Lowbed	1	50000	2000	25	35,00	1,40
Pipe Layer Dozer	1	30000	2000	15	12,50	0,83
Belt reeler	1	20000	2000	10	4,43	0,44
Cable reeler	1	20000	4000	5	3,05	0,61
Total					1 646,06	93,66
Production Mtpa						56,71
Unit Owning Cost ZAR/t						**1,65**

Table 23: FMIPCC Loading Fleet Owning Cost

Equipment Type	Fleet Size	Service Life Hrs	Operating Hours Hrs/yr	Service Life Yrs	Capital Cost ZAR m	Annual Capital ZAR m/yr
Eletric Rope Shovel (P&H 4100 XPC cl	1	100000	5560	18	328,15	18,24
Hydraulic Shovel (Komatsu PC8000 cla	1	60000	5560	11	191,77	17,77
Grader 16M	1	50000	2000	25	12,23	0,49
Komatsu WD600 Wheel Dozer	1	50000	4000	13	9,51	0,76
CAT 740 ADT Diesel Bowser	1	35000	4000	9	10,86	1,24
Komatsu HD785 Water Truck	1	45000	2000	23	17,43	0,77
CAT D10 Dozer	2	35000	4000	9	31,80	3,63
Total Cost ZARm/yr						42,91
Production Mtpa						56,71
Unit Owning Cost ZAR/t						**0,76**

Table 24: FMIPCC Electrical Power Cost

Electricity Price ZAR/ KwHr	0,96				
Equipment Type	**Quantity**	**Operating Power Kw**	**Operating Hours Hrs/yr**	**Power Consumption MwHr/yr**	**Cost ZAR m/yr**
Sizer	2	1 800	5 560	20 016	19,22
Belt Wagon	2	490	5 560	5 449	5,23
Link Conveyor	2	460	5 560	5 115	4,91
1200m Face conveyor	2	922	5 560	10 253	9,84
Bench Link Conveyor	2	280	5 560	3 114	2,99
Bridge Conveyors	2	480	5 560	5 338	5,12
Bench Incline Conveyor 500m	2	1 125	5 560	12 510	12,01
Overland Conveyor 1000m	2	578	5 560	6 427	6,17
Waste Dump Incline Conveyor	1	578	5 560	3 214	3,09
Waste Dump Flat Conveyor 1200m	1	578	5 560	3 214	3,09
Spreader	2	600	5 560	3 336	3,20
Total		7 891		77 985	74,87
Production Mtpa					56,71
Unit Cost ZAR/t					**1,32**

Table 25: Ancillary Equipment Fuel Cost

Fuel Price ZAR/Ltr	12,76			
Equipment Type	**Quantity**	**Operating Hours Hrs/year**	**Fuel Consumption Ltr/Hr**	**Cost ZAR m/year**
Transporter	1	1000	100	1,28
Crane 120t/150t	1	1000	30	0,38
Excavator 2 Tonne	1	2000	15	0,38
Bobcat	1	2000	10	0,26
IT Loader	1	2000	18	0,46
Maintenance Truck	2	2400	18	1,10
Conveyor Side Lifting Truck	1	2000	18	0,46
Rock Breaker	1	4000	25	1,28
Track Dozer (D10 Class)	3	4000	35	5,36
Truck & Lowbed	1	2000	15	0,38
Pipe Layer Dozer	1	2000	34	0,87
Belt reeler	1	2000	25	0,64
Cable reeler	1	4000	25	1,28
Total				14,12
Production Mtpa				56,71
Fuel Cost ZAR/t				**0,25**

Table 26: FMIPCC System Maintenance Cost

Equipment Type	Quantity	Mtce Cost ZAR/Hr	Machine Hours Hrs/yr	Mtce Cost ZAR m/yr
Sizer	2	6177	5560	68,68
Belt Wagon	2	965	5560	10,73
Link Conveyor	2	1544	5560	17,17
1200m Face conveyor	2	1544	5560	17,17
Bench Link Conveyor	2	1544	5560	17,17
Bridge Conveyors	2	1544	5560	17,17
Bench Incline Conveyor 500m	2	1930	5560	21,46
Overland Conveyor 1000m	2	1544	5560	17,17
Waste Dump Incline Conveyor	1	3860	5560	21,46
Waste Dump Flat Conveyor 1200m	1	3860	5560	21,46
Spreader	2	1930	5560	21,46
Total				251,13
Production Mtpa				56,71
Unit Mtce Cost ZAR/t				**4,43**

Table 27: Ancillary Equipment Maintenance Cost

Equipment Type	Quantity	Mtce ZAR/Hr	Engine Hours Hrs/yr	Mtce Cost ZAR m/yr
Transporter	1	1955	1000	1,96
Crane 120t/150t	1	782	1000	0,78
Excavator 2 Tonne	1	391	2000	0,78
Bobcat	1	335	2000	0,67
IT Loader	1	425	2000	0,85
Maintenance Truck	2	425	2400	1,02
Conveyor Side Lifting Truck	1	425	2000	0,85
Rock Breaker	1	670	4000	2,68
Track Dozer (D10 Class)	3	1331	4000	5,32
Truck & Lowbed	1	1761	2000	3,52
Pipe Layer Dozer	1	1034	2000	2,07
Belt reeler	1	559	2000	1,12
Cable reeler	1	559	4000	2,23
Total				23,85
Production Mtpa				56,71
Unit Mtce Cost ZAR/t				**0,42**

FMIPCC Loading System Operating Cost

The operating cost for the loading system including energy and maintenance are given in the table below. The hourly rates are derived from the company's models where the costs were built up from expected component change out, energy and fluid consumption but exclude the labour component.

Table 28: FMIPCC Loading System Operating Cost

Equipment	Fleet Size	Unit Op Cost ZAR/hr	Op Hours Hrs/yr	Op Cost ZAR m/yr
P&H 4100 XPC	1	3546	5560	19,72
Komatsu PC8000	1	4005	5560	22,27
Grader 16M	1	591	2000	1,18
Komatsu WD600 Wheel Dozer	1	735	2000	1,47
CAT 740 ADT Diesel Bowser	1	535	2000	1,07
Komatsu HD785 Water Truck	1	751	2000	1,50
CAT D10 Dozer	2	1230	2000	4,92
Total Cost ZARm/yr				52,13
Production Mtpa				56,71
Unit Operating Cost ZAR/t				**0,92**

The labour cost for the FMIPCC system as well as the loading system is build up as in the tables below.

Table 29: FMIPCC System Labour Cost

IPCC Component	Manning Level	CTC ZAR/yr	CTC ZAR m/yr
Supervisor	4,0	491 448	1,97
Control Room Operator	4,8	280 201	1,34
Crusher Station Attendant	4,8	280 201	1,34
Spreader Attendant	4,8	280 201	1,34
Belt Attendant	4,8	280 201	1,34
Mechanical Artisan	4,0	470 564	1,88
Electrical Artisan	4,0	470 564	1,88
Assistants	4,8	222 352	1,07
Sub Total			12,18
Ancillary Equipment Operators			
Transporter	-	222 352	-
Crane 120t/150t	4,0	222 352	0,89
Excavator 2 Tonne	4,0	222 352	0,89
Bobcat	4,0	222 352	0,89
IT Loader	-	222 352	-
Maintenance Truck	4,0	222 352	0,89
Conveyor Side Lifting Truck	4,0	222 352	0,89
Rock Breaker	-	222 352	-
Track Dozer (D10 Class)	12,0	222 352	2,67
Truck & Lowbed	-	222 352	-
Pipe Layer Dozer	-	222 352	-
Belt reeler	4,0	222 352	0,89
Cable reeler	-	222 352	-
Sub Total			8,00
Total	72,0		20,18
Production Mtpa			56,71
Unit Cost ZAR/t			**0,36**

Table 30: FMIPCC Loading System Labour Cost

Equipment	Ratios	Manning Level	CTC ZAR/yr	Total CTC ZAR m/yr
Operators Primary Equip	4,8	10	280201	2,69
Operators Support Equip	4,8	29	222352	6,40
Maintenance Operators	1,0	8	222352	1,78
Artisans- Primary Equipment	2,0	4	470564	1,88
Artisans- Support Equipment	1,0	6	470564	2,82
Total Cost ZARm/yr		56		15,58
Production Mtpa				56,71
Unit Cost ZAR/t				**0,27**

The Owning and Operating Cost of the Fully Mobile IPCC system is therefore made up of the following sub categories

IPCC System Owning Cost	ZAR 1.65/t
IPCC System Maintenance Cost	ZAR 4.85/t
IPCC System Energy Cost	ZAR 1.57/t
IPCC System Labour Cost	ZAR 0.36/t
Loading System Owning Cost	ZAR 0.76/t
Loading System Operating Cost	ZAR 0.92/t
Loading System Labour Cost	ZAR 0.27/t

The Owning and Operating Cost for the operation is thus estimated at ZAR 10.38/t in 2014 terms.

SMIPCC System

Table 31: SMIPCC Time Usage Model

SMIPCC	Average										
Design Operating Hours	**Shovel**	**SM Crusher**	**Bench Link Conveyor**	**Bridge Conveyor**	**Bench Incline Conveyor**	**Overland Conveyor**	**Waste Dump Incline**	**Waste Dump Flat Conveyor**	**50/50 Radial Spreader**	**Spreader Spare**	**IPCC SYSTEM**
Calendar Hours	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**	**8 760**
Weather losses	120	120	120	120	120	120	120	120	120	120	120
SM Crusher Relocation		286									286
In pit Conveyor Relocations			72	72	72						72
Dump Conveyor Relocations							72	72			72
Spreader Relocations											0
Scheduled Hours	**8 640**	**8 354**	**8 568**	**8 568**	**8 568**	**8 640**	**8 568**	**8 568**	**8 640**	**8 640**	**8 210**
Daily Service	361	180	180	180	180	180	180	180	0	180	361
Weekly Maintenance	411	617	309	309	309	309	309	309	0	617	617
Other Maintenance Shutdown	120	240	0	0	0	0	0	0	0	0	240
Scheduled Maintenance	801	1 037	489	489	489	489	489	489	0	797	1 218
Available Hours											
Scheduled Availability	90,7%	87,6%	94,3%	94,3%	94,3%	94,3%	94,3%	94,3%	100,0%	90,8%	85,2%
Breakdowns as % of Scheduled Hrs	6,0%	3,0%	2,0%	2,0%	2,0%	2,0%	2,0%	2,0%	0,0%	2,0%	8,9%
Breakdowns	518	251	171	171	171	173	171	171	0	173	622
BUDGET Overall Availability	84,7%	84,6%	92,3%	92,3%	92,3%	92,3%	92,3%	92,3%	100,0%	88,8%	77,6%
Available Hours	**7321**	**7066**	**7908**	**7908**	**7908**	**7978**	**7908**	**7908**	**8640**	**7670**	**6370**
Design Operating Hours	**Shovel**	**SM Crusher**	**Bench Link Conveyor**	**Bridge Conveyor**	**Bench Incline Conveyor**	**Overland Conveyor**	**Waste Dump Incline**	**Waste Dump Flat Conveyor**	**50/50 Radial Spreader**	**Spreader Spare**	**IPCC SYSTEM**
Utilization											
Shift Duration (hrs)	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00	12,00
Shift duration (mins)	720	720	720	720	720	720	720	720	720	720	720
No of shifts/day	2	2	2	2	2	2	2	2	2	2	2
Shift startup + meeting	10	10	10	10	10	10	10	10	10	10	10
Travel to /from pit	5	5	5	5	5	5	5	5	5	5	5
Travel from pit	0	0	0	0	0	0	0	0	0	0	0
Operator changeout	0	0	0	0	0	0	0	0	0	0	0
Equipment Inspection	10	15	10	10	10	10	10	10	10	10	15
Meal break	40	40	40	40	40	40	40	40	40	40	40
Blasting delays	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0	20
Fuel/Lubrication	15	15	15	15	15	15	15	15	15	15	15
Manoeuvre	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Manoeuvre	0	0	0	0	0	0	0	0	0	0	0
Fatigue + Safety Meeting Delays	10	10	10	10	10	10	10	10	10	10	10
Not required	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Effective Operation/Shift	608,0	603,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	608,0	603
Equipment Utilization	**84,4%**	**83,8%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**84,4%**	**83,8%**
	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Shift startup + meeting	0	0	0	0	0	0	0	0	0	0	1
Travel to /from pit	0	0	0	1	0	0	1	0	1	1	1
Travel from pit	0	0	0	1	0	0	1	0	1	1	1
Operator changeout	0	0	0	0	0	0	0	0	0	0	0
Equipment Inspection	0	0	0	0	0	0	0	0	0	0	0
Meal break	1	1	1	1	1	1	1	1	1	1	1
Blasting delays	1	1	1	1	1	1	1	1	1	1	1
Fuel/Lubrication	0	0	0	0	0	0	0	0	0	0	0
Manoeuvre											
Manoeuvre	0	0	0	0	0	0	0	0	0	0	0
Fatigue + Safety Meeting Delays	0	0	0	0	0	0	0	0	0	0	0
Not required	1	1	1	1	1	1	1	1	1	1	1
SMU Factors (Engine to OpHrs)											
Shift startup + meeting	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
Travel to /from pit	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
Travel from pit	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
Operator changeout	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Equipment Inspection	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Meal break	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Blasting delays	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Fuel/Lubrication	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Manoeuvre	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Manoeuvre	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Fatigue + Safety Meeting Delays	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Not required	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
SMU Factor	**1,09**	**1,09**	**1,09**	**1,08**	**1,09**	**1,09**	**1,08**	**1,09**	**1,08**	**1,08**	**1,07**
Effective Operating Hours	**Shovel**	**SM Crusher**	**Bench Link Conveyor**	**Bridge Conveyor**	**Bench Incline Conveyor**	**Overland Conveyor**	**Waste Dump Incline**	**Waste Dump Flat Conveyor**	**50/50 Radial Spreader**	**Spreader Spare**	**IPCC SYSTEM**
Annual Hours	8 640	8 354	8 568	8 568	8 568	8 640	8 568	8 568	8 640	8 640	8 210
Equipment Availability	84,7%	84,6%	92,3%	92,3%	92,3%	92,3%	92,3%	92,3%	100,0%	88,8%	77,6%
Possible Mine Operating Hours	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Equipment Utilization	84,4%	83,8%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	84,4%	83,8%
Factor for start up years	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Effective Operating Hours	**6 182**	**5 918**	**6 678**	**6 678**	**6 678**	**6 737**	**6 678**	**6 678**	**7 296**	**6 477**	**5 335**
SMU (Engine) Hrs / year	**6 711**	**6 478**	**7 249**	**7 194**	**7 249**	**7 313**	**7 194**	**7 249**	**7 860**	**6 978**	**5 706**

The effective operating hours are 5 335 hours per year. The nominal capacity of the system with the two sizers is 12 000 tph and at 85% efficiency the expected production rate is 10 200 tph. The annual capacity of the system is thus determined at 10 200 tph x 5335 hrs giving an estimated annual capacity of 54.42 Mtpa.

Table 32: SMIPCC Owning Cost

Equipment Replacement Schedule	Qty	Life Hrs Hrs	Op Hrs Hrs/yr	Service Life Yrs	Capital Cost ZAR m	Annual Capital ZAR m/yr
Sizer	2	100000	5335	19	394,53	21,05
Bench Link Conveyor	2	100000	5335	19	61,39	3,28
Bridge Conveyors	2	100000	5335	19	61,67	3,29
Bench Incline Conveyor 500m	2	100000	5335	19	25,63	1,37
Overland Conveyor 1000m	2	100000	5335	19	129,82	6,93
Waste Dump Incline Conveyor	1	100000	5335	19	23,09	1,23
Waste Dump Flat Conveyor 1200m	1	100000	5335	19	82,09	4,38
Spreader	2	100000	5335	19	260,20	13,88
Transporter	1	50000	1000	50	49,76	1,00
Crane 120t/150t	1	25000	1000	25	14,54	0,58
Excavator 2 Tonne	1	10000	2000	5	0,50	0,10
Bobcat	1	10000	2000	5	0,44	0,09
IT Loader	1	20000	2000	10	4,42	0,44
Maintenance Truck	2	15000	2400	6	3,66	0,59
Conveyor Side Lifting Truck	1	15000	2000	8	3,11	0,41
Rock Breaker	1	24000	4000	6	3,55	0,59
Track Dozer (D10 Class)	3	35000	4000	9	43,50	4,97
Truck & Lowbed	1	50000	2000	25	35,00	1,40
Pipe Layer Dozer	1	30000	2000	15	12,50	0,83
Belt reeler	1	20000	2000	10	4,43	0,44
Cable reeler	1	20000	4000	5	3,05	0,61
Total					1 216,90	67,46
Production Mtpa						54,42
Unit Owning Cost ZAR/t						**1,24**

Table 33: SMIPCC Loading Fleet Owning Cost

Equipment Type	Fleet Size	Service Life Hrs	Operating Hours Hrs/yr	Service Life Yrs	Capital Cost ZAR m	Annual Capital ZAR m/yr
P&H 4100 XPC	1	100 000	5 335	18,7	328,15	17,51
Komatsu PC8000	1	60 000	5 335	11,2	191,77	17,05
Komatsu 960E Trucks	9	60 000	5 335	11,2	658,40	58,54
Grader 16M	1	50 000	4 000	12,5	12,23	0,98
Komatsu WD600 Wheel Dozer	1	50 000	4 000	12,5	9,51	0,76
CAT 740 ADT Diesel Bowser	1	35 000	4 000	8,8	10,86	1,24
Komatsu HD785 Water Truck	1	45 000	4 000	11,3	17,43	1,55
CAT D10 Dozer	2	35 000	4 000	8,8	31,80	3,63
Total Cost ZARm/yr						101,26
Production Mtpa						54,42
Unit Owning Cost ZAR/t						**1,86**

Table 34: SMIPCC Electrical Power Cost

Equipment Type	Quantity	Operating Power Kw	Operating Hours Hrs/yr	Power Consumption MwHr/yr	Cost ZAR m/yr
Sizer	2	1 800	5 335	19 206	18,44
Bench Link Conveyor	2	280	5 335	2 988	2,87
Bridge Conveyors	2	480	5 335	5 122	4,92
Bench Incline Conveyor 500m	2	1 125	5 335	12 004	11,52
Overland Conveyor 1000m	2	578	5 335	6 167	5,92
Waste Dump Incline Conveyor	1	578	5 335	3 084	2,96
Waste Dump Flat Conveyor 1200m	1	578	5 335	3 084	2,96
Spreader	2	600	5 335	3 201	3,07
Total		6 019		54 854	52,66
Production Mtpa					54,42
Unit Cost ZAR/t					**0,97**

Table 35: Ancillary Equipment Fuel Cost

Equipment Type	Quantity	Operating Hours Hrs/year	Fuel Consumption Ltr/Hr	Cost ZAR m/year
Transporter	1	1000	100	1,28
Crane 120t/150t	1	1000	30	0,38
Excavator 2 Tonne	1	2000	15	0,38
Bobcat	1	2000	10	0,26
IT Loader	1	2000	18	0,46
Maintenance Truck	2	2400	18	1,10
Conveyor Side Lifting Truck	1	2000	18	0,46
Rock Breaker	1	4000	25	1,28
Track Dozer (D10 Class)	3	4000	35	5,36
Truck & Lowbed	1	2000	15	0,38
Pipe Layer Dozer	1	2000	34	0,87
Belt reeler	1	2000	25	0,64
Cable reeler	1	4000	25	1,28
Total				14,12
Production Mtpa				54,42
Fuel Cost ZAR/t				**0,26**

Table 36: SMIPCC System Maintenance Cost

Equipment Type	Quantity	Mtce Cost ZAR/Hr	Machine Hours Hrs/yr	Mtce Cost ZAR m/yr
Sizer	2	6177	5335	65,90
Bench Link Conveyor	2	1544	5335	16,48
Bridge Conveyors	2	1544	5335	16,48
Bench Incline Conveyor 500m	2	1930	5335	20,60
Overland Conveyor 1000m	2	1544	5335	16,48
Waste Dump Incline Conveyor	1	3860	5335	20,60
Waste Dump Flat Conveyor 1200m	1	3860	5335	20,60
Spreader	2	1930	5335	20,60
Total				197,71
Production Mtpa				54,42
Unit Cost ZAR/t				**3,63**

Table 37: Ancillary Fleet Maintenance Cost

Equipment Type	Quantity	Mtce Cost ZAR/Hr	Machine Hours Hrs/yr	Mtce Cost ZAR m/yr
Transporter	1	1955	1000	1,96
Crane 120t/150t	1	782	1000	0,78
Excavator 2 Tonne	1	391	2000	0,78
Bobcat	1	335	2000	0,67
IT Loader	1	425	2000	0,85
Maintenance Truck	2	425	2400	1,02
Conveyor Side Lifting Truck	1	425	2000	0,85
Rock Breaker	1	670	4000	2,68
Track Dozer (D10 Class)	3	1331	4000	5,32
Truck & Lowbed	1	1761	2000	3,52
Pipe Layer Dozer	1	1034	2000	2,07
Belt reeler	1	559	2000	1,12
Cable reeler	1	559	4000	2,23
Total				18,82
Production Mtpa				54,42
Unit Cost ZAR/t				**0,35**

Table 38: SMIPCC Loading and Hauling System Operating Cost

Equipment	Fleet Size	Unit Op Cost ZAR/hr	Op Hours Hrs/yr	Op Cost ZAR m/yr
P&H 4100 XPC	1	3 546	5 335	18,92
Komatsu PC8000	1	4 005	5 335	21,37
Komatsu 960E	9	2 972	5 335	142,69
Grader 16M	1	591	4 000	2,36
Komatsu WD600 Wheel Dozer	1	735	4 000	2,94
CAT 740 ADT Diesel Bowser	1	535	4 000	2,14
Komatsu HD785 Water Truck	1	751	4 000	3,00
CAT D10 Dozer	2	1 230	4 000	9,84
Total Cost ZARm/yr				203,26
Production Mtpa				54,42
Unit Cost ZAR/t				**3,74**

Table 39: SMIPCC System Labour Cost

IPCC Component	Manning Level	CTC ZAR/yr	CTC ZAR m/yr
Supervisor	4,0	491 448	1,97
Control Room Operator	4,8	280 201	1,34
Crusher Station Attendant	4,8	280 201	1,34
Spreader Attendant	4,8	280 201	1,34
Belt Attendant	4,8	280 201	1,34
Mechanical Artisan	4,0	470 564	1,88
Electrical Artisan	4,0	470 564	1,88
Assistants	4,8	222 352	1,07
Sub Total			12,18
Ancillary Equipment Operators			
Transporter	-	222 352	-
Crane 120t/150t	4,0	222 352	0,89
Excavator 2 Tonne	4,0	222 352	0,89
Bobcat	4,0	222 352	0,89
IT Loader	-	222 352	-
Maintenance Truck	4,0	222 352	0,89
Conveyor Side Lifting Truck	4,0	222 352	0,89
Rock Breaker	-	222 352	-
Track Dozer (D10 Class)	12,0	222 352	2,67
Truck & Lowbed	-	222 352	-
Pipe Layer Dozer	-	222 352	-
Belt reeler	4,0	222 352	0,89
Cable reeler	-	222 352	-
Sub Total			8,00
Total	72		20,18
Production Mtpa			54,42
Unit Cost ZAR/t			**0,37**

Table 40: SMIPCC Loading and Hauling System Labour Cost

Equipment	Ratios	Manning Level	CTC ZAR/yr	Total CTC ZAR m/yr
Operators Primary Equip	4,8	53	280201	14,79
Operators Support Equip	4,8	29	222352	6,40
Maintenance Operators	1,0	17	222352	3,78
Artisans- Primary Equipment	2,0	22	470564	10,35
Artisans- Support Equipment	1,0	6	470564	2,82
Total Cost ZARm/yr		127		38,15
Production Mtpa				54,42
Unit Cost ZAR/t				**0,70**

The Owning and Operating Cost of the Semi Mobile IPCC system is therefore made up of the following sub categories

IPCC System Owning Cost	ZAR 1.24/t
IPCC System Maintenance Cost	ZAR 3.98/t
IPCC System Energy Cost	ZAR 1.23/t
IPCC System Labour Cost	ZAR 0.37/t
Loading and Hauling System Owning Cost	ZAR 1.86/t
Loading and Hauling System Operating Cost	ZAR 3.74/t
Loading and Hauling System Labour Cost	ZAR 0.70/t

The Owning and Operating Cost for the operation is thus estimated at ZAR 13.12/t in 2014 terms.

Chapter 4: Analysis and Benchmarking

4.1 Truck and Shovel System

Planning and Design

Experience at Sishen mine has shown that there is a well developed planning approach for the Truck and Shovel system. High productivity can be achieved by ensuring that the haul roads and ramp systems are properly designed and maintained. Simulations are also important in determining the equipment requirements and system capabilities taking into account the impact of increasing pit depth as well as traffic density on the haul roads and ramps. The haul roads and ramp systems are dependent on the pit layout. High productivity is also influenced by the shovel dig rates which depend largely on the fragmentation of the material.

Pit Layout

Figure 11: Sishen North Pit (GR80/GR50 Area) – Sishen 2013

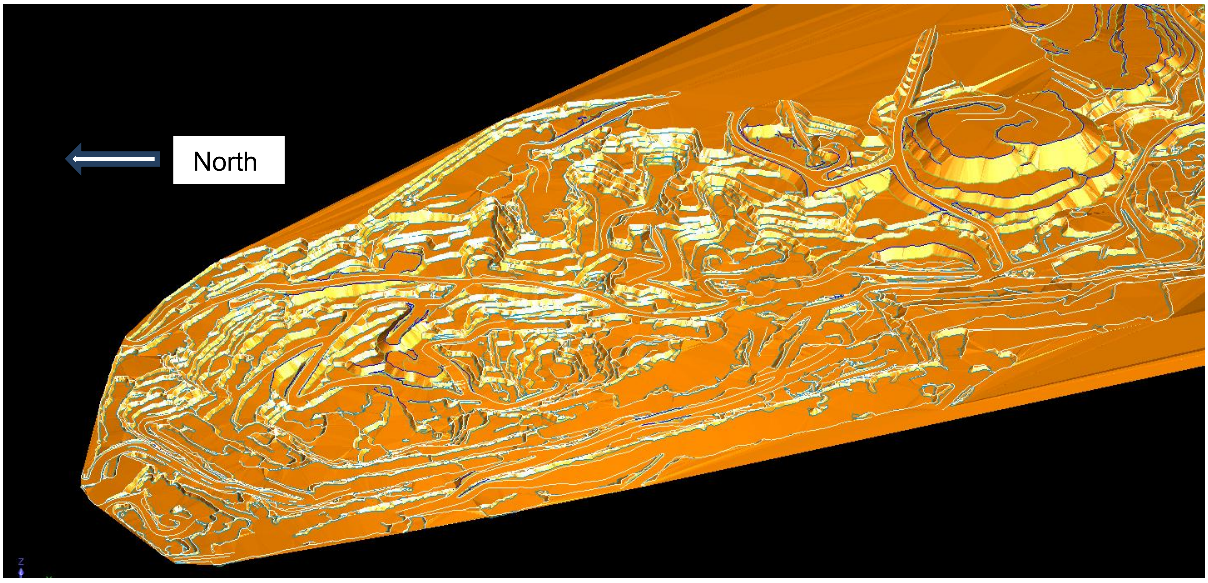
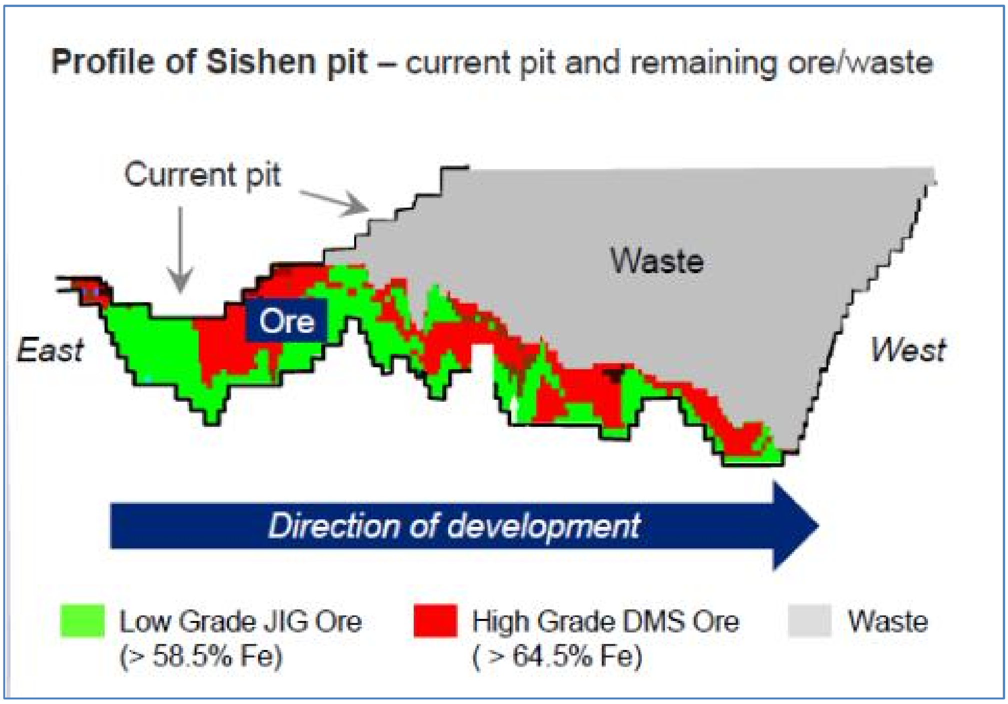


Figure 12: Sishen Pit Cross Section – Sishen 2013



The pit layout shown above in figure 10 and 11 indicates that the pit deployment is based on targeting the ore areas through a system of permanent and temporary ramps to the bench faces with multi levels and faces being mined at the same time. This is done after the overlying waste has been stripped. The waste stripping is done in phases called pushbacks which last about three years. Mining in the upper levels has been easier with a lot of flexibility in terms of areas to open up for ore. However, currently and going forward, to access the dipping ore in the deeper part, that flexibility is diminished. There is one possible schedule or mining sequence that has to be followed to access the next easy ore while ensuring life of mine sustainability. This involves mining high tonnages from a confined area, a few loading faces with a high rate of vertical advance so as to quickly get to the deep lying ore. This prompted the mine to change to bigger high capacity equipment, such as the following:-

- P&H 2300 rope shovels being replaced by P&H 2800 and 4100 rope shovels.
- Demag 285 hydraulic shovels replaced by Komatsu PC8000, Liebherr 996 and 9800 hydraulic shovels.
- CAT994 /Komatsu WA1200 front-end loaders replaced by Le Tourneau L2350 front-end loaders.
- Komatsu 730E trucks replaced by Komatsu 960E trucks.

Although the larger equipment provides high capacity and a smaller fleet, they require larger operating space, and wider haul roads and ramps.

Skills

The truck and shovel fleet for the designated area requires an average of 231 operators, including a 20% over compliment, over the life of the project to sustain a 24 hour operation.

Operator training includes theoretical as well as simulator training on the particular equipment before any field training begins. The field training requires a minimum of 580 hours including 130 hours observing an experienced operator in the field and 450 hours of operating under supervision by an experienced operator. Operating a truck is not a complicated skill and this in-house training programme mentioned above has proved to be adequate.

The challenges currently being experienced are related to staff retention and the sheer numbers of trainee operators that have to be taken through the programme in the ramp up phase. The average age of the truck operator is getting younger and the minimum requirement is for them to have at least a high school qualification. These are ambitious young people who are hoping to have a career on the mine and advance within a short time, and thus are impatient and always looking for alternative career opportunities if they do not progress on the mine.

Automating the truck and shovel system is currently receiving a lot of focus, but the business case is proving to be a challenge to develop since the automated trucking technology is not cheap relative to manning the trucks in the developing world of which South Africa is part of. However, once the technology has been well proven and costs come down, this would create an opportunity for more efficient and safer truck and shovel operations.

Maintenance of the equipment requires 84 qualified artisans. Skilled artisans are scarce in the country currently and training takes time.

Setting up a Truck and Shovel operation does not require as much supplier support as the IPCC system would due to experience that has been acquired over the years.

Efficiency

Productivity is influenced by direct operating hours, the effective hours when the equipment is performing the intended duty and operational efficiency which depend on the operator skill and prevailing conditions such as haul roads or working areas.

There has been challenges with achieving the planned productivity with the truck and shovel system at the mine. Details are shown in table 10 below.

Table 41: Ultra-class Electric Rope Shovel- P&H 4100XPC Benchmarks, Targets and Actual performance per annum

	GBI 95th Percentile	LOM Target	2014 YTD
Direct Operating Hours	6357	6357	4964
Production Dig Rate (tph)	7683	6221	3127
Annual Production (tonnes)	48.8Mt	36.6Mt	18Mt

GBI – GBI Mining Intelligence.

LOM – Life of Mine

YTD – Year- to-date (annualised)

The results above indicate that although the truck and shovel system appears to be simple, it is not always easy to set up to achieve maximum benefits. The main issues identified were that the direct operating hours were difficult to achieve due to frequent stoppages due to blasting in an increasingly confined pit relative to the equipment size. Bucket fill factors were also not optimum due to blasting fragmentation issues leading to lower dig rates. Simulation results demonstrate diminishing returns in terms of system productivity as more trucks are added to the system. This is due to truck queuing and bunching as numbers increase. Operational set up requires modification to suit the ultra-class equipment and the operational philosophy should be one that treats the shovel and truck fleet as a unit including the mining support equipment such as graders, dozers and water trucks. Big blasts need to be adopted and operating space increased. Dedicated routes separated from the rest of the traffic would also be imperative. These are conditions that an IPCC system would also require.

Material Type

Productivity is also affected by the shovel dig rate which in turn is influenced by fragmentation from blasting. Blasting design is largely influenced by rock characteristics and therefore by material type.

The objective of blasting waste material is to reduce the material to a particle size that can be loadable by the equipment applied. Poor fragmentation results in poor dig rates and therefore lower productivity. Although big boulders would also make it difficult to build properly laid out waste dumps, however, no further processing of the material would be required unlike in the case of the IPCC system.

Safety and Health

Figure 13: Sishen High Potential Truck Incidents- 2013

At the time of writing this report, there has not been a fatal accident at Sishen mine in 2013. However there were thirty nine high potential incidents at the mine so far in 2013 which could have resulted in a fatality. Twenty five of these incidents involved truck haulage.

The captions above depict some of the high potential incidents involving trucks at Sishen mine from January 2013 to end of November 2013. These include:-

- truck colliding with truck in front (dove tailing),
- trucks veering off the haul road due to operator fatigue,
- head on collisions at intersection,
- truck losing control and overturning,
- truck catching fire while travelling,
- collision at park up area,

- truck driving over lighter vehicle,
- truck driving over spillage on the haul road,
- Run-away truck due to brake failure on the ramp.

Historically, there has been a fatal accident on the mine every year on average in the past ten years and 90% of those have been from truck incidents.

There is a huge continuous focus on safety and health which demands a lot of management effort and resources. Interventions include:-

- Supervision (dealing with many individual components e.g. each truck).
- Fatigue management.
- Health monitoring (e.g. hypertension, diabetes, alcohol and drug testing).
- Technological enhancements (e.g. collision awareness devices, blind spot cameras on trucks, fatigue monitors inside truck cabs).
- Training (continuous, task observations).
- Dust suppression

Given these challenges and the required interventions, Health and Safety becomes critical in comparing the two systems. The other issue of the environment that may become critical in the future is the carbon footprint. South African electrical power supply is from largely from coal fired stations and the mobile equipment on the other hand also uses a lot of diesel.

Costs

The cost of the Truck and Shovel system is estimated ZAR 4.39/t owning cost and ZAR 11.41/t operating cost.

A new state of the art workshop including a tyre handling facility and a bucket and bowel section has since been constructed at a cost of ZAR 1400M to cater for a fleet that will move 298 Mtpa at peak. On a pro-rata basis therefore, for 55Mtpa fleet, infrastructure cost would be ZAR 258M in 2014 terms. On the other hand the IPCC system would require a power reticulation system to be installed at a cost as well.

The cost of housing was not included in the economic evaluations but the mine is currently constructing housing for its employees as part of the requirements of the Mining Charter (South Africa Legislation). The manning requirement for the Truck and Shovel option including operators, supervisors and maintenance personnel is

368. The Fully Mobile IPCC system would require 128 people and the Semi Mobile IPCC would have a labour compliment of 203 employees.

It currently cost above ZAR 1M to provide housing for an operator and therefore additional housing cost of the truck and shovel option would be at least ZAR 165M above the IPCC options.

Cost therefore would be a one of the key distinguishing feature between the two systems

Flexibility

The truck and shovel system is generally more flexible than the IPCC system in that smaller sub units can be created in the form of several loading faces at the same time and even multiple routes and dump points. The units consisting of mainly a shovel and support equipment and trucks allocated to it can also be easily moved from one area of the mine to another.

The unit can also carry on operating though sub-optimally if one of the components, other than the shovel, is down such as a truck or a piece of support equipment.

In the event of down scaling operations, smaller sub-units can be decommissioned at a time and even sold as single units such as trucks thus enabling some of the capital to be salvaged. A wholesale disposal of a whole unit of an integrated system would be a challenge especially since these integrated systems are usually custom designed for a particular operation.

The truck and shovel system enables pre-stripping to be maintained just ahead of ore extraction thus limiting the impact of economic down turns by limiting commitment of capital.

In the case of Sishen, however, this flexibility has become quite limited in that as the pit is getting deeper and more constrained, there is not much room to change the mining sequence without negatively affecting the business plan. This negates the advantage that the Truck and Shovel system would have over the IPCC in terms of flexibility on projects such as Sishen.

4.2 In-pit Crushing and Conveying

Planning and Design

Complete planning and design was done by the three consultants engaged by Sishen mine, Snowden, Sandvik and SKM. Technical viability was demonstrated. A different approach to opening up the mine would need to be taken. Bigger push backs, straighter and longer pit walls would assist in making the IPCC system more efficient by limiting the crusher and conveyor moves. This would entail more pre-stripping for future ore and thus upfront commitment of capital. The layout of the pit can therefore make or break the project.

Skills

Sishen mine once operated a semi mobile in-pit crushing and conveying for waste. This was however a long time ago and the crusher and conveyor belts were never moved from their initial position since installation. This system was later converted to an ore crushing and conveying system with the crusher still maintaining its initial position in the pit which is now quite high up relative to the final pit bottom.

The skills required to operate the IPCC system do exist on Sishen mine from the processing plant where crushers and multitudes of conveyors are used to handle the ore from the pit and spreaders used to dump the discard after processing the ore. These skills would need to be transferred to the mining personnel.

Skills that would need to be developed would be for planning and design as well as for the conveyor and crusher moves. Sourcing of these skills could be a challenge since there are not that many such systems currently operating in the region.

The manning levels for the IPCC systems are less than those of a truck and shovel operation thereby reducing the burden of training of operators. The proposed FMIPCC system requires 94 operators and 18 artisans and the SMIPCC would require 137 operators and 36 artisans. The equivalent Truck and Shovel system would require 231 operators and 84 artisans by comparison. The required level of skill of the IPCC operators is also not as high as that of shovel or truck operator and therefore the training is quicker and easier.

The whole IPCC system can be more easily automated and centrally controlled using PLC and SCADA technology thereby limiting the dependency on operator interventions.

Maintenance of an IPCC would be easier to manage through real time diagnostics due to advances in control systems for such plants.

Setting up an IPCC operation would require expert support from the supplier due to limited experience on such systems in the region. The supplier may need to move the necessary skills from other parts of the world to assist in the installation and start up.

Although there may be challenges in the acquisition of skills, this does not appear to be insurmountable.

Efficiency

One of the biggest challenges that have been highlighted in terms of operational efficiency of the IPCC systems is that of achieving the required direct operating hours. This is due to the fact that the system from the crusher to the spreaders is integrated and therefore if one component is down then the whole system is down. Major equipment moves which are necessary from time to time, such as crusher and conveyor relocations, tend to take a lot of time thus reducing the annual operating hours of the system.

As in the case of the Truck and Shovel operation, fragmentation of the material and therefore material type also affects productivity.

Material Type

The availability of a suitable crusher in a fully or semi mobile configuration for the type of material concerned is critical in the consideration of evaluating the IPCC system

The tables below show typical industry targets. Rock strength determines the crusher type that can be used and the throughput that can be achieved.

Table 42: FMIPCC Capacities- Morriss 2013

FMIPCC Maximum Capacity - WASTE					
Rock Strength	Crusher Type	Instant tpoh	Average tpoh	Op Hrs per Year	Annual Mtpa
100 Mpa	DRC	8,200	7790	5,200	40.51
100 Mpa	Hybrid DRC	9,500	9025	5,200	46.93
50 Mpa	DRC/Sizer	9,000	8550	5,200	44.46
25 Mpa	Sizer	10,000	9500	5,200	49.40
Clay	Sizer	10,000	9000	5,200	46.80

Table 43: SMIPCC Capacities– Morriss 2013

SMIPCC Maximum Capacity - WASTE					
Rock Strength	Crusher Type	Instant tpoh	Average tpoh	Op Hrs per Year	Annual Mtpa
150 Mpa	Gyratory	8,500	8075	5,600	45.22
100 Mpa	Gyratory	10,000	9500	5,600	53.20
50 Mpa	Gyratory	11,500	10925	5,600	61.18
100 Mpa	DRC	8,200	7790	5,600	43.62
100 Mpa	Hybrid DRC	9,500	9025	5,600	50.54
50 Mpa	DRC/Sizer	9,000	8550	5,600	47.88
25 Mpa	Sizer	10,000	9500	5,600	53.20
Clay	Sizer	10,000	9000	5,600	50.40

Safety

IPCC systems are relatively much safer than the truck and shovel set up. At Sishen mine, there has not been a single fatal accident involving crushing, conveying and stacking in the ore processing based on the accident records dating back to more than ten years ago. Less than 10% of the high potential incidents have occurred in the crushing, conveying and stacking systems of the processing plant compared to the more than 90% involving trucks and shovels in the pit. Transport and Machinery has been identified by the South African mining industry as one of the main hazard areas in the mining industry. Issue of health and fatigue are also more manageable in the IPCC system due to the fact that operators are not on board the moving equipment such as conveyors unlike in the Truck and Shovel system where operators have to be on board the trucks.

Costs

The cost estimates are as shown in table 45 below.

Table 44: Cost Summary

Cost	Truck and Shovel	FMIPCC	SMIPCC
Initial Capital ZAR m	1675	2248	2477
Owning Cost ZAR/t	4.39	2.41	3.10
Operating Cost ZAR/t	11.41	7.97	10.02
Total ZAR/t	**15.80**	**10.38**	**13.12**

Both the Owning and Operating cost for the IPCC options are lower over the life of the project than the Truck and Shovel option in this case. The initial capital for the Truck and Shovel system is lower due to the fact that the truck fleet starts lower at 13 trucks and ramps up gradually to 21 by the end of the project as the pit deepens. There are truck and support equipment replacements in the course of the project. In the case of the IPCC system, the most of the equipment is purchased at the start of the project but lasts till the end of the project with only support equipment being replaced during the life of the project.

The cost estimates indicate that the IPCC system is more cost effective over the life of the project for a high volume long life project such as the Sishen case. The initial capital expenditure is higher than the Truck and Shovel option. Cost is therefore a major consideration due to the different cost profile that each system has.

Flexibility

IPCC systems are generally less flexible than the truck and shovel system because the following:

- Require more operational space which takes time to establish.
- Relocations need to be kept at a minimum because they consume operating time.
- They not suited to handling varying material types because the equipment selection is very much linked to the material being handled e.g. crusher type.
- The system components are not sub-divisible such as in the case of trucks which can be moved around and re-allocated to other shovels.

This inflexibility is not significant in the case of a deep pit that is confined and from which huge volumes have to be moved at a time. Options are limited and even in the case of a truck and shovel operation, loading areas are limited and both systems operate in a similar fashion the IPCC system having any advantage in terms of steady throughput.

Chapter 5: Score Card

Evaluation of either the Truck and Shovel system or the IPCC system requires time and money. A preliminary evaluation method that eliminates one system in favour of the other even before a lot of work is put into a study would be useful. This may not always be easy if both systems are both suitable given that there are always advantages and disadvantages in each system in any given situation.

The approach taken in this research was to evaluate quantitatively and qualitatively the Truck and Shovel system as well as the IPCC system using some general criteria commonly applied to mining method evaluations namely:

- Planning and Design
- Skills
- Efficiency
- Safety
- Costs
- Flexibility

The analysis of these factors has highlighted four major areas which can be focussed on to arrive at some informed decision on which system to take further for detailed evaluation. These areas are **cost, pit layout, material types** and **occupational health and safety**.

Cost

For a mining project to be viable, costs should be kept a low as possible. This is due to the fact that mining companies are usually price takers and mineral commodity prices are cyclic. For any mining project, it is therefore critical to be located on the lower end of the producer cost curve relative to competitors so that in times of commodity price recession, the project can remain viable. Technologies that support a low cost operation over a long period are therefore more favourable. Investing in technology requires capital and capital investments require long project life to realise the full economic benefit. Economies of scale also do apply and therefore high volume systems tend to be more economic. For example, the Ulan Coal (Australia) Fully Mobile IPCC unit was discontinued due to the fact that it was handling low volumes of 2300 tonnes per hour, was maintenance intensive and required frequent relocations. It therefore became uneconomic to run. A typical IPCC system handles around 10 000 tonnes per hour.

Other cost drivers include energy and labour costs, hauling distances, operational efficiencies including skills, as well as supporting infrastructure such as workshops.

Pit Layout

The way the pit is deployed is dependent on the nature of the ore body and the pit optimisation process. For the Truck and Shovel system, ramp and dump locations need to be established and have a direct impact on productivity. The volume to be mined from a specific area at a particular time determines the type and number of equipment that can be applied. In confined pit conditions, high capacity machines and less equipment numbers would be suitable to avoid congestion and achieve the required productivity. In shallow and wide pits with many loading area options, a more flexible system that can be quickly relocated would be ideal.

Material Types

The number and type of material to be handled, be it over burden, general waste or ore, is critical in determining a suitable materials handling system. Crushing waste or overburden for conveying is usually a concern since it is an additional cost that is avoided in a truck and shovel set up. Conveying is, however, more efficient and cheaper when distances are long and the pit depths are significant.

Crushers are selected on the basis of the material to be crushed. The capabilities and throughput of the crusher depends on material properties such as strength, abrasiveness, moisture content, etc. It is therefore desirable to have limited material types for the IPCC system because the crusher selection is dependent on the properties of the material. Truck and shovel systems usually accommodate material type variations.

Occupational Health and Safety

Employee safety and health has become very prominent and critical in mining projects and have to be considered in the planning stage. Environmental issues are also catching up with sustainable mining having become a catch phrase. In deciding what system of handling material from the pit to apply, these factors have to be taken into consideration as they can threaten the licence to operate. In the South African context, there has been increased focus on eliminating fatalities on the mines with transport and machinery having been identified as one of the main contributors to mine accidents. For a large operation where high volumes are moved, this can potentially be a challenge to sustainable mining especially where equipment fleets are likely to be huge in the case of a truck and shovel system.

Chapter 6: Conclusion and Recommendation

Results from this research indicate that they are cases in which either the Truck and Shovel system or the IPCC system can be applied to move material from a pit although with different cost profiles and safety and health risks. The cost profiles would depend on the required production rate, the distance from the loading to the dumping points and the life of the project. The costs would have to be determined including the initial capital for a comparison to be made. There are also cases where the IPCC system would not be viable due to practical considerations which include material type with respect to the availability of crushing systems that would achieve the required throughput or a pit layout that would render it impossible to fit in an IPCC system.

The table below summarises the four criteria that can be used for evaluating the two systems including typical characteristics of each system.

Table 45: Evaluation Criteria

Criteria	Drivers	Characteristics	
		Truck & Shovel	IPCC
Material type	Material variations Material type volumes	-Accommodates material variations	- Requires less material variations. -Requires high volumes of target material type
Pit Layout	Pit extent Permanent ramps Dump locations	-Several Loading points -Nearby dumping -Easier ramp development	-Concentrated mining. -Far dumping locations. -Less ramp relocations
Occupational Health and Safety	Equipment interactions Dust and fumes	-Has more equipment interactions -More dependent on human action. -Fatigue challenges -Safety supervision challenges	-More control -Less human interference
Cost	Mine life Volumes Hauling distance Access to Capital Energy cost Labour cost Efficiencies Skills Supporting infrastructure	-Medium to long life. -Any volume -More labour -Lower efficiency with increasing volume. -Phased capital	-Long life -High volumes -Lower operating cost -High initial capital cost -Distant dump points -Less flexible

The criteria would be applied to the Sishen case as follows:-

Material Type

There were only two targeted waste material types which are clay and calcrete in sufficient high volumes per area per period. The target was 55 Mtpa. Both the Truck and Shovel and the IPCC system could be considered in this regard.

Pit Layout

Practical pit layout designs done showed that both systems could be accommodated over the life of the project. Both systems are faced with similar challenges as the pit goes deeper and the operating space becomes minimum significantly reducing flexibility in terms of loading areas. No one system had an advantage over the other over the life of the project in this aspect.

Occupational Health and Safety

The IPCC system has an advantage over the Truck and Shovel system in this regard. There has been safety challenges posed by the truck and shovel system due to the large fleet size and increased interactions in a confined pit. However, through the various mine interventions such as the fatigue management system, the safety and health risk posed by the Truck and Shovel option has been minimised.

Cost

Given that neither of the two systems can be eliminated on the basis of the three criteria above, a cost evaluation of both systems would therefore be necessary. The average Owning and Operating Costs over the life of the project till 2030, disregarding salvage value, escalation and discounting, were estimated as follows:-

Table 46: Cost Comparisons

Cost	Truck and Shovel	FMIPCC	SMIPCC
Production Potential Mt	1029	907	870
Initial Capital ZAR m	1675	2248	2477
Total Capex ZAR m	4516	2186	2698
Owning Cost ZAR/t	4.39	2.41	3.10
Operating Cost ZAR/t	11.41	7.97	10.02
Total ZAR/t	**15.80**	**10.38**	**13.12**

The IPCC options in this case are more economically viable than the Truck and Shovel option. The availability and cost of capital might still make the Truck and Shovel option more favourable due to its lower initial capital with the first equipment replacements coming in after eight years of operation. In an environment where capital is available at low cost then the IPCC system would be the preferred option.

Given the above observations, it would be recommended to take the following approach in evaluating a system to handle broken material from the pit to the dumping locations.

The first step would be to examine the characteristics of the project to see if both the IPCC system configurations can readily be eliminated on the basis of material types and pit layout using the characteristics listed in table 46. If viable then make a high level evaluation of both Truck and Shovel and the IPCC systems to compare them on the basis of cost. Occupational Safety and Health issues would then need to be taken into consideration. This process would then enable the decision on whether both systems or only the Truck and Shovel option can be taken forward for a more detailed study at the appropriate level of accuracy depending on the project study phase. This approach assumes that the Truck and Shovel option would always be part of the evaluation as the base case. However there are cases when this option is not possible such as when the operation is located in difficult terrain with dumps located across steep gorges or when the mine is located in environmentally sensitive areas that restrict haul roads.

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Appendix

Appendix 1

Talpac Truck/Shovel Simulation Results

Production Summary - Full Simulation			
Haulage System: GR80_2016_Rev		*Haul Cycle: [PRJ] Haul Cycle_GR80_2016*	
Material: [PRJ] Oher Waste GR80		*Roster: [PRJ] GR80_5339_OpHrs*	
Loader		*[PRJ] P&H 4100 XPC (AC)-Cost_GR80*	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,08	
Average Payload	tonne	101,66	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 893,85	
Production per Loader Operating Shift	tonne	55 500	Max. prod. based on 100% avail.
Production per Year	tonne	31 468 732	Avg. production factored by avail.
Wait Time per Operating Hour	min	3,35	
Truck		*[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost*	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,88	
Production per Operating Hour	tonne	453,37	
Production per Loader Operating Shift	tonne	4 269	
Production per Year	tonne	2 420 672	
Queue Time at Loader	min/ Cycle	3,12	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	23,94	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	31,05	
Fleet Size		13	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	31 468 732	

Run No.	*Fleet Size*	*Fleet Production Per Year* tonne	*Production Change* %	*Loader on Per Oper. Hour* tonne	*Truck Avg. Cycle Time* min	*Truck Production Per Oper. Hour* tonne	*Truck Avg. Load Queue Time* min
1	1,00	2 684 147,32	0,00	502,72	27,93	502,72	0,00
2	2,00	5 341 881,21	99,02	1 000,49	28,08	500,25	0,15
3	3,00	7 918 431,53	195,01	1 483,06	28,26	494,35	0,32
4	4,00	10 511 869,65	291,63	1 968,79	28,43	492,20	0,51
5	5,00	13 116 118,65	388,65	2 456,55	28,63	491,31	0,70
6	6,00	15 598 905,57	481,15	2 921,55	28,81	486,93	0,89
7	7,00	18 095 601,42	574,17	3 389,17	29,03	484,17	1,11
8	8,00	20 498 381,95	663,68	3 839,19	29,26	479,90	1,34
9	9,00	22 921 123,63	753,94	4 292,95	29,49	476,99	1,56
10	10,00	25 157 088,34	837,25	4 711,73	29,80	471,17	1,87
11	11,00	27 397 575,48	920,72	5 131,35	30,14	466,49	2,22
12	12,00	29 530 436,32	1 000,18	5 530,82	30,53	460,90	2,61
13	13,00	31 399 664,19	1 069,82	5 880,91	31,12	452,38	3,19
14	14,00	32 892 405,14	1 125,43	6 160,49	32,00	440,04	4,08
15	15,00	33 618 785,71	1 152,49	6 296,54	33,67	419,77	5,74
16	16,00	33 817 389,33	1 159,89	6 333,73	35,74	395,86	7,82
17	17,00	34 009 466,38	1 167,05	6 369,71	37,90	374,69	9,97
18	18,00	34 156 445,99	1 172,53	6 397,24	39,99	355,40	12,06
19	19,00	34 320 827,12	1 178,65	6 428,02	42,11	338,32	14,19

Production Summary - Full Simulation

Haulage System: GR80_2017_Rev		***Haul Cycle: [PRJ] Haul Cycle_GR80_2017***	
Material: [PRJ] Oher Waste GR80		***Roster: [PRJ] GR80_5339_OpHrs***	
Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,09	
Average Payload	tonne	101,67	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	6 031,29	
Production per Loader Operating Shift	tonne	56 795	Max. prod. based on 100% avail.
Production per Year	tonne	32 202 551	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,30	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,96	
Production per Operating Hour	tonne	430,81	
Production per Loader Operating Shift	tonne	4 057	
Production per Year	tonne	2 300 182	
Queue Time at Loader	min/ Cycle	3,69	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	24,98	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	32,66	
Fleet Size		14	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	32 202 551	

Run No.	Fleet Size	Fleet Production Per Year	Production Change	Loader on Per Oper. Hour	Truck Avg. Cycle Time	Truck Production Per Oper. Hour	Truck Avg. Load Queue Time
		tonne	%	tonne	min	tonne	min
1	2,00	5 141 326,46	0,00	962,93	29,13	481,47	0,16
2	3,00	7 666 397,63	49,11	1 435,86	29,29	478,62	0,33
3	4,00	10 142 915,12	97,28	1 899,69	29,48	474,92	0,51
4	5,00	12 616 728,25	145,40	2 363,02	29,64	472,60	0,68
5	6,00	15 050 060,14	192,73	2 818,76	29,85	469,79	0,89
6	7,00	17 426 917,48	238,96	3 263,93	30,06	466,28	1,10
7	8,00	19 743 261,04	284,01	3 697,76	30,28	462,22	1,32
8	9,00	22 083 451,49	329,53	4 136,06	30,53	459,56	1,57
9	10,00	24 302 125,97	372,68	4 551,60	30,84	455,16	1,87
10	11,00	26 516 741,66	415,76	4 966,38	31,10	451,49	2,14
11	12,00	28 528 317,80	454,88	5 343,13	31,49	445,26	2,53
12	13,00	30 564 586,91	494,49	5 724,51	31,94	440,35	2,97
13	14,00	32 196 693,90	526,23	6 030,19	32,64	430,73	3,68
14	15,00	33 322 556,99	548,13	6 241,06	33,90	416,07	4,93
15	16,00	33 653 183,64	554,56	6 302,98	35,84	393,94	6,88
16	17,00	33 841 539,33	558,23	6 338,26	38,00	372,84	9,04
17	18,00	34 026 556,50	561,82	6 372,91	40,10	354,05	11,14
18	19,00	34 174 345,09	564,70	6 400,59	42,21	336,87	13,25
19	20,00	34 343 300,78	567,99	6 432,23	44,31	321,61	15,34

Production Summary - Full Simulation

Haulage System: GR80_2018_Rev			Haul Cycle: [PRJ] Haul Cycle_GR80_2018
Material: [PRJ] Oher Waste GR80			Roster: [PRJ] GR80_5339_OpHrs
Loader			**[PRJ] P&H 4100 XPC (AC)-Cost_GR80**
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,09	
Average Payload	tonne	101,67	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 761,21	
Production per Loader Operating Shift	tonne	54 251	Max. prod. based on 100% avail.
Production per Year	tonne	30 760 542	Avg. production factored by avail.
Wait Time per Operating Hour	min	4,15	
Truck			**[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost**
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,90	
Production per Operating Hour	tonne	443,17	
Production per Loader Operating Shift	tonne	4 173	
Production per Year	tonne	2 366 196	
Queue Time at Loader	min/ Cycle	3,03	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	24,70	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	31,71	
Fleet Size		13	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	30 760 542	

Run No.	Fleet Size	Fleet Production Per Year tonne	Production Change %	Loader on Per Oper. Hour tonne	Truck Avg. Cycle Time min	Truck Production Per Oper. Hour tonne	Truck Avg. Load Queue Time min
1	13,00	30 760 542,24	0,00	5 761,21	31,71	443,17	3,03
2	1,00	2 603 753,02	0,00	487,66	28,68	487,66	0,00
3	2,00	5 186 395,97	99,19	971,37	28,83	485,69	0,15
4	3,00	7 743 587,02	197,40	1 450,31	29,02	483,44	0,34
5	4,00	10 255 829,87	293,89	1 920,84	29,18	480,21	0,51
6	5,00	12 706 986,86	388,03	2 379,92	29,39	475,98	0,72
7	6,00	15 202 267,86	483,86	2 847,27	29,57	474,54	0,89
8	7,00	17 583 633,69	575,32	3 293,28	29,76	470,47	1,08
9	8,00	20 015 540,13	668,72	3 748,75	29,99	468,59	1,30
10	9,00	22 332 399,75	757,70	4 182,68	30,24	464,74	1,57
11	10,00	24 543 770,17	842,63	4 596,86	30,53	459,69	1,85
12	11,00	26 733 896,90	926,74	5 007,05	30,83	455,19	2,15
13	12,00	28 808 075,80	1 006,41	5 395,53	31,25	449,63	2,57
14	13,00	30 727 612,27	1 080,13	5 755,04	31,71	442,70	3,03
15	14,00	32 387 111,40	1 143,86	6 065,85	32,45	433,28	3,78
16	15,00	33 364 726,23	1 181,41	6 248,95	33,81	416,60	5,14
17	16,00	33 713 247,09	1 194,79	6 314,23	35,81	394,64	7,13
18	17,00	33 867 658,68	1 200,72	6 343,15	37,95	373,13	9,27
19	18,00	34 075 286,03	1 208,70	6 382,04	40,07	354,56	11,39
20	19,00	34 243 143,01	1 215,15	6 413,47	42,20	337,55	13,52

Production Summary - Full Simulation

Haulage System: GR80_2019_Rev		Haul Cycle: [PRJ] Haul Cycle_GR80_2019		
Material: [PRJ] Oher Waste GR80		Roster: [PRJ] GR80_5339_OpHrs		
Loader		**[PRJ] P&H 4100 XPC (AC)-Cost_GR80**		
Availability	%	85,00		
Bucket Fill Factor		0,81		
Average Bucket Load Volume	cu.metres	49,08		
Average Payload	tonne	101,66		
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability	
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability	
Average Bucket Cycle Time	min	0,72		
Production per Operating Hour	tonne	5 957,69		
Production per Loader Operating Shift	tonne	56 102	Max. prod. based on 100% avail.	
Production per Year	tonne	31 809 606	Avg. production factored by avail.	
Wait Time per Operating Hour	min	2,58		
Truck		**[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost**		
Availability	%	100,00		
Payload in Template	tonne	326,60		
Operating Hours per Year	OpHr/Year	5 339,25		
Average Payload	tonne	304,88		
Production per Operating Hour	tonne	397,18		
Production per Loader Operating Shift	tonne	3 740		
Production per Year	tonne	2 120 640		
Queue Time at Loader	min/ Cycle	3,88		
Spot Time at loader	min/ Cycle	0,75		
Average Loading Time	min/ Cycle	1,43		
Travel Time	min/ Cycle	27,45		
Spot Time at Dump	min/ Cycle	0,80		
Average Dump Time	min/ Cycle	1,00		
Average Cycle Time	min/ Cycle	35,31		
Fleet Size		15		
Average No. of Bucket Passes		3,00		
Haulage System				
Production per Year	tonne/Year	31 809 606		

Run No.	Fleet Size	Fleet Production Per Year tonne	Production Change %	Loader on Per Oper. Hour tonne	Truck Avg. Cycle Time min	Truck Production Per Oper. Hour tonne	Truck Avg. Load Queue Time min
1	15,00	31 809 605,81	0,00	5 957,69	35,31	397,18	3,88
2	1,00	2 372 154,98	0,00	444,29	31,45	444,29	0,00
3	2,00	4 717 971,42	98,89	883,64	31,60	441,82	0,17
4	3,00	7 052 399,85	197,30	1 320,86	31,77	440,29	0,33
5	4,00	9 335 541,95	293,55	1 748,47	31,94	437,12	0,51
6	5,00	11 619 322,57	389,82	2 176,21	32,11	435,24	0,68
7	6,00	13 844 629,75	483,63	2 592,99	32,33	432,17	0,90
8	7,00	16 034 522,48	575,95	3 003,14	32,53	429,02	1,10
9	8,00	18 209 045,57	667,62	3 410,41	32,75	426,30	1,32
10	9,00	20 378 237,91	759,06	3 816,69	32,99	424,08	1,56
11	10,00	22 457 057,06	846,69	4 206,03	33,25	420,60	1,81
12	11,00	24 492 407,82	932,50	4 587,24	33,51	417,02	2,08
13	12,00	26 478 036,45	1 016,20	4 959,13	33,82	413,26	2,39
14	13,00	28 410 018,00	1 097,65	5 320,98	34,21	409,31	2,78
15	14,00	30 218 087,59	1 173,87	5 659,61	34,69	404,26	3,25
16	15,00	31 753 766,09	1 238,60	5 947,23	35,33	396,48	3,89
17	16,00	32 916 370,27	1 287,61	6 164,98	36,42	385,31	4,98
18	17,00	33 371 631,26	1 306,81	6 250,25	38,24	367,66	6,81
19	18,00	33 608 416,89	1 316,79	6 294,60	40,33	349,70	8,89
20	19,00	33 796 101,52	1 324,70	6 329,75	42,45	333,14	11,01
21	20,00	33 947 750,15	1 331,09	6 358,15	44,58	317,91	13,15
22	21,00	34 131 149,84	1 338,82	6 392,50	46,72	304,40	15,29

Production Summary - Full Simulation

Haulage System: GR80_2020_Rev		*Haul Cycle: [PRJ] Haul Cycle_GR80_2020*	
Material: [PRJ] Oher Waste GR80		*Roster: [PRJ] GR80_5339_OpHrs*	
Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,10	
Average Payload	tonne	101,69	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 942,56	
Production per Loader Operating Shift	tonne	55 959	Max. prod. based on 100% avail.
Production per Year	tonne	31 728 816	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,30	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,97	
Production per Operating Hour	tonne	349,56	
Production per Loader Operating Shift	tonne	3 292	
Production per Year	tonne	1 866 401	
Queue Time at Loader	min/ Cycle	4,53	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	31,41	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	39,92	
Fleet Size		17	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	31 728 816	

Run No.	***Fleet Size***	***Fleet Production Per Year*** tonne	***Production Change*** %	***Loader on Per Oper. Hour*** tonne	***Truck Avg. Cycle Time*** min	***Truck Production Per Oper. Hour*** tonne	***Truck Avg. Load Queue Time*** min
1	17,00	31 728 815,76	0,00	5 942,56	39,92	349,56	4,53
2	3,00	6 215 311,29	0,00	1 164,08	35,71	388,03	0,33
3	4,00	8 255 852,55	32,83	1 546,26	35,89	386,56	0,51
4	5,00	10 290 596,83	65,57	1 927,35	36,09	385,47	0,70
5	6,00	12 294 651,52	97,81	2 302,69	36,28	383,78	0,89
6	7,00	14 245 873,86	129,21	2 668,14	36,48	381,16	1,09
7	8,00	16 173 591,72	160,22	3 029,19	36,71	378,65	1,33
8	9,00	18 101 746,91	191,24	3 390,32	36,91	376,70	1,52
9	10,00	20 039 954,13	222,43	3 753,33	37,17	375,33	1,77
10	11,00	21 827 857,39	251,19	4 088,19	37,42	371,65	2,04
11	12,00	23 702 340,98	281,35	4 439,26	37,66	369,94	2,28
12	13,00	25 433 603,25	309,21	4 763,52	37,97	366,42	2,58
13	14,00	27 168 137,86	337,12	5 088,38	38,35	363,46	2,96
14	15,00	28 850 324,15	364,18	5 403,44	38,70	360,23	3,31
15	16,00	30 389 600,93	388,95	5 691,74	39,22	355,73	3,83
16	17,00	31 717 438,58	410,31	5 940,43	39,95	349,44	4,57
17	18,00	32 702 256,23	426,16	6 124,88	41,12	340,27	5,73
18	19,00	33 142 641,29	433,24	6 207,36	42,93	326,70	7,54
19	20,00	33 291 944,12	435,64	6 235,32	45,01	311,77	9,62
20	21,00	33 490 423,04	438,84	6 272,50	47,11	298,69	11,72
21	22,00	33 666 953,03	441,68	6 305,56	49,23	286,62	13,84
22	23,00	33 847 895,67	444,59	6 339,45	51,39	275,63	16,00

Production Summary - Full Simulation

Haulage System: GR80_2021_Rev | *Haul Cycle: [PRJ] Haul Cycle_GR80_2021*

Material: [PRJ] Oher Waste GR80 | *Roster: [PRJ] GR80_5339_OpHrs*

Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,07	
Average Payload	tonne	101,63	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 711,07	
Production per Loader Operating Shift	tonne	53 779	Max. prod. based on 100% avail.
Production per Year	tonne	30 492 806	Avg. production factored by avail.
Wait Time per Operating Hour	min	3,85	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,80	
Production per Operating Hour	tonne	356,94	
Production per Loader Operating Shift	tonne	3 361	
Production per Year	tonne	1 905 800	
Queue Time at Loader	min/ Cycle	3,89	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	31,21	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	39,09	
Fleet Size		16	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	30 492 806	

Run No.	Fleet Size	Fleet Production Per Year (tonne)	Production Change (%)	Loader on Per Oper. Hour (tonne)	Truck Avg. Cycle Time (min)	Truck Production Per Oper. Hour (tonne)	Truck Avg. Load Queue Time (min)
1	16,00	30 492 806,29	0,00	5 711,07	39,09	356,94	3,89
2	1,00	2 110 162,69	0,00	395,22	35,21	395,22	0,00
3	2,00	4 197 345,78	98,91	786,13	35,36	393,07	0,16
4	3,00	6 271 172,13	197,19	1 174,54	35,53	391,51	0,33
5	4,00	8 324 571,52	294,50	1 559,13	35,71	389,78	0,51
6	5,00	10 324 515,51	389,28	1 933,70	35,91	386,74	0,72
7	6,00	12 356 574,73	485,57	2 314,29	36,09	385,72	0,90
8	7,00	14 360 124,58	580,52	2 689,54	36,29	384,22	1,09
9	8,00	16 320 913,76	673,44	3 056,78	36,50	382,10	1,31
10	9,00	18 162 426,34	760,71	3 401,68	36,76	377,96	1,55
11	10,00	20 104 952,69	852,77	3 765,50	36,98	376,55	1,78
12	11,00	21 984 168,64	941,82	4 117,46	37,23	374,31	2,04
13	12,00	23 804 493,06	1 028,09	4 458,40	37,50	371,53	2,30
14	13,00	25 594 372,66	1 112,91	4 793,63	37,82	368,74	2,63
15	14,00	27 334 874,78	1 195,39	5 119,61	38,13	365,69	2,94
16	15,00	28 920 757,46	1 270,55	5 416,63	38,58	361,11	3,39
17	16,00	30 514 720,51	1 346,08	5 715,17	39,04	357,20	3,85
18	17,00	31 864 109,90	1 410,03	5 967,90	39,79	351,05	4,59
19	18,00	32 747 947,60	1 451,92	6 133,44	41,02	340,75	5,83
20	19,00	33 156 596,76	1 471,28	6 209,97	42,90	326,84	7,70
21	20,00	33 372 627,41	1 481,52	6 250,43	45,05	312,52	9,85
22	21,00	33 547 695,46	1 489,82	6 283,22	47,13	299,20	11,94
23	22,00	33 668 919,52	1 495,56	6 305,93	49,23	286,63	14,04

Production Summary - Full Simulation

Haulage System: GR80_2022_Rev — *Haul Cycle: [PRJ] Haul Cycle_GR80_2022*

Material: [PRJ] Oher Waste GR80 — *Roster: [PRJ] GR80_5339_OpHrs*

Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,07	
Average Payload	tonne	101,63	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 818,45	
Production per Loader Operating Shift	tonne	54 790	Max. prod. based on 100% avail.
Production per Year	tonne	31 066 143	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,99	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,82	
Production per Operating Hour	tonne	342,26	
Production per Loader Operating Shift	tonne	3 223	
Production per Year	tonne	1 827 420	
Queue Time at Loader	min/ Cycle	4,33	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	32,39	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	40,70	
Fleet Size		17	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	31 066 143	

Run No.	Fleet Size	Fleet Production Per Year tonne	Production Change %	Loader on Per Oper. Hour tonne	Truck Avg. Cycle Time min	Truck Production Per Oper. Hour tonne	Truck Avg. Load Queue Time min
1	17,00	31 066 143,31	0,00	5 818,45	40,70	342,26	4,33
2	2,00	4 073 682,36	0,00	762,97	36,54	381,48	0,18
3	3,00	6 083 257,36	49,33	1 139,35	36,71	379,78	0,34
4	4,00	8 050 426,86	97,62	1 507,78	36,87	376,95	0,50
5	5,00	9 997 967,61	145,43	1 872,54	37,06	374,51	0,69
6	6,00	11 963 354,20	193,67	2 240,64	37,29	373,44	0,92
7	7,00	13 861 054,25	240,26	2 596,07	37,46	370,87	1,09
8	8,00	15 769 636,15	287,11	2 953,53	37,68	369,19	1,31
9	9,00	17 588 791,31	331,77	3 294,24	37,90	366,03	1,53
10	10,00	19 479 030,47	378,17	3 648,27	38,12	364,83	1,74
11	11,00	21 325 335,12	423,49	3 994,07	38,38	363,10	2,01
12	12,00	23 063 979,76	466,17	4 319,70	38,61	359,98	2,24
13	13,00	24 740 599,32	507,33	4 633,72	38,94	356,44	2,58
14	14,00	26 525 956,86	551,15	4 968,11	39,26	354,86	2,88
15	15,00	28 180 850,90	591,78	5 278,05	39,66	351,87	3,29
16	16,00	29 645 615,07	627,74	5 552,39	40,10	347,02	3,73
17	17,00	31 061 908,59	662,50	5 817,65	40,71	342,21	4,34
18	18,00	32 251 675,90	691,71	6 040,49	41,63	335,58	5,25
19	19,00	32 931 187,01	708,39	6 167,76	43,13	324,62	6,76
20	20,00	33 154 372,34	713,87	6 209,56	45,13	310,48	8,76
21	21,00	33 326 295,95	718,09	6 241,76	47,26	297,23	10,90
22	22,00	33 492 780,72	722,17	6 272,94	49,34	285,13	12,97
23	23,00	33 685 498,31	726,91	6 309,03	51,50	274,31	15,13

Production Summary - Full Simulation			
Haulage System: GR80_2023_Rev		*Haul Cycle: [PRJ] Haul Cycle_GR80_2023*	
Material: [PRJ] Oher Waste GR80		*Roster: [PRJ] GR80_5339_OpHrs*	
Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,10	
Average Payload	tonne	101,69	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 927,97	
Production per Loader Operating Shift	tonne	55 822	Max. prod. based on 100% avail.
Production per Year	tonne	31 650 918	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,39	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	305,00	
Production per Operating Hour	tonne	348,70	
Production per Loader Operating Shift	tonne	3 284	
Production per Year	tonne	1 861 819	
Queue Time at Loader	min/ Cycle	4,49	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	31,61	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	40,09	
Fleet Size		17	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	31 650 918	

Run No.	***Fleet Size***	***Fleet Production Per Year*** tonne	***Production Change*** %	***Loader on Per Oper. Hour*** tonne	***Truck Avg. Cycle Time*** min	***Truck Production Per Oper. Hour*** tonne	***Truck Avg. Load Queue Time*** min
1	17,00	31 650 918,30	0,00	5 927,97	40,09	348,70	4,49
2	5,00	10 222 134,96	0,00	1 914,53	36,31	382,91	0,71
3	6,00	12 229 245,82	19,63	2 290,44	36,51	381,74	0,92
4	7,00	14 193 562,15	38,85	2 658,34	36,69	379,76	1,10
5	8,00	16 146 319,09	57,95	3 024,08	36,89	378,01	1,30
6	9,00	18 024 911,47	76,33	3 375,93	37,11	375,10	1,52
7	10,00	19 900 779,54	94,68	3 727,26	37,36	372,73	1,76
8	11,00	21 734 236,24	112,62	4 070,65	37,59	370,06	2,01
9	12,00	23 535 518,16	130,24	4 408,02	37,87	367,33	2,28
10	13,00	25 371 759,41	148,20	4 751,93	38,15	365,53	2,56
11	14,00	26 992 875,76	164,06	5 055,56	38,50	361,11	2,92
12	15,00	28 669 669,14	180,47	5 369,61	38,89	357,97	3,30
13	16,00	30 251 964,03	195,95	5 665,96	39,43	354,12	3,84
14	17,00	31 589 975,69	209,04	5 916,56	40,09	348,03	4,50
15	18,00	32 548 900,83	218,42	6 096,16	41,18	338,68	5,60
16	19,00	33 106 918,27	223,87	6 200,67	42,95	326,35	7,36
17	20,00	33 300 125,81	225,76	6 236,85	45,01	311,84	9,42
18	21,00	33 470 750,36	227,43	6 268,81	47,14	298,51	11,54
19	22,00	33 622 026,76	228,91	6 297,14	49,24	286,23	13,66
20	23,00	33 769 675,83	230,36	6 324,80	51,36	274,99	15,78
21	24,00	33 980 883,02	232,42	6 364,36	53,49	265,18	17,91
22	25,00	34 144 995,52	234,03	6 395,09	55,53	255,80	19,94
23	26,00	34 317 235,24	235,71	6 427,35	57,63	247,21	22,04
24	27,00	34 483 543,20	237,34	6 458,50	59,74	239,20	24,15

Production Summary - Full Simulation

Haulage System: GR80_2024_Rev		Haul Cycle: [PRJ] Haul Cycle_GR80_2024	
Material: [PRJ] Oher Waste GR80		Roster: [PRJ] GR80_5339_OpHrs	
Loader		[PRJ] P&H 4100 XPC (AC)-Cost_GR80	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,06	
Average Payload	tonne	101,61	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 892,52	
Production per Loader Operating Shift	tonne	55 488	Max. prod. based on 100% avail.
Production per Year	tonne	31 461 629	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,17	
Truck		[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,72	
Production per Operating Hour	tonne	310,13	
Production per Loader Operating Shift	tonne	2 920	
Production per Year	tonne	1 655 875	
Queue Time at Loader	min/ Cycle	5,19	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	35,61	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	44,78	
Fleet Size		19	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	31 461 629	

Run No.	Fleet Size	Fleet Production Per Year tonne	Production Change %	Loader on Per Oper. Hour tonne	Truck Avg. Cycle Time min	Truck Production Per Oper. Hour tonne	Truck Avg. Load Queue Time min
1	19,00	31 461 629,45	0,00	5 892,52	44,78	310,13	5,19
2	7,00	12 696 934,23	0,00	2 378,04	40,70	339,72	1,11
3	8,00	14 436 122,17	13,70	2 703,77	40,95	337,97	1,35
4	9,00	16 135 830,33	27,08	3 022,12	41,13	335,79	1,53
5	10,00	17 856 169,75	40,63	3 344,32	41,37	334,43	1,77
6	11,00	19 535 071,33	53,86	3 658,77	41,62	332,62	2,03
7	12,00	21 182 659,75	66,83	3 967,35	41,86	330,61	2,27
8	13,00	22 809 937,73	79,65	4 272,12	42,09	328,62	2,50
9	14,00	24 428 819,05	92,40	4 575,33	42,42	326,81	2,82
10	15,00	25 948 679,66	104,37	4 859,99	42,80	324,00	3,20
11	16,00	27 515 519,10	116,71	5 153,44	43,11	322,09	3,51
12	17,00	28 916 049,34	127,74	5 415,75	43,54	318,57	3,94
13	18,00	30 260 247,32	138,33	5 667,51	44,06	314,86	4,46
14	19,00	31 492 299,94	148,03	5 898,26	44,78	310,43	5,18
15	20,00	32 373 312,34	154,97	6 063,27	45,94	303,16	6,35
16	21,00	32 770 316,95	158,10	6 137,63	47,65	292,27	8,05
17	22,00	33 008 359,98	159,97	6 182,21	49,79	281,01	10,19
18	23,00	33 129 629,92	160,93	6 204,92	51,90	269,78	12,31
19	24,00	33 329 506,20	162,50	6 242,36	53,97	260,10	14,38
20	25,00	33 516 462,52	163,97	6 277,37	56,09	251,09	16,49
21	26,00	33 684 485,28	165,30	6 308,84	58,18	242,65	18,58
22	27,00	33 827 714,48	166,42	6 335,67	60,28	234,65	20,69
23	28,00	33 988 252,32	167,69	6 365,74	62,32	227,35	22,72
24	29,00	34 202 415,84	169,38	6 405,85	64,39	220,89	24,79

Production Summary - Full Simulation

Haulage System: GR80_2025_Rev		*Haul Cycle: [PRJ] Haul Cycle_GR80_2025*	
Material: [PRJ] Oher Waste GR80		*Roster: [PRJ] GR80_5339_OpHrs*	
Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,07	
Average Payload	tonne	101,63	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 744,51	
Production per Loader Operating Shift	tonne	54 094	Max. prod. based on 100% avail.
Production per Year	tonne	30 671 361	Avg. production factored by avail.
Wait Time per Operating Hour	min	3,21	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,81	
Production per Operating Hour	tonne	319,14	
Production per Loader Operating Shift	tonne	3 005	
Production per Year	tonne	1 703 964	
Queue Time at Loader	min/ Cycle	4,57	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	35,00	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	43,55	
Fleet Size		18	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	30 671 361	

Run No.	*Fleet Size*	*Fleet Production Per Year* tonne	*Production Change* %	*Loader on Per Oper. Hour* tonne	*Truck Avg. Cycle Time* min	*Truck Production Per Oper. Hour* tonne	*Truck Avg. Load Queue Time* min
1	18,00	30 671 360,70	0,00	5 744,51	43,55	319,14	4,57
2	6,00	11 123 233,64	0,00	2 083,30	39,88	347,22	0,90
3	7,00	12 930 665,76	16,25	2 421,81	40,11	345,97	1,12
4	8,00	14 676 638,11	31,95	2 748,82	40,32	343,60	1,33
5	9,00	16 375 525,94	47,22	3 067,01	40,53	340,78	1,56
6	10,00	18 147 343,60	63,15	3 398,86	40,75	339,89	1,77
7	11,00	19 852 752,54	78,48	3 718,27	40,98	338,02	2,00
8	12,00	21 494 766,33	93,24	4 025,80	41,24	335,48	2,27
9	13,00	23 136 766,71	108,00	4 333,34	41,50	333,33	2,53
10	14,00	24 820 959,07	123,15	4 648,77	41,80	332,06	2,82
11	15,00	26 335 727,58	136,76	4 932,48	42,17	328,83	3,20
12	16,00	27 885 594,34	150,70	5 222,75	42,53	326,42	3,55
13	17,00	29 342 578,86	163,80	5 495,64	42,93	323,27	3,96
14	18,00	30 695 326,51	175,96	5 749,00	43,55	319,39	4,57
15	19,00	31 811 697,73	185,99	5 958,08	44,35	313,58	5,37
16	20,00	32 559 142,04	192,71	6 098,07	45,65	304,90	6,68
17	21,00	32 947 367,87	196,20	6 170,79	47,51	293,85	8,53
18	22,00	33 077 744,70	197,38	6 195,20	49,68	281,60	10,70
19	23,00	33 240 133,62	198,84	6 225,62	51,77	270,68	12,79
20	24,00	33 419 602,87	200,45	6 259,23	53,89	260,80	14,92
21	25,00	33 613 409,35	202,19	6 295,53	55,96	251,82	16,98
22	26,00	33 798 757,13	203,86	6 330,24	58,12	243,47	19,13
23	27,00	33 961 565,12	205,32	6 360,74	60,16	235,58	21,18
24	28,00	34 142 400,23	206,95	6 394,61	62,22	228,38	23,24

Production Summary - Full Simulation

Haulage System: GR80_2026_Rev | ***Haul Cycle: [PRJ] Haul Cycle_GR80_2026***

Material: [PRJ] Oher Waste GR80 | ***Roster: [PRJ] GR80_5339_OpHrs***

Loader		***[PRJ] P&H 4100 XPC (AC)-Cost_GR80***	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,07	
Average Payload	tonne	101,62	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 739,99	
Production per Loader Operating Shift	tonne	54 052	Max. prod. based on 100% avail.
Production per Year	tonne	30 647 263	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,87	
Truck		***[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost***	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,79	
Production per Operating Hour	tonne	287,00	
Production per Loader Operating Shift	tonne	2 703	
Production per Year	tonne	1 532 363	
Queue Time at Loader	min/ Cycle	5,25	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	39,00	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	48,23	
Fleet Size		20	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	30 647 263	

Run No.	***Fleet Size***	***Fleet Production Per Year*** tonne	***Production Change*** %	***Loader on Per Oper. Hour*** tonne	***Truck Avg. Cycle Time*** min	***Truck Production Per Oper. Hour*** tonne	***Truck Avg. Load Queue Time*** min
1	20,00	30 647 262,73	0,00	5 739,99	48,23	287,00	5,25
2	8,00	13 281 504,20	0,00	2 487,52	44,32	310,94	1,33
3	9,00	14 856 345,39	11,86	2 782,48	44,55	309,16	1,57
4	10,00	16 386 537,54	23,38	3 069,07	44,78	306,91	1,80
5	11,00	17 973 131,81	35,32	3 366,23	45,01	306,02	2,02
6	12,00	19 534 594,51	47,08	3 658,68	45,27	304,89	2,27
7	13,00	21 036 388,31	58,39	3 939,95	45,50	303,07	2,50
8	14,00	22 538 550,93	69,70	4 221,30	45,77	301,52	2,78
9	15,00	23 993 745,14	80,66	4 493,84	46,04	299,59	3,05
10	16,00	25 475 923,61	91,82	4 771,44	46,37	298,22	3,38
11	17,00	26 820 376,65	101,94	5 023,25	46,73	295,49	3,75
12	18,00	28 122 913,31	111,74	5 267,20	47,17	292,62	4,18
13	19,00	29 405 689,36	121,40	5 507,46	47,61	289,87	4,63
14	20,00	30 681 646,04	131,01	5 746,43	48,21	287,32	5,22
15	21,00	31 651 843,71	138,32	5 928,14	49,06	282,29	6,07
16	22,00	32 311 067,69	143,28	6 051,61	50,45	275,07	7,46
17	23,00	32 577 509,07	145,28	6 101,51	52,28	265,28	9,29
18	24,00	32 786 023,58	146,85	6 140,57	54,47	255,86	11,48
19	25,00	32 978 368,89	148,30	6 176,59	56,55	247,06	13,56
20	26,00	33 109 698,61	149,29	6 201,19	58,69	238,51	15,71
21	27,00	33 332 651,18	150,97	6 242,95	60,70	231,22	17,70
22	28,00	33 512 555,57	152,33	6 276,64	62,84	224,17	19,85
23	29,00	33 673 003,80	153,53	6 306,69	64,92	217,47	21,93
24	30,00	33 863 333,80	154,97	6 342,34	66,91	211,41	23,92

Production Summary - Full Simulation

Haulage System: GR80_2027_Rev		Haul Cycle: [PRJ] Haul Cycle_GR80_2027	
Material: [PRJ] Oher Waste GR80		Roster: [PRJ] GR80_5339_OpHrs	
Loader		[PRJ] P&H 4100 XPC (AC)-Cost_GR80	
Availability	%	85,00	
Bucket Fill Factor		0,81	
Average Bucket Load Volume	cu.metres	49,07	
Average Payload	tonne	101,63	
Operating Hours per Year	OpHr/Year	5 339,25	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	567,00	Shifts factored by availability
Average Bucket Cycle Time	min	0,72	
Production per Operating Hour	tonne	5 725,87	
Production per Loader Operating Shift	tonne	53 919	Max. prod. based on 100% avail.
Production per Year	tonne	30 571 850	Avg. production factored by avail.
Wait Time per Operating Hour	min	2,77	
Truck		[PRJ] KOMATSU 960 E-2K (3500hp)_GR80_Cost	
Availability	%	100,00	
Payload in Template	tonne	326,60	
Operating Hours per Year	OpHr/Year	5 339,25	
Average Payload	tonne	304,80	
Production per Operating Hour	tonne	272,66	
Production per Loader Operating Shift	tonne	2 568	
Production per Year	tonne	1 455 802	
Queue Time at Loader	min/ Cycle	5,57	
Spot Time at loader	min/ Cycle	0,75	
Average Loading Time	min/ Cycle	1,43	
Travel Time	min/ Cycle	41,10	
Spot Time at Dump	min/ Cycle	0,80	
Average Dump Time	min/ Cycle	1,00	
Average Cycle Time	min/ Cycle	50,65	
Fleet Size		21	
Average No. of Bucket Passes		3,00	
Haulage System			
Production per Year	tonne/Year	30 571 850	

Run No.	Fleet Size	Fleet Production Per Year tonne	Production Change %	Loader on Per Oper. Hour tonne	Truck Avg. Cycle Time min	Truck Production Per Oper. Hour tonne	Truck Avg. Load Queue Time min
1	21,00	30 571 849,93	0,00	5 725,87	50,65	272,66	5,57
2	9,00	14 164 187,94	0,00	2 652,84	46,67	294,76	1,57
3	10,00	15 629 203,08	10,34	2 927,23	46,89	292,72	1,80
4	11,00	17 156 003,22	21,12	3 213,19	47,11	292,11	2,03
5	12,00	18 578 352,87	31,16	3 479,58	47,37	289,97	2,28
6	13,00	20 040 675,79	41,49	3 753,46	47,61	288,73	2,53
7	14,00	21 508 184,83	51,85	4 028,32	47,86	287,74	2,77
8	15,00	22 884 911,82	61,57	4 286,17	48,13	285,74	3,04
9	16,00	24 264 199,45	71,31	4 544,50	48,46	284,03	3,38
10	17,00	25 649 019,20	81,08	4 803,86	48,79	282,58	3,71
11	18,00	26 947 317,24	90,25	5 047,02	49,11	280,39	4,03
12	19,00	28 179 099,87	98,95	5 277,73	49,62	277,78	4,54
13	20,00	29 394 449,38	107,53	5 505,35	50,07	275,27	4,98
14	21,00	30 529 521,41	115,54	5 717,94	50,66	272,28	5,58
15	22,00	31 508 580,30	122,45	5 901,31	51,48	268,24	6,40
16	23,00	32 113 011,77	126,72	6 014,52	52,90	261,50	7,82
17	24,00	32 422 570,13	128,91	6 072,50	54,80	253,02	9,71
18	25,00	32 632 584,07	130,39	6 111,83	56,82	244,47	11,73
19	26,00	32 821 436,05	131,72	6 147,20	59,00	236,43	13,91
20	27,00	32 960 274,42	132,70	6 173,20	61,10	228,64	16,02
21	28,00	33 117 790,03	133,81	6 202,70	63,18	221,53	18,10
22	29,00	33 326 470,51	135,29	6 241,79	65,25	215,23	20,17
23	30,00	33 501 728,30	136,52	6 274,61	67,21	209,15	22,13
24	31,00	33 649 240,64	137,57	6 302,24	69,29	203,30	24,21